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Impact of fracturing stratigraphy on paleo-hydrodynamics, the Madison Formation case study (Bighorn Basin, Wyoming,USA).

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A unique outcrop dataset, including the analysis of the vertical persistence and cement stratigraphy of vein sets as well as paleo-overpressure estimates from calcite twinning paleopiezometry is used to demonstrate the impact of folding and fracturing on paleo-hydrodynamics.
The studied fold is Sheep Mountain, an asymmetric basement cored anticline corresponding to a typical Laramide arch of the Bighorn Basin (Wyoming, USA). It is affected by three main fracture sets. The first two ones were formed before folding as regional joints sets during layer parallel shortening related to Sevier and then Laramide orogeny. The third one corresponds to outer arc extension veins formed during folding, parallel to fold axis. Most of the presented data come from Carboniferous (Mississipian) limestones of the Madison formation outcropping in the core of Sheep Mountain Anticline. For sake of comparison complementary data were collected in the Rattle Snake anticline.
The quantitative study of the vertical connectivity and of the hierarchy of fractures allows constraining how the various vein sets have controlled the hydrodynamic communication during fold evolution. Three order of fracturing can be described. The third-order corresponds to the bed-confined fractures, the first and second order to highly persistent fractures. First and second order fractures appear only during folding (third vein set).
In parallel, the Madison paragenesis constrained by stable and Sr isotope geochemistry of matrix and vein cements, allows proposing hypothesis concerning the various fluid sources active during burial and folding. The cements corresponding to the LPS related vein sets are characterized by isotopic signatures typical of marine formation waters progressively heated during burial. In contrast, the formation of the through going veins belonging to the third set is coeval with the penetration of deeper fluids from the underlying Devonian aquifer within the Madison Limestone.
Finally the calcite twinning paleopiezometry demonstrates that the end of the Laramide LPS phase corresponds to an overpressure climax reaching the lithostatic pressure. The formation of the third set that increases the vertical communication through the formation during folding induces a brutal release of this overpressure of at least 15Mpa.
The coherency between the three types of data (fracture stratigraphy, cement geochemistry, paleopiezometry) allows to demonstrate in Sheep Mountain anticline how fracturing stratigraphy can control paleo-hydrodynamics. This conclusion is tested by comparing Sheep Mountain with Rattle Snake anticline. In the latter, the pre-folding Laramide veins are persistent and act as pathways for the deeper fluid to penetrate the limestone early in the history of fold evolution. Taking advantage from this outcrop example some perspectives concerning the impact of paleo-hydrodynamics studies on fractured reservoir characterization are drawn in conclusion.