Most of our laboratory measurements on gas shales have been obtained on samples from wells in the Devonian Woodford Shale. We have also begun studies on Marcellus and Mahantango Shale (MSEE SW).

ABSTRACT

The use of water-based hydraulic fracturing fluids in stimulation of unconventional reservoirs is problematic because of formation damage from water blocking, and because of costs associated with use of large volumes of water are required treatment of flowback water. This research is aimed at understanding of how water interferes with the desired counter-flow of gas from shale into fractures, and also is exploring approaches for significantly reducing water use in fracturing. Most of our experiments have been conducted on Woodford Shales, which were found to exhibit strongly hysteretic water uptake and drainage. Very high capillary retention (water blocking). The measured diffusion-limited approaches to equilibrium are being modeled. Influences of gravity on draining of injected water from hydraulic fractures and enhancing gas production are being explored through simulations of fracture-shale matrix interactions. A novel natural bio surfactant is being developed for supercritical fluid foams for reducing water use in fracturing.

OBJECTIVES

• Understand coupling between water imbibition and gas counterflow in shales in order to help identify approaches to improving production.
• Understand the effectiveness of low-water fracturing fluids on shale gas/oil mobilization, and improve performance of fracturing fluids.

SHALE SAMPLES AND MEASUREMENTS

Most of our laboratory measurements on gas shales have been obtained on samples from wells in the Devonian Woodford Shale. We have also begun studies on Marcellus and Mahantango Shale (MSEE SW).

Measuring shale wetting and drainage (a.) fixed relative humidity systems, (b.) pressure plate device, (c.) transient imbibition and gas counterflow core holder.

STRONG CAPILLARY RETENTION OF WATER IN SHALE

Relation capillary pressure (Pc) and water saturation need to be understood to predict water distribution in shales and pressure differences needed to allow gas flow. We have measured shale water saturation relations over a wide range of water activities and P.
• Large capillary hysteresis of water retention.
• Very strong retention of water in most samples.
• Less hydrophobic behavior of calcite-rich shale.

DIFFUSION-LIMITED WATER VAPOR ADSORPTION

Time needed to reach equilibrium in adsorption-desorption, and imbibition-drainage processes is often underestimated, and leads to errors in measured capillary relations. Our vapor adsorption experiments on ~1 cm pieces of shales required weeks to reach equilibrium.
• Effective diffusion coefficients in the range of 9E-9 to 3E-8 m²/s were obtained through modeling of the diffusion process. These values are consistent with other measurements on low-porosity rocks.
• Experiments and simulations of diffusion in anisotropic shales are underway.

INFLUENCES OF WATER IMBIBITION THROUGH MICROFRACTURE NETWORKS

• Predominantly vertical hydraulic fractures supply fracturing fluids to primarily horizontally oriented microfractures in shales.
• Initial imbibition enhanced via flow in microfractures (natural and stimulated).
• Imbibition into shale over shorter and longer times is dominated by microfracture and matrix imbibition, respectively.

INFLUENCES OF GRAVITY DRAINAGE OF WATER IN FRACTURES ON GAS FLOW

Given the large fractions of hydraulic fracturing fluid remaining in reservoirs long after injection, and the measured strong capillary retention of water in shale, why are wells commonly so productive? Gravity drainage of hydraulic fractures above horizontal wells is very effective, leaving little water to imbibe into shale in the upper portion of reservoirs, thereby allowing efficient gas production shales. The importance of fracture drainage is being investigated through modeling studies of shale fracture-matrix systems. Preliminary results are showing how vertically stratified water distributions affect the distribution of gas flow into wells.

HIGH PRESSURE CO₂ - WATER FOAM DEVELOPMENT

Given the detrimental impacts of injecting large volumes of water into unconventional reservoirs, it is desirable to develop alternative, low-water fracturing fluids. Foams can constitute a potentially viable alternative.
• We have identified humic-rich early Carboniferous crude oils as sources of inexpensive natural bio surfactants (NBS). A simple, efficient procedure was developed for extracting NBS from raw materials.
• Ability of NBS to effectively lower interfacial tension of supercritical CO₂-water systems was demonstrated.
• NBS-stabilized scCO₂-water foams with capillary number up to 30 cP have been generated.

REFERENCES

Cardot, B.J. (2012), Thermal maturity of Woodford Shale gas and oil plays, Oklahoma, USA, Int. J. Coal Geol. 103, 109-119.

ACKNOWLEDGMENTS

This work was supported by the National Energy Technology Laboratory (NETL) under U.S. Department of Energy Contract No. ESD-14085, “Understanding Water Controls on Shale Gas Mobilization into Fractures”. We thank Steve Henry, NETL, for project guidance. The Oklahoma Geological Survey (OGS) is acknowledge for use of Woodford Shale samples, and Brian Coddit (OGS) for helpful discussions. The Marcellus Shale Energy and Environment Laboratory and NETL are acknowledged for providing Marcellus Shales.