Effects of Petrophysical and Engineering Factors on Fluid Flow and Production in Gas Shales

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Shale quality, gas deliverability, and production sustainability determine the success of a shale-gas play. With the evolution of horizontal-well and multistage-fracturing technologies, many high-quality shale resources have become productive and the most interesting reservoirs today. The objective of this study was to investigate some unique properties of gas shales, and their influence on fluid flow and production.

Organic pores in gas shales play an important role in petrophysical properties, fluid flow, and production. Because organics are oil-wet, gas flow in organic pores is predominately single phase, which markedly enhances permeability. Because the pore volume in organics is estimated to be larger than the pore volume in fractures, organic pore networks can be hidden production fairways for high gas production.

Connate water saturations in high-quality gas shales are low and vary from 15 to 40% in Barnett, Haynesville, Marcellus, and Eagle Ford Shales. The low connate water saturations in gas shales might have been caused by excessive drying of shale at high temperatures and pressures during gas generation and migration, as well as effects of burial history and capillary hysteresis. Low connate water saturation has two important impacts on fluid flow in gas shales: (1) decrease in likelihood of water production and (2) low frac-water recovery.

Both thermal and geopressure gradients are important in screening shale-gas plays. Although the Barnett Shale in North Texas is intrinsically more brittle than the Haynesville Shale in East Texas and North Louisiana, initial potentials in the Haynesville Shale are four to five times greater than those in the Barnett. The high production rate in the Haynesville Shale stems from its high porosity, permeability, free-gas content, and effective brittleness associated with its high pressure and pressure gradient, which in turn enhances shale quality. Moreover, increases in porosity and gas density result in a double enhancement in free-gas content, and the low effective stress caused by the near-fracture-gradient formation pressure enhances the effectiveness of hydraulic fracturing in the Haynesville Shale.

Initial potential (IP) and estimated ultimate recovery (EUR) are indicators of deliverability and sustainability. IP, a short-term measurement of well performance by a completion, reflecting the free gas content in fracture and organic networks, and quality of gas shale near the stimulated reservoir volume, is a complex function of reservoir and operational parameters such as mineral composition, reservoir pressure, type and size of fracturing treatment, choke size, and number of frac stages. EUR, a long-tern measurement of well performance, reflects free and adsorbed gas content, gas-shale quality of the reservoir volume drained by a well through one or more completions. Statistically, EUR increases with IP in a specific area and their relationship can be complicated by the variations in reservoir quality, brittleness of shale, time of completion, and production technologies applied.