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Capillary mechanics, thermodynamics and seal leakage potential

A reservoir seal will fail when physical conditions are sufficient for the hydrocarbon fluid to overcome the mechanical and capillary constraints that define the seal capacity. It is common to separate risk of seal failure into capillary and mechanical elements. However, an analysis of the reservoir and seal as a thermodynamic system allows us to see that these two aspects are linked. Furthermore, the phenomenon of capilarity includes not only mechanical force balance between fluid pressures and surface tensions at the pore scale, but also the influence that temperatures and pressures themselves have on physico-chemical propererties: solubility, wettability, and interphase transport. A most powerful way to describe systems at or close to equilibrium is with thermodynamic potentials, which describe the energy balances of the phases and components irrespective of their extent. We apply this analysis to the case of a petroleum reservoir sealed by a shale cap and lateral fault. We compare and contrast the mechanical and thermodynamic consequences, in terms of leakage risk, of two scenarios. 1. An increase in the relative hydrocarbon phase pressure potential due to increased column height. 2. An increase in fluid phase total pressures caused by (an arbitrary) overpressuring mechanism.