Natural Fracture Characterization in Shale-Gas Reservoirs: Spatial Organization and Fracture Sealing

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Natural fracture systems are important for production in shale-gas reservoirs in two ways. They may reactivate during hydraulic fracture treatments or they may be partly open, contributing to permeability without reactivation. Degree of openness and fracture plane strength are related in part to the specific structural-diagenetic history of each fracture set and shale host rock. Several possible mechanisms control fracture formation. A key variable is the depth of burial, and thereby the temperature, pore-fluid pressure and effective stress at the time of fracture development. Examples exist across the spectrum; from veins developing before host-rock compaction is complete, to veins forming at maximum burial due to hydrocarbon generation or other mineral reactions, to late, shallow veins of gypsum formed due to pyrite oxidation in the weathering zone. We present examples that illustrate these mechanisms from several US shales, including the Devonian New Albany Shale in the Illinois Basin, the Mississippian Barnett Shale from the Delaware Basin, west Texas, and the Marcellus Shale from SW Pennsylvania.

The techniques we employ for fracture characterization can be utilized in any shale-gas reservoir but require specific data sets. We focus here on two aspects: fracture spatial organization and fracture sealing cements. We use a modified two-point correlation integral method to analyze horizontal image log data, which allows us to quantify spatial organization, and to assess the degree of fracture clustering. We compare the results of this analysis with geomechanical models of growing fracture patterns, informed by knowledge of fracture population size-scaling relationships. Our goal is to develop a methodology for fracture spacing prediction. Fracture sealing cements follow similar patterns to those in fractures in tight gas sandstones and dolostones. The synkinematic cement phase is commonly characterized by crack seal texture and mineral bridges. Scanning Electron Microscope-based cathodoluminescence, coupled with fluid inclusion analysis has allowed constraints to be placed on the timing and during of fracture formation. Hydrocarbon inclusions are commonly observed in the fracture sealing cements and provide insights into processes associate with cracking of kerogen to oil and oil to gas.

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