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Mechanical study of the Chartreuse Fold-and-Thrust Belt: relationships between fluids overpressure and decollement within the Toarcian source-rock

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Many source-rocks are shale and constitute potential detachment levels in Fold-and-Thrust Belts (FTB): the toarcian Schistes-Cartons in the French Chartreuse FTB for example. Their mechanical properties can change during their burial and thermal maturation, as for example when large amount of hydrocarbon fluids are generated. A structural reconstruction of the Chartreuse FTB geo-history places the Toarcian Formation as the major decollement horizon. In this work, a mechanical analysis integrating the fluids overpressuring development is proposed to discuss on the validity of the structural interpretation. At first, an analogue of the Chartreuse Toarcian Fm, the albanian Posidonia Schist, is documented as it can provide insights on its initial properties and composition of its kerogen content. Laboratory characterisation documents the vertical evolution of the mineralogical, geochemical and mechanical parameters of this potential decollement layer. These physical parameters (i.e. Total Organic Carbon (TOC), porosity/permeability relationship, friction coefficient) are used to address overpressure buildup in the frontal part of the Chartreuse FTB with TEMISFlow Arctem Basin modelling approach (Faille et al, 2014) and the structural emplacement of the Chartreuse thrust units using the FLAMAR thermo-mechanical model (Burov et al, 2014). The hydro-mechanical modeling results highlight the calendar, distribution and magnitude of the overpressure that developed within the source-rock in the footwall of a simple fault-bend fold structure localized in the frontal part of the Chartreuse FTB. Several key geological conditions are required to create an overpressure able to fracture the shale-rocks and induce a significant change in the rheological behaviour: high TOC, low permeability, favourable structural evolution. These models highlight the importance of modeling the impact of a diffuse natural hydraulic fracturing to explain fluids propagation toward the foreland within the decollement layer. In turn, with the FLAMAR geo-mechanical models it is shown that for key mechanical parameters within the Chartreuse mechanical stratigraphy (such as friction coefficient, cohesion and viscosity properties), the mechanical boundary conditions to activate, localize and propagate shear thrust in the toarcian source-rock can be found to discuss on the hydro-mechanics of the structural evolution: the very weak mechanical properties that must be attributed to the source-rock to promote the formation of a decollement tend to justify the hypothesis of high fluids pressures in it. In FLAMAR, the evolution of the toarcian source-rock mechanical properties, calibrated on the temperature of kerogen-to-gas transformation, can be introduced to allow its activation as a decollement at a burial threshold. However, without hydro-mechanical coupling, it is not possible to predict where the overpressured regions that localised these changes are positioned. As such, this work also highlights the need for a fully-coupled hydro-mechanical model to further investigate the relationship between fluids and deformations in FTB and accretionary prisms.

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