

UNCONVENTIONAL SHALE-GAS RESOURCE SYSTEMS AND PROCESSES AFFECTING HYDROCARBON GENERATION, RETENTION, AND STORAGE

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Unconventional shale resource systems, which are oil or gas plays where the reservoir unit is also the source rock, are present over broad geographic areas. While shale oil has been produced from a number of source rocks and basins for quite some time, exploitation of shale gas has only evolved in the last five years. Of these systems, the Mississippian Barnett Shale in the Fort Worth Basin, Texas is the pre-eminent example, having become the fourth largest gas field in the United States. The Barnett Shale is a low porosity (avg. 5%), nano-darcy permeability resource play that encompasses about 4500 square miles. It has served as a model in the pursuit of other shale gas resource plays.

Geochemical and petrophysical characterization of various shale gas systems in the U.S. suggests a variety of unconventional shale-gas system types (Fig. 1). The most basic distinction is gas type: biogenic and thermogenic, although there can also be mixtures of the two gas types. Thermogenic shale-gas systems are further segregated into various sub-types depending on geochemistry and geology. The shale-gas system categories are: (1) high thermal maturity shale; (2) low thermal maturity shales; (3) mixed lithology intra-formational systems containing shale, sands, and silts; (4) inter-formational systems where gas is generated in a mature shale and stored in a less mature shale, and (5) mixed systems. A key difference among these shale-gas systems are initial gas flow rates. High thermal maturity systems tend to have much higher gas flow rates than low maturity systems due to gas charge and storage mechanisms. Certainly other non-geochemical factors, such as mineralogy, are extremely important in being able to stimulate these shales to flow gas.

Both source rock potential and thermal maturity play key roles in generation, retention, and storage of hydrocarbons. High thermal maturity shales have porosity development related to their original TOC content, less the mass balance loss as a result of generation. Thus, 7 wt.% TOC is *ca.* 14 vol.%, which at 35% conversion of organic matter, yields 4.9% porosity development. At low to moderate thermal maturity the organic carbon provides adsorptive sites for retention of hydrocarbons. This results in less efficient expulsion and increased gas generation amplified by secondary cracking of hydrocarbons. Estimated expulsion efficiency from the Barnett Shale is only *ca.* 55%. Adsorption may also play a role in the increased cracking of hydrocarbons as a function of reduced bond breaking energies due to bond angle

strain (Sheiko et al., 2006). In addition, if transition metal catalysis plays any role in increased gas generation, the close association of generated hydrocarbons to residual organic matter would provide a possible avenue for such catalysis to occur.

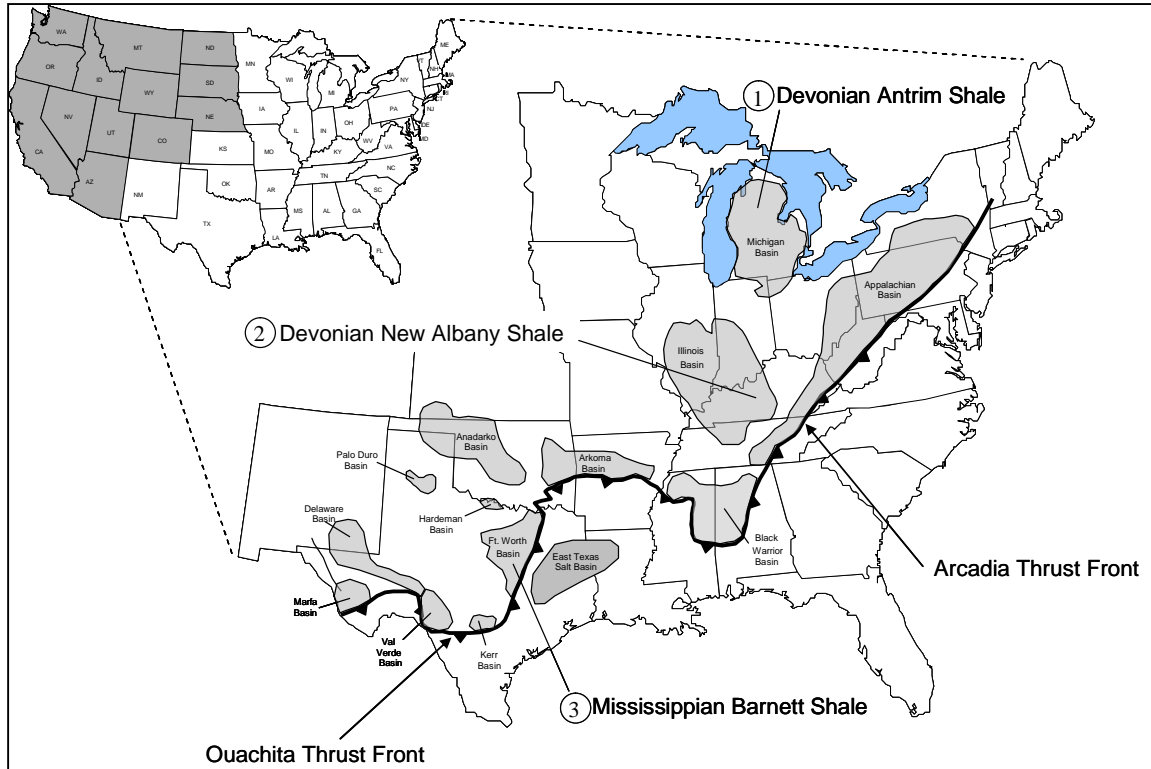


Figure 1. Various shale gas resource plays in the United States. Data from three systems are used to illustrate system types: (1) the immature Antrim Shale, (2) the low thermal maturity New Albany shale, and (3) the high thermal maturity Barnett Shale.

Gas storage capacity of a shale at low porosity can be quite high, depending on pressure and temperature. For example, at 5% porosity, 80°C, and 3800 psi (typical porosity and reservoir conditions for the Barnett Shale) over 121 scf/ton of gas can be stored. This gas content translates into a GIP (gas-in-place) of over 200 Bcf/section (mi.²) or about 20 Bcf EUR (estimated ultimate recoverable).

Interpreted maturity values in the absence of black oil allow estimates of initial gas flow rates from shales for economic evaluation. Black oil components occlude pore throats in these shales possibly due to both molecular size and adsorption-induced flow restrictions.

REFERENCE

Sheiko, S. S., F. C. Sun, A. Randall, D. Shirvanyants, M. Rubinstein, H-il Lee, and K. Matyjaszewski, 2006, Adsorption-induced scission of carbon-carbon bonds: *Nature*, v. 440/9, p. 191-194.