EVOLUTION OF STRUCTURAL FAULT PERMEABILITY IN ARGILLACEOUS ROCKS IN POLYPHASED TECTONIC CONTEXT

J. Constantin [1], J.B. Peyaud [1], P. Vergély [1], M. Pagel [1], J. Cabrera [2]

1. **ORSAYTERRE, FRE 2566, Bâtiment 504, Université de Paris Sud-Orsay, 91405 Orsay Cédex, France**
2. **Institut de Radioprotection et de Sûreté Nucléaire – DPRE/SERGD, 92265 Fontenay-aux-Roses**

Deep argillaceous formations have petrophysical and hydrodynamical properties favourable to the long-term radioactive waste disposal (very low intrinsic permeability, fission products migration retardation...). However these properties may be modified by the occurrence of discontinuities in the host rock. It is then necessary to characterize the processes of paleofluids circulations associated with the tectonic fracturing to understand the factors and contexts in which the containment properties may be modified. The studied argillaceous formation corresponds to a 250 m thick Domerian-Toarcian shale unit located in the Causses basin (Aveyron, France). The present study is part of the Tournemire experimental research program developed at the Institute for Nuclear Safety and Radioprotection (IRSN). Tectonic fracturing was characterized and the tectonic events that were responsible on the one hand for the creating of the fractures and on the other hand for their eventual reactivation were identified. The fractures in the study area result from two main tectonic phases. The first, extensional, occurred during Mesozoic. Fracturing associated with this tectonic phase occurred at two periods: (1) as early as the rock compaction, under an extensional stress state with $\sigma3$ trending NW-SE, during Dogger, (2) under an extensional tectonic event with $\sigma3$ trending N-S, during Upper Jurassic (and probably Lower Cretaceous). This second event produced E-W conjugate normal faults and two perpendicular sets of extensional joints trending E-W and N-S. The second main tectonic phase corresponds to the Eocene Pyrenean compression. The $\sigma1$ directions varied from NE/SW to NW/SE, with two major pulses striking N020-N030 and N160-N170. The fractures associated with this tectonic phase are mainly joints trending N020 and N160. These joints may have been reactivated during this same phase as sinistral strike-slip faults. The normal E/W trending faults may have been reactivated as reverse or dextral strike-slip faults and the N/S and E/W trending joints as dextral or sinistral strike-slip faults.

Today, the calcite crystallizations in faults give evidence of paleofluid flows during the tectonic deformation. Several fault fillings (minor fault with metric offset) were sampled and analysed to understand the mechanisms creating structural porosity (and structural permeability) and the factors of paleofluid transfers in faults. Microstructural analyses of the fault fillings showed that faults were alternately and temporarily impermeable, permeable or semi-permeable (or semi-impermeable). These "hydraulic states" were controlled by the nature and architecture of microstructures and by variations of the shale petrophysical properties in the core zone (CZ) and damage zone (DZ) of the faults. In DZ, the structural fault permeability evolution is associated with (1) microcracking and (2) deformation related to a probable ductile behaviour of shale. The structural fault permeability in CZ is associated with the development of cavities generated by (1) dilatation – this occurred during the first steps of fractures development and mainly during the extensional tectonic phase with fluid overpressures - (2) shearing and cavities opening in extensional stepover (3) microcracking in pre-existing calcite fillings. The development of a new structural porosity both in CZ and DZ has made the faults permeable. The crystallisation sealing of the structural porosity has made impermeable the faults and the sealing only in DZ (CZ sealed) semi-permeable. Mechanisms and chronology of microstructures development involve that (1) the fluid transfers occurred from the DZ to the CZ and that (2) the DZ constituted a "storage zone" in fluids for the CZ. The DZ remained then permeable longer than the core zone.

Besides the contribution of geochemical data (isotopic data and fluid inclusion) on the fault fillings (structurally constrained) allows specifying the consequences of the structural fault permeability evolution during the polyphased tectonic context.