Predicting Natural Fracture Patterns in Unconventional Resource Plays: New Insights from Rocky Mountain Tectonics

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Natural fractures can play a huge role in determining the viability of unconventional resource plays. Tight shear fractures (faults) can form seals that compartmentalize reservoirs whereas open extensional fractures (joints) and jogs on faults can provide enhanced permeability. Understanding the operative fracture mechanisms can help predict fracture types, orientations and zones of enhanced natural fracturing.

In the Niobrara Formation, open outcrop fractures are commonly controlled by regional tectonics, with outcrop fractures largely following regional fracture patterns. Thus, along the eastern edge of the Front and Laramie ranges, E-W-striking left-lateral faults, NE-SW-striking right-lateral faults, and thrust faults with E-W to ENE-WSW slip are dominant. While jogs on strike-slip faults can contain substantial voids, open fractures are dominated by late Laramide, ENE-striking splitting joints. In contrast, open Niobrara fractures in NW Colorado near Craig are dominated by NW-SE-striking joints related to post-Laramide extension. Thus, the optimum trajectory for drilling horizontal wells differs across northern Colorado.

In addition, 3-D seismic data from basins have revealed complex arrays of normal faults which sole into bedding near the base of the Niobrara Formation. These are probably due to overpressuring during hydrocarbon generation in the Niobrara. Outcrops show that some of the normal faults are reactivated Laramide strike-slip faults, but others create puzzling polygonal patterns suggesting multi-directional detachment and/or diagenetic mechanisms.

Research in central Wyoming has demonstrated additional fracture mechanisms that may locally control Niobrara fracturing. Multi-directional Laramide shortening has been documented in several locations, and may be due to an additional component of gravity spreading during Late Laramide deformation. Adjacent to master Laramide thrust faults, concentrations of post-Laramide normal faults suggest localized back-sliding on the master thrusts (e.g., Jonah Field in the Green River Basin and the northern margin of the Wind River Basin). One thing is clear - Rocky Mountain fractures are complex, with multiple ages and mechanisms of formation, and simplistic unified models will fail to predict them.