Spatially Variable Natural Fractures and Enhanced Shale Gas Production: A Case Study from the Pierre and Niobrara Formations, Raton Basin, CO

Colin R. O'Farrell*, Sarah J. Hawkins, William R. Drake, Hadi P. Soetrisno, and Todd W. Peters

Pioneer Natural Resources, 1401 17th St., Suite 1200, Denver, CO USA

Natural fractures have long been recognized for their strong control on hydrocarbon production, via roles as storage mechanisms (e.g. Landon et al., 1992) and enhanced permeability pathways (e.g. Murray, 1968). The unconventional oil and gas shales that have recently become the focus of industry interest may have no meaningful matrix porosity and typically possess matrix permeabilities in the micro- to nano-darcy range. These plays are reliant to fractures (whether induced or natural) to deliver hydrocarbons to the wellbore. Previous workers have shown that natural fractures may enhance production by increasing permeability (Engelder et al., 2009) or hinder it by acting as baffles to flow (Bourne et al., 2000). Here, we present a study of natural fractures and their impact on the gas producibility of the Cretaceous Pierre and Niobrara formations in the northern Raton Basin of southeast Colorado.

The Raton Basin is positioned at the crossroads of Laramide mountain building, Rio Grande rifting, and Tertiary intrusions and volcanism. The resulting temporally variable stress regime (~70-110º rotation of principal horizontal stress) has induced at least three identifiable fracture families with characteristic orientations and has led to present-day horizontal stress anisotropy. The three distinct fracture families are consistent with mechanical models for the region proposed by Lorenz and Cooper (2004) and appear to be areally consistent between wells with image logs. However, localized fracture swarms identified from image logs exhibit a compilation of fracture orientations that are inconsistent with the regular spacing of the three fracture families. Intersection of these localized swarms appears to be a key driver in well performance, as inferred from production logs and well production histories. Given the potentially limiting effect of present day horizontal stress anisotropy on generating fracture complexity through stimulation, intersection of these natural fracture swarms with completions is all the more important. Representation of regional fracture sets via assignment of characteristic spacing may be appropriate for some settings (e.g. Engelder et al., 2009). However, our results suggest that meaningful characterization of natural fractures and their impacts on production must go beyond this methodology to consider spatially variable fracture patterns, as they may be key to unlocking fractured reservoir plays.