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Evolution of paleostress magnitudes and pore fluid pressure during folding above a basement thrust: an integrated mechanical study at Sheep Mountain anticline (Wyoming, USA).

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In this contribution, we reconstruct the evolution of principal stress magnitudes sustained by folded sedimentary rocks, from the stage when strata are still flat-lying at the maximum burial until they deform by folding while being progressively exhumed toward the surface. The mechanical scenario relies on the well-documented kinematic and chronological evolution of development of faults, fractures and microstructures in a well-exposed basement-cored fold, Sheep Mountain Anticline (Wyoming, USA). There, Permo-Carboniferous limestone strata were fractured and exhumed by folding during Laramide contractional deformation. Paleostress orientations and regimes as well as differential stress magnitudes were determined from the analysis of fault slips and calcite twins; these data were further combined with rock mechanics data to derive first-order estimates of principal stress magnitudes related to layer-parallel shortening and late fold tightening.

Effective principal stress values are in the range of 20-60 MPa for sigma1 and -3-10 MPa for sigma3, with a fluid pressure between 18 MPa and 27 MPa in the limestone rocks deformed at ∼1000-2000m depth. Despite uncertainties, these values are amongst the very few paleostress estimates available for the uppermost crust at the particular time of tectonic deformation, especially in contractional settings. Noticeably, they are of the same order than modern principal stress values determined in situ in strike-slip or compressional stress regimes at various places.

A second important result is the evolution of the fluid (over)pressure. We document a rise of the fluid pressure (up to the lithostatic value) during layer-parallel shortening that is related to the activation of pressure-solution in limestone strata overlain by Mesozoic shales which behave as an impermeable barrier for fluids. The decrease of the fluid pressure during folding is explained by the development of bending-related fractures at the fold hinge: these fractures enhanced the overall fracture connectivity and therefore the vertical permeability of the entire stratigraphic sequence, including the impermeable Mesozoic shales, causing an upward fluid exhaust and a subsequent major drop of the fluid pressure.

Assuming that the entire fluid overpressure was released during folding, it is further possible to derive the maximum value of syn-folding erosion, estimated about 1000m. Assuming a duration of the folding event of 5-20 Ma leads to a rough estimate of the exhumation rate by folding of about 0.05-0.2 mm/yr, in line with exhumation-uplift rates of 0.1-0.3 mm/yr estimated from apatite fission-track data in other Laramide uplifts.

Beyond regional implications, this study opens promising perspectives for future integrated mechanical descriptions of folded-fractured reservoirs and may provide a useful alternative to pure kinematic models of thrust belts and foreland basins.