Constraining Permeability Evolution During and After Natural Fracturing in Overpressured Shales: Implications on Basin-Scale Stress and Pore Pressure

Laainam Chaipornkaew[1], Marek Kacewicz[2], Peter Lovely[2]
[1]Stanford University; [2]Chevron Energy Technology Company

9.29.2020 - 10.1.2020 – AAPG Annual Convention and Exhibition 2020, Online/Virtual

Abstract

Most shales undergo some form of inelastic deformation, which may include effects from compaction under increased confining pressure, with additional enhancement via horizontal tectonic stresses. Chaipornkaew et al. (EAGE 2019) proposed a mechanism that allows dissipation through fractured shales (seals) as a function of effective stress and pore pressure criteria. These overpressure-driven fractures allow episodic discharge of excessive fluid and consequently overpressure dissipation from fractured elements via a permeability modification function that enhance flow transmissivity. This study focuses on refining this function by considering contributions from (1) initial permeability increases during tensile fracture formation and (2) subsequent permeability reduction due to stress-induced closure. To demonstrate the effects of permeability evolution during and after fracturing, we generate end-member examples of Discrete Fracture Network (DFN) representing densely-spaced, sub-vertical tensile fractures with hierarchical geometry. Fractures are stochastically seeded with exponentially-distributed fracture size. We assume fracture aperture is correlated with fracture size because we model fracture at the time of formation when chemical alteration is insignificant. Stress-induced fracture behavior is modelled with simple constitutive relation. Evolution of fracture aperture and permeability are first explored on single fractures of various size with various elastic moduli. Subsequently, this relationship is applied to all fractures in the target DFN. Since matrix permeability in shales is typically very low, we assume that a modification of fracture permeability when upscaling to an effective permeability for large-sized elements suitable for basin-scale application is a sufficient approximation. The upscaled permeability reflects the initial permeability range representing statistics (size, density, transmissivity) of selected DFN and elastic properties of shales. To study evolving properties of shales we built a series of synthetic models using a finite element code designed for Evolutionary Geomechanical Basin Modeling (ParaGeo). We present two fracture permeability evolution scenarios: 1. step function (base case) and 2. continuous permeability change with stress for two shale end-member scenarios: Soft Shale and Stiff Shale (Young modulus 3GPa vs 30GPa). Soft Shale reveals much larger changes in permeability as compared to Stiff Shale under applied effective stress. We concluded that immediate cutoff in fracture permeability as stress and pressure condition drop below fracturing criterion (base case scenario) may lead to incorrect rock properties and computed pore pressure in fractured elements. This may have signification implications for modeling hydrocarbon migration efficiency and expulsion from fractured shales.

AAPG Datapages/Search and Discovery Article # 91200 © 2020 AAPG Annual Convention & Exhibition Online, Sept. 29- Oct. 1.