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Fluid pressure evolution in overpressured limestone reservoir at basin-scale: example of the Bighorn Basin (Wyoming, USA) and lessons from comparison with other reservoirs

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In many natural cases, an hydrostatic gradient prevails in strata, and some oil-producing basins are the location of underpressured reservoirs. This contribution presents the fluid paleo-(over)pressure evolution in a carbonate reservoir, reconstructed using a paleo-stress dataset and novel methodology. The case study of the Madison-Phosphoria reservoir (Bighorn Basin, Wyoming, USA) is an interesting example to assess the problem of the fluid overpressure evolution in deforming media. Indeed it proposes among the first paleo-overpressure reconstruction in strata regarding both burial and subsequent compressional deformation. Results point out that in the Bighorn Basin, supra-hydrostatic pressure values prevail in the Madison-Phosphoria reservoir during most of its whole Sevier-Laramide history, except during the stage of Sevier foreland flexure/forebulge. At the basin-scale, the evolution of fluid overpressure can easily be related to large-scale fluid migrations characterized independently using geochemistry of vein-filling cements.

We propose a comparison of the reconstructed fluid overpressure values with in situ measurements in various overpressured reservoirs in other oil-producing basins with respect to burial depth. The comparison with natural pressure data measured in several basins suggests the existence of a mean gradient of overpressure level in carbonates, and the pressure values reconstructed in vertical veins that accommodated the layer-parallel shortening respect this mean gradient. Strikingly, the fluid overpressure measured or recorded in porous media like sandstones are systematically beyond this mean gradient, as are the fluid pressure values related to extensional stress regimes. On the opposite, when the stress regime become compressional, we observe that fluid pressure is above the mean gradient, illustrating that during orogenic stress build-up, the supra-hydrostatic fluid pressure may gradually reach and exceed the lithostatic value, marked by the development of reverse faults and horizontal veins parallel to bedding.

Thus, the difference between this mean gradient and the reconstructed pressure values may be related to three main parameters: the lithology and the vertical permeability of fractures (i.e. the mechanical stratigraphy), and the local stress regime. The hydraulic permeability related to mechanical stratigraphy and/or to stress regime seems to impact more the fluid pressure level than the chemical compaction related to hydrocarbon generation, or to differential compaction related to sedimentation rates.