Determining the Origin of Structural Variability in the Easternmost Wind River Basin Using Fracture Analysis and 3-D Restoration

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Rocky Mountain basement-involved structures commonly occur as anastomosing networks of bifurcating arches and intermountain basins. These structures often host significant amounts of hydrocarbon accumulations. The search for these accumulations requires an understanding of their complex geometries and the kinematic origin of the structures that host them. Due to the diverse orientations of the structures in the Rocky Mountain foreland, determining their origin can be problematic. Current hypotheses explaining their diverse orientations include (1) single-stage NE- directed shortening with reactivation of some pre-existing weaknesses and (2) sequential multi-directional shortening. This study uses kinematic analysis of fractures and 3D modeling and restoration to address the origin of these complex structures on the southeastern margin of the Wind River Basin, Wyoming.

Data from 494 minor faults and 600 joints from three Laramide arches with different orientations ranging from E-W (i.e. Casper Mountain) to NW (i.e. Oil Mountain) and exhumed Laramide basins were used to determine the orientation of stresses during and after the Laramide Orogeny. Regional NW-SE joints occur in most of the syn and post-Laramide rocks, suggestive of a NE-directed extension after Laramide deformation ceased. Regional faults cutting pre-Laramide rocks are predominantly NW-SE striking thrust faults and E-W and NE-SW strike-slip faults, consistent with an ENE-trending regional Laramide compression. Similarly, ENE striking joint sets in pre-Laramide rocks are also consistent with regional Laramide compression. These results indicate that there was a uniform ENE-directed shortening direction during the Laramide Orogeny, despite the diverse orientation of arches and basins. Consequently, this ENE-directed shortening was used as a guide for restoration of a 3-D model of the study area created using surface geology, well, and seismic data.

The focus of the study area is a complex zone of intersection between the SW-verging Casper Arch and the E-verging Laramie Range. Between the two major arches lies the anomalous, steeply dipping, E-W striking Casper Mountain Fault Zone. 3-D restoration of this area not only requires there to have been significant left-lateral slip between the Casper Arch and the Laramie Range, but also requires 1.5° counterclockwise rotation of Casper Mountain during deformation. Ultimately, these results suggest that the Casper Mountain block experienced counterclockwise rotation compatible with oblique left-lateral convergence to serve as an accommodation block in a transfer zone between the two larger structures during uniform ENE-directed shortening.