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From fold-related fracture population analysis to paleofluid flow reconstruction at basin-scale : a case study in the Bighorn Basin (Wyoming, USA)

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While fluid flows associated with thin-skinned folded structures have been extensively studied, reconstructions of paleofluid systems associated with thick-skinned tectonics remain scarce. In addition, major thrusts are usually considered as the preferential channels for fluids: investigating the role of diffuse fracture sets as potential drains for fluids has received poor attention. In this work, we tentatively reconstruct the paleofluid system related to the Bighorn basin (Wyoming, USA), a Sevier-Laramide foreland basin affected by large basement uplifts during the Laramide thick-skinned tectonic event.

Fracture pattern and related paleofluid flow were studied in selected folds within this basin. For this purpose, Oxygen, Carbon and Strontium isotopic studies were performed on host rocks as well as on pre-folding and on fold-related calcite veins; these studies were combined to fluid inclusion chemical and microthermometric analysis. The results suggest a strong control of fluid chemistry by the tectonic style: our work evidences migration of exotic hydrothermal fluids (temperatures of homogenisation of fluid inclusion reaching 140°C) in basement-cored, thrust-related folds, while in detachment folds, only intra-formational fluids were characterized.At the scale of the entire basin, the open paleofluid system reconstructed in basement-cored folds appears to be consistent, with oxygen isotopic signature ranging from -25‰ to -5‰ PDB. Indeed, the scattering of oxygen isotopic signatures in cemented veins shows different degree of mixing between local basinal fluids and exotic hydrothermal fluids remaining unequilibrated with surrounding limestones. Strontium isotopic analyses suggest that these exotic hydrothermal fluids are a mixing of meteoric fluids and basinal fluids that havemigrated in basement rocks, likely deeper than the basement/cover interface. The timing of the fast upward flow of these fluids through the cover is given by, and related to, different fracturing events and the associated sudden increase of hydraulic permeability (related to the vertical persistence of the fractures). The local opening of the fluid system to the fast hydrothermal fluid flow is however diachronic: it occurs as early as Sevier in age in the western part of the basin (in foreland flexure-related fractures) and later, during the Laramide phase, in the eastern part (in the fold curvature-related fractures).

This raise of hydraulic permeability allows fluid to flow vertically, which caused a fluid pressure drop in the Paleozoic strata, as demonstrated independently by the combined analysis of striated microfaults and fracture sets in terms of stress with calcite twinning paleopiezometry. The timing of the vertical hydraulic permeability increase also suggests that mode I fractures due to strata bending, either related to far-field (plate flexure) or local (strata curvature) stresses, were more efficient vertical drains than mode I fractures opened during layer-parallel shortening phases and connected the fracture pattern to allow lateral fluid flow.