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Pore Structure, Diffusion and Gas Recovery in Barnett Shale

HU Qinhong^{1,*} and GAO Xubo²

1 The University of Texas at Arlington, 500 Yates Street, Arlington, TX 76019, USA

2 China University of Geosciences-Wuhan, 388 Lumo Road, Wuhan, 430074, China

Located in the Fort Worth Basin in north-central Texas, the Barnett shale is a Mississippian-age marine shelf deposit, ranging in thickness from about 60 m in the southwest region to 305 m to the northeast. The formation is a black, organic-rich (4.5% organic carbon) shale composed of fine-grained, siliciclastic rocks with extremely low permeability (0.07-5 μd). As the birthplace of successful commercialization of an unconventional reservoir, the Barnett shale currently has some 16,000 producing wells. The reservoir produces at commercially viable levels only with hydraulic fracturing that establish long and wide fracture pathways, which connect large surface areas of the formation through a complex fracture network. However, the main challenge facing hydrocarbon producers is the rapid initial depletion rate of new wells, with first year declines averaging around 64% for Barnett shale. Total gas recovery from the Barnett shale was reported to be only 8%-15% in 2002, and 15%-30% in 2012, even with stimulation, and there are few investigations into root causes of this low gas recovery.

We use various approaches to investigating pore

structure, and the resulting anomalous diffusion, in Barnett Shale. These experimental approaches include imbibition, tracer diffusion, porosimetry (mercury intrusion porosimetry, water vapor transport and capillary condensation, and nuclear magnetic resonance cryoporometry), and imaging (Wood's metal impregnation, focused ion beam/SEM). Results show that the Barnett Shale pores are predominantly in the nm size range, with a measured median pore-throat diameter of about 6 nm. The nm-sized pores, combined with low pore connectivity, lead to extremely low diffusion in shale matrix as measured using liquid diffusion and laser ablation-ICP-MS. Chemical diffusion in sparsely-connected pore spaces is not well described by classical Fickian behavior; anomalous behavior is suggested by percolation theory, and confirmed by results of imbibition tests. Monthly gas production data for wells in the Barnett shale are obtained from the Texas Railroad Commission, and gas production decline behavior from producing wells is analyzed from the topological aspects of shale pores.

* Corresponding author. E-mail: maxhu@uta.edu