Journal of Unconventional Oil and Gas Resources 7 (2014) 1–10

Contents lists available at ScienceDirect

Journal of Unconventional Oil and Gas Resources

journal homepage: www.elsevier.com/locate/juogr

Lessons learned from the Floyd shale play

Harry Dembicki Jr. *, Jonathan D. Madren

Geological Technology Group, Anadarko Petroleum Corporation, P.O. Box 1330, Houston, TX 77251-1330, USA

ARTICLE INFO

Article history:
Received 15 August 2013
Revised 3 January 2014
Accepted 5 March 2014
Available online 21 March 2014

Keywords:
Shale gas
Organic geochemistry
Petroleum systems
Clay sensitivity
Geomechanics
Seal

ABSTRACT

Detailed analysis of the organic matter, mineralogy, and related rock properties of the sediments of the Neal shale member of the Floyd shale group in the Black Warrior Basin were done to determine the cause of the lack of adequate production in this shale gas play. Analysis of pilot well cores found the organic-richness, kerogen type, maturity, thickness, porosity/permeability, and geomechanical behavior were all found to be satisfactory for a potential shale play. Although bulk mineralogy compared favorably with other shale plays, some of the testing pointed toward fluid–clay interactions and proppant embedment as the cause for the lack of production in this shale gas play. However, close proximity to gas charged overlying sandstones along with normal pressure in this shale reservoir suggest potential seal problems have reduced the gas charge in the shale. This led to changes in the screening parameters for new plays, emphasized the importance of doing look backs on failed projects, and the need to integrate learnings into future project evaluations.

Introduction

Shale gas plays are often viewed simply as black shales that are sufficiently rich in organic matter, at a high enough maturity, and within economic depths for horizontal drilling that can be induced to produce gas by artificially fracturing the shale. But shale gas plays are much more complex. They are true petroleum systems as defined by Magoon and Dow, 1994. They contain elements of a petroleum system: source rock, reservoir, seals, and overburden. And they must undergo the same processes as a petroleum system, such as trap formation, generation, migration/accumulation, and preservation/destruction. It is, however, necessary to think about the elements and processes in a different context when dealing with shale gas plays. Shown schematically in Fig. 1, an idealized shale gas petroleum system is one where the source, reservoir, trap, and seal are all present within the same formation. Overburden is required to reach a depth of burial adequate for gas window generation and migration pathways are short and simple, from the kerogen to the pore space. Competent top and bottom seals are needed to contain the gas and to act as fracture barriers during well stimulation. Just like in conventional petroleum systems, experience with the unconventional petroleum systems has shown that although they have some commonality, more often they are defined by unique sets of characteristics that contribute to their successful development or failure.

The Floyd shale in the Black Warrior Basin has long been considered a potential shale gas play. It is a known source rock in the basin, responsible for conventional oil and gas production from Pennsylvanian and Mississippian age deltaic sands (Telle et al., 1987; Carroll et al., 1995). It is also the stratigraphic equivalent of successful shale gas plays in the Barnett Shale in the Fort Worth Basin and the Fayetteville Shale in the Arkoma Basin (Pashin, 2008). Within the Black Warrior Basin, there are areas where the Floyd shale has an adequate thickness (up to 200 feet), has a high enough organic matter content (2.0–7.0% total organic carbon or TOC), and has reached a high enough thermal maturity (vitrinite reflectance >1.30% Ro) to pass the initial screening for a shale gas opportunity. But tests of the interval with both vertical and horizontal wells have yet to produce gas volumes approaching commercial quantities or rates (see Section 4).

In order to determine what is limiting the deliverability of gas from the Floyd Shale, the characteristics of these sediments were compared to more successful shale gas plays. The results shows the Floyd compares favorably with respect to kerogen type, organic matter content, thermal maturity, and bulk mineralogy with at least one or more of these plays. In addition, analysis of core and cuttings samples indicates the Floyd Shale is charged with gas and monitoring of the well completion process indicated that fractures were opened and proppant was successfully pumped out into the formation during reservoir stimulation. So why did the Floyd shale fail to produce?

* Corresponding author. Tel.: +1 832 636 3459; fax: +1 832 636 9882.
E-mail address: harry.dembicki@anadarko.com (H. Dembicki Jr.).

http://dx.doi.org/10.1016/j.juogr.2014.03.001
2213-3976/

	Seal – competent rock to contain the gas and to act as fracture barriers during stimulation
Gas Shale	*Source Rock* – an organic-rich shale in the gas window *Reservoir* – a shale with some porosity and permeability that can be fractured to recover the gas *Trap* – essentially a stratigraphic trap *Seal* – minimal open natural fractures to leak off gas
	Seal – competent rock to contain the gas and to act as fracture barriers during stimulation

Fig. 1. An idealized gas shale source rock/reservoir petroleum system.

Floyd/Neal shale in the Black Warrior Basin

The Black Warrior Basin is a late Paleozoic foreland basin in northwest Alabama and northeast Mississippi bounded by the Ouachita thrust belt on the southwest and the Appalachian Thrust Belt to the southeast (Thomas, 1977) as shown in Fig. 2. Within the Black Warrior, two potential targets for unconventional development have been identified, the Devonian Chattanooga and the Mississippian Neal shales. While the Chattanooga is a mature organic-rich shale, it is relatively thin and discontinuous (Pashin, 2008), indicating a limited resource potential for unconventional development. The Neal shale is an organic-rich facies of the Upper Mississippian Floyd Shale. Its stratigraphic position in the Mississippian and Pennsylvanian sediments is shown in Fig. 3. The Neal Shale is a resistive, organic-rich interval deposited in a distal setting in a progradational deltaic sequence in the lower part of the Floyd Shale (Pashin, 1994) The Neal Shale is suspected to be the source of the gas found in the overlying Hartselle sandstone and the small oil and gas accumulations in the Upper Mississippian sands of the Parkwood formation representing approximately 1.1 TCF of gas and 10.6 MMB of oil (Carroll et al., 1995). It is likely the Neal Shale has also contributed to the Pennsylvanian Pottsville gas sands and coal bed methane (Telle et al., 1987), as well as the tar deposits in the Hartselle Sandstone and Pride Mountain formation (Carroll et al., 1995).

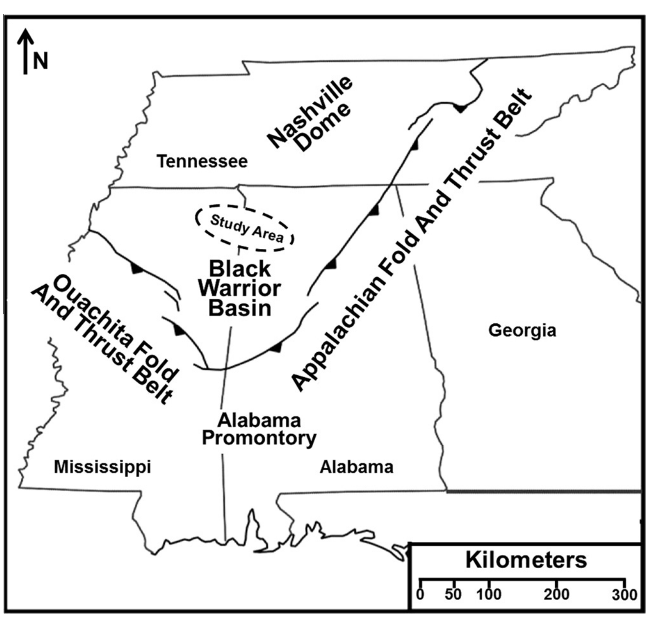

Fig. 2. Map showing the location of the Black Warrior Basin in Mississippi and Alabama situated between the Ouachita and Appalachian Fold-Thrust belts (modified from Thomas, 1988). The study area outlined represents the focus of the exploration effort.

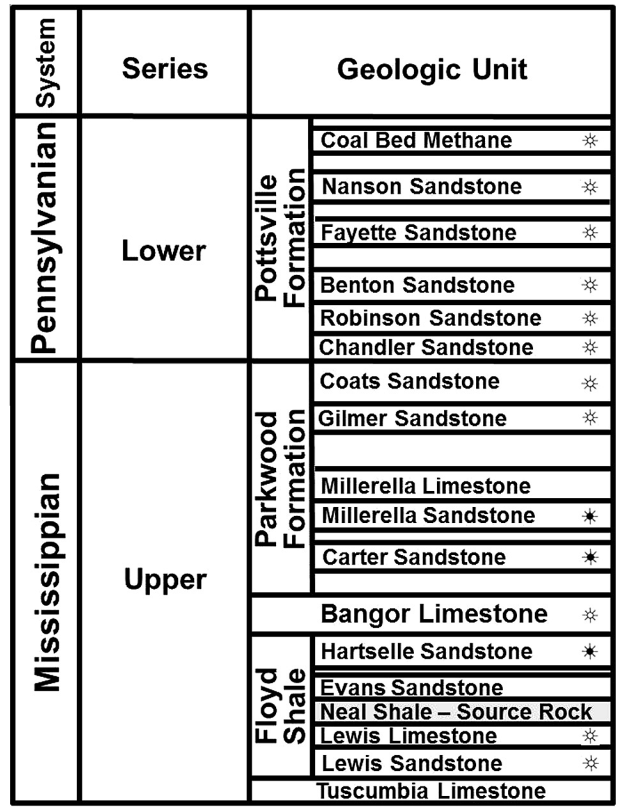

Fig. 3. Generalized Upper Mississippian-Lower Pennsylvanian stratigraphy in the Black Warrior Basin showing suspected Neal Shale sourced production (modified from Ettensohn and Pashin, 1993).

Pre-drilling evaluation

Anadarko's technical evaluation of the Floyd/Neal took place in the 2nd and 3rd Q of 2005. Pre-drill screening of the play consisted of reviewing in-house data, published reports (e.g. Carroll et al., 1995), and commercially available data (e.g. Castano and Talukdar, 1992). Typical shale gas play screening parameters were fairly simplistic at the time, and they were highly influenced by what appeared to be the conditions in the productive parts of the Barnett Shale in the Fort Worth Basin.

Based on the Barnett analog, the organic matter content needed to be adequate to produce large quantities of gas, with TOC contents required to be 2.0% or greater. The shale's original kerogen type needed to be oil-prone (dominated by Type I or II kerogen) because it will yield more gas than a gas-prone kerogen (dominated by Type III kerogen) in a source rock of equivalent richness. The sediments needed to be in the gas window, indicating thermal maturity of 1.3% Ro or greater for vitrinite reflectance. As a result, the Rock–Eval pyrolysis hydrogen index (HI) values should currently be less than 100 mg hydrocarbon/g organic carbon (mg HC/g C). In order to have a sufficient resource available, the net shale thickness needed to be 75 feet or greater. There was also a concern at that time that the shale's mineralogy needed to be more quartz- and/or carbonate-rich and less clay-rich (usually less than 40% clay) so the rock would be more brittle and fracture-prone. And drilling depth needed to be deep enough for pressure support to produce the gas (usually more than 5000–6000 feet), but shallow enough for economic drilling (usually less than 11,000–12,000 feet).

When the Neal Shale data was researched, there were areas in the basin where the TOC contents ranged from 2% to 6% with the thickness ranging from 50 to 190 feet. The presence of oil-prone