Variability of Geologic Properties in Shale Gas and Tight Oil Plays

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ABSTRACT

Major productive shale gas and tight oil formations in the U.S. share common features including high total organic carbon (TOC) content (>2%), appreciable porosity (>5%), low clay volume (<40%), and optimal thermal maturities (0.6–3.0% vitrinite reflectance [R_o]). However, variability in the geologic properties of shales, created by their differing depositional environments and burial histories, has implications for the extent of resource development, the delineation of potentially productive areas, and the recovery efficiency of horizontal wells, among other factors. Furthermore, many studies on emerging unconventional oil and gas plays that lack robust data (e.g., in the U.K., Mexico, and China, as well as in the U.S.) use mature U.S. shale plays as analogs. Understanding the variability of geologic properties in mature U.S. plays allows for comparison between plays, development of appropriate proxies for new exploration wells, and understanding of the ranges of geologic factors that may limit or enhance productivity in each play.

Here we present a summary of the geologic characteristics of eight major U.S. shale gas and tight oil plays, including the Barnett, Haynesville, Fayetteville, Marcellus, Bakken, Eagle Ford, and the Wolfcamp of the Midland and Delaware basins. The Bureau of Economic Geology has been conducting resource evaluation studies on these plays since 2012, resulting in the assembly of a comprehensive dataset of properties from original Bureau studies and literature. Subsurface well log interpretations, when calibrated to core data, allow for mapping properties on a basin-wide scale. In each shale basin, 150–1200 wells have been studied.

The depth, thickness, and stratigraphic relationships of producing formations and subjacent/superjacent formations, and reservoir properties including porosity, TOC, lithofacies, and thermal maturity, are summarized

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and linked to the depositional and tectonic history of the plays. Properties are mapped on a square-mile block basis, providing a consistent characterization of the nature of the play without sampling bias, which is important for plays that are underdrilled relative to their size such as the Marcellus.

Play size ranges greatly, from ~2300 mi^2 to more than 46,000 mi^2 for the Fayetteville and Marcellus, respectively. Formation depths average from <4000 ft in the Fayetteville to >12,000 ft in the Haynesville, and formation thicknesses vary from <50 ft in the Middle Bakken to several thousands of feet in the Wolfcamp of the Permian Basin. Average shale play porosity ranges from 5.6–7.4%, and average present-day TOC concentration ranges from 2–3% for the Wolfcamp to >12% for the Upper and Lower Bakken source rocks.