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Characteristics and New Scaling for Forced Imbibition Based on Low-Field Nuclear Magnetic Resonance Measurements

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Hydraulic fracturing is an effective method to improve oil recovery by injecting massive fracturing fluid to create complex fracture networks. After that, the well is commonly shut down for a period to promote water uptake and appropriate shut-time is of vital importance. One effective way to predict shut-in time is to combine experimental results of spontaneous imbibition (SI) and dimensionless time model. But the physical simulation of SI is commonly performed at atmospheric pressure and the characteristics of imbibition considering the effect of confining pressure (named as forced imbibition, FI) is often neglected. In this study, pose size distribution in tight core samples was firstly obtained in combination of high pressure mercury intrusion (HPMI) measurements and low-field nuclear magnetic (LF-NMR) measurements and oil distribution in tight core samples was discussed correspondingly. And then experiments of SI and FI were performed in a sealed and pressurized system and oil recovery was measured using a LF-NMR system. Finally, a new scaling law for FI was proposed to predict shut-in time in field scale.

The results showed that 95.94% - 98.12% of the oil was distributed in nano-pores (0.1 ms < T2 < 100 ms) of core samples, and the average amount of oil in nano-micro-pores, nano-meso-pores and nano-macro-pores were 34.04%, 40.15% and 22.75%, respectively. Ultimate oil recovery of core samples were 22.41%, 44.41%, 57.27%, 61.84% and 62.82%, respectively, as confining pressure increased from 0 psi to 2175 psi. The improved oil recovery of FI was mainly associated with the drop of effective pore radius as a function of confining pressure. Finally, a new scaling law for FI was proposed to calculate shut-in time in field scale by combining experimental results of FI, Mason's dimensionless time (tD) model and Leverett's capillary model.

References

[1] Holditch, S.A., Tschirhart, N. Optimal Stimulation Treatments in Tight Gas Sands. SPE Annual Technical Conference and Exhibition, Dallas, Texas, 9-12 October 2005; SPE 96104.
[2] Barzegar Alamdari B, Kiani M, Kazemi H. Experimental and Numerical Simulation Of Surfactant-Assisted Oil Recovery In Tight Fractured Carbonate Reservoir Cores. SPE Improved Oil Recovery Symposium, Tulsa, Oklahoma, USA, 14-18 April 2012; SPE 153902.
[3] Dehghanpour H, Lan Q, Saeed Y, Fei H, Qi Z. Spontaneous Imbibition of Brine and Oil in Gas Shales: Effect of Water Adsorption and Resulting Microfractures. Energy Fuels. 2013, 27(6):3039-49.
[4] Kathel P, Mohanty K.K. Wettability Alteration in a Tight Oil Reservoir. Energy Fuels. 2013, 27(11):6460-8.
[5] Roychaudhuri B, Xu J, Tsotsis TT, Jessen K. Forced and Spontaneous Imbibition Experiments for Quantifying Surfactant Efficiency in Tight Shales. SPE Western North American and Rocky Mountain Joint Meeting, Denver, Colorado, 17-18 April, 2014; SPE 169500.
[6] Habibi A, Xu M, Dehghanpour H, Bryan D, Uswak G. Understanding Rock-Fluid Interactions in the Montney Tight Oil Play. SPE/CSUR Unconventional Resources Conference, Calgary, Alberta, Canada, 20-22 October, 2015; SPE 175924.
[7] Habibi A, Binazadeh M, Dehghanpour H, Bryan D, Uswak G. Advances in Understanding Wettability of Tight Oil Formations. SPE Annual Technical Conference and Exhibition, Houston, Texas, USA, 28-30 September, 2015; SPE 175157.

[8] Ghanbari E, Abbasi M.A., Dehghanpour H, Bearinger D. Flowback Volumetric and Chemical Analysis for Evaluating Load Recovery and Its Impact on Early-Time Production. SPE Unconventional Resources Conference Canada, Calgary, Alberta, Canada, 5-7 November, 2013; SPE 167165.
[9] Carpenter C. Impact of Liquid Loading in Hydraulic Fractures on Well Productivity. Journal of Petroleum Technology. 2013, 65 (11):162-165.
[10] Ghanbari E, Dehghanpour H. The fate of fracturing water: A field and simulation study. Fuel. 2016, 163:282-94.
[11] Lan Q, Ghanbari E, Dehghanpour H, Hawkes R. Water Loss Versus Soaking Time: Spontaneous Imbibition in Tight Rocks. Energy Technology. 2014, 2(12):1033-9.
[12] Zhang X, Morrow N.R., Ma S. Experimental Verification of a Modified Scaling Group for Spontaneous Imbibition. Spe Reservoir Engineering. 1996, 11(04):280-5.
[13] Shouxiang M, Morrow N.R., Zhang X. Generalized scaling of spontaneous imbibition data for strongly water-wet systems. Journal of Petroleum Science and Engineering. 1997, 18:165-78.
[14] Roychaudhuri B, Tsotsis T.T, Jessen K. An experimental investigation of spontaneous imbibition in gas shales. Journal of Petroleum Science and Engineering. 2013, 111:87-97.
[15] Makhanov K, Habibi A, Dehghanpour H, Kuru E. Liquid uptake of gas shales: A workflow to estimate water loss during shut-in periods after fracturing operations. Journal of Unconventional Oil and Gas Resources. 2014, 7(Supplement C):22-32.
[16] Mason G, Morrow N.R.. Developments in spontaneous imbibition and possibilities for future work. Journal of Petroleum Science and Engineering. 2013, 110:268-93.
[17] Handy L.L.. Determination of Effective Capillary Pressures for Porous Media from Imbibition Data. Petroleum Transactions, AIME. 1960, 209: 75-80.
[18] Saidian M, Godinez L.J., Rivera S, Prasad M. Porosity and Pore Size Distribution in Mudrocks: A Comparative Study for Haynesville, Niobrara, Monterey, and Eastern European Silurian Formations. Unconventional Resources Technology Conference, Denver, Colorado, USA. 25-27 August, 2014; URTEC 1922745.
[19] Sayed A.M.A.E., Sayed N.A.E.. Petrophysical Properties of Clastic Reservoirs Using NMR Relaxometry and Mercury Injection Data: Bahariya Formation, Egypt. Iop Conference Series: Earth and Environmental Science. 2016, 44(4):42018.
[20] Zhao H, Ning Z, Zhao T, Che F, Zhang R, Hou T. Applicability Comparison of Nuclear Magnetic Resonance and Mercury Injection Capillary Pressure in Characterisation Pore Structure of Tight Oil Reservoirs. SPE Asia Pacific Unconventional Resources Conference and Exhibition, Brisbane, Australia. 9-11 November, 2015; SPE 177026.
[21] Zhao H, Ning Z, Wang Q, Zhang R, Zhao T, Niu T, et al. Petrophysical characterization of tight oil reservoirs using pressure-controlled porosimetry combined with rate-controlled porosimetry. Fuel. 2015, 154:233-42.
[22] Tinni A, Odusina E, Sulucarnain I, Sondergeld CH, Rai CS. Nuclear-Magnetic-Resonance Response of Brine, Oil, and Methane in Organic-Rich Shales. Spe Reservoir Evaluation and Engineering. 2015, 18(03):400-6.
[23] Odusina E.O., Sondergeld C.H., Rai CS. NMR Study of Shale Wettability. Canadian Unconventional Resources Conference, Calgary, Alberta, Canada. 15-17 November, 2011; SPE 147371.
[24] Sulucarnain I.D., Sondergeld C.H., Rai C.S.. An NMR Study of Shale Wettability and Effective Surface Relaxivity. SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada. 30 October-1 November, 2012. SPE 162236.
[25] Washburn E.W.. The Dynamics of Capillary Flow. Physical Review. 1921, (3):273-83.
[26] Haugen Å, Fernø M.A., Mason G, Morrow N.R.. Capillary pressure and relative permeability estimated from a single spontaneous imbibition test. Journal of Petroleum Science and Engineering. 2014, 5:66-77.
[27] Mcwhorter D.B., Sunada D.K.. Exact integral solutions for two-phase flow. Water Resources Research. 1990, (3):399-413.
[28] Li K, Horne R.N.. Generalized Scaling Approach for Spontaneous Imbibition: An Analytical Model. Spe Reservoir Evaluation and engineering. 2006, 9(03):251-8.
[29] Schmid K.S., Geiger S. Universal scaling of spontaneous imbibition for arbitrary petrophysical properties: Water-wet and mixed-wet states and Handy's conjecture. Journal of Petroleum Science and Engineering. 2013, 101:44-61.
[30] Morrow N.R., Mason G. Recovery of oil by spontaneous imbibition. Current Opinion in Colloid and Interface Science. 2001, (4):321-37.
[31] Mason G, Fischer H, Morrow N.R., Ruth D.W.. Correlation for the effect of fluid viscosities on counter-current spontaneous imbibition. Journal of Petroleum Science and Engineering. 2010, 72(1-2):195-205.
[32] Ghaedi M, Riazi M. Scaling equation for counter current imbibition in the presence of gravity forces considering initial water saturation and SCAL properties. Journal of Natural Gas Science and Engineering. 2016,

34:934-47.
[33] Klinkenberg L.J. The Permeability Of Porous Media To Liquids And Gases. Socar Proceedings. 1941, 2(2):200-213.
[34] Fatt I. The Effect of Overburden Pressure on Relative Permeability. Journal of Petroleum Technology. 1953, 5(10):15-6.
[35] Tian X, Cheng L, Cao R, Wang Y, Zhao W, Yan Y, et al. A new approach to calculate permeability stress sensitivity in tight sandstone oil reservoirs considering micro-pore-throat structure. Journal of Petroleum Science and Engineering. 2015, 133(Supplement C):576-88.
[36] Shar A.M., Mahesar A.A., Chandio A.D., Memon K.R. Impact of confining stress on permeability of tight gas sands: an experimental study. Journal of Petroleum Exploration and Production Technology. 2017, 7(3):717-26.
[37] Saidian M, Prasad M. Effect of mineralogy on nuclear magnetic resonance surface relaxivity: A case study of Middle Bakken and Three Forks formations. Fuel. 2015, 161:197-206.
[38] Tiab D, Donaldson E.C. Chapter 6 - Wettability. Petrophysics (Third Edition) ed. Boston: Gulf Professional Publishing; 2012. p. 371-418.
[39] Sander R, Pan Z, Connell L.D.. Laboratory measurement of low permeability unconventional gas reservoir rocks: A review of experimental methods. Journal of Natural Gas Science and Engineering. 2017, 37:248-79.
[40] Leverett M.C.. Capillary Behavior in Porous Solids. Transactions of the Aime. 1940, 142 (1) :152-169.

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