Fractured Reservoirs, Fractured Niobrara

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Understanding the effects of natural fractures on a reservoir requires data on the fracture types, distributions, and their relationship to the in situ stresses. Prediction of these fracture characteristics requires information on the mechanical properties of the fractured rock and degree of structural deformation. In general, fractures found in brittle strata are more closely spaced but they are not as sensitive as fractures in ductile strata to damage caused by diminishing pore pressures during production. Fractures may strike parallel, oblique, or normal to the present-day maximum horizontal in situ stress, controlling whether the fractures will, respectively, be little affected, prone to shear offset, or susceptible to closure during production. Stress magnitudes as well as the angle between fractures and the in situ stresses also control the interaction between natural fractures and hydraulic stimulation fractures. Niobrara fracture systems vary significantly in these respects. A structural history reconstructed from outcrop and core suggests that pre- or syn-compactional shale injections formed normal to extensional stresses, possibly due to down-slope gravitational stress normal to the paleoshoreline. Most of these sedimentary structures have strikes that were, serendipitously, normal to later thrust-related Laramide horizontal compression and were therefore prone to dissolution, becoming the locus of bed-normal stylolites. This compression also created numerous vertical hairline extension fractures that strike normal to the injections. In dirtier lithologies, hairlines developed in closely-spaced bundles that were susceptible to later dissolution, forming open slots along the parent fracture bundles. These slots were, finally, partially re-mineralized with euhedral calcite. Geometric relationships in core show that most of the slots strike parallel to the present-day maximum horizontal in situ compressive stress and should therefore lose minimal aperture and permeability during production. In the Raton Basin, the ratio between the overburden and the horizontal stress created by basin-margin thrusting varied due to both lateral stress dissipation and lateral changes in the overburden thickness, creating a laterally variable fracture system.