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Development and Challenges during Shale Gas Exploitation

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ABSTRACT

Shale gas is becoming the interest of petroleum industry because of ease of extraction through advance technologies like hydraulic fracturing, micro-seismic mapping and horizontal drilling. Exploration of shale gas also attracts due to its lower intrinsic risk in its exploitation because of its abundance in the area wherever it is present. This review paper of shale gas identified some challenges during recovery of shale gas i.e. Unreliability in flow models due to non-Darcy flow, fracture intensity, rock properties like water saturation. It gives insight on differences of hydraulic fracturing show efficient fracture at brittle shale formation and inefficient fracture in ductile shale formation. Water saturation in shale is also so much controversial issue. NMR method is more reliable as compare to other conventional methods, because it directly detect fluids in the rock irrespective of rock matrix. The micro-seismic mapping is also discussed to monitor the fracture growth in reservoir to mitigate the risk of any undesirable activity originates in the response of hydraulic fracturing. This paper is the critical review on exploitation of shale gas and addressed some problems and challenges during its recovery.
KEYWORDS: Simulation, Rock Properties, Hydraulic Fracturing, Micro-Seismic Mapping.

INTRODUCTION

Gas produced from shale gas reservoirs has become vital source of production of natural gas in the United State of America and this source could become the world remarkable hydrocarbon source. Shale gas became important energy source after the Mississippian Barnet shale in the Fort Worth Basin was developed by using the technology of hydraulic fracturing and horizontal drilling [1]. Generally, the shale contains huge amount of clay contents in its composition, which make it more complex in sense of exploitation. In the last decade, due to improvement in technology of hydraulic fracturing, the shale gas exploitation become accessible to get production around the world. According to U.S. Energy Information Administration, the shale gas formation is present in every region but China, Argentina, Algeria, U.S and Canada are the top five countries with technically recoverable unconventional resources.

Shale gas act as both source rock and reservoir rock with permeability near to zero, and that is why it form its own Seal [1]. In shale gas, the gas trapped as free gas in natural fractures and intergranular porosity, gas Sorbed into kerogen and clay particles surfaces or dissolved in kerogen and bitumen [2]. Hydraulic fracturing of shale gas depend upon the total permeability system i.e. matrix permeability (micro-Darcy-down), plus permeability due to natural fractures. Shale gas composed of fine grain particles with organically rich in TOC varying in range from 1-20wt%. Shale is basically a formation of very tightly packed clastic sedimentary rock having very fine sediments. These fine grains are so tightly packed that its porosity and permeability become very low. Porosity and permeability of the shale gas reservoirs depend upon its natural fractures due to its low matrix permeability [1, 3]. Hydrocarbon recovery factor of unconventional shale gas is less than conventional resources due to its very low permeability that require hydraulic fracturing and shale gas cannot give economic production rates without horizontal drilling and hydraulic fracturing [4]. The organized application of hydraulic fracturing and horizontal drilling make the oil industry enable to get production in more efficient way from wide spread shale gas resources.

Challenges

The technology has been improved but still the E&P companies will have to face many challenges like water saturation, instantaneous capillary pressure etc. and are discussed one by one. Shale formation has high quantity of clay minerals in their composition, and due to affinity of these clay minerals toward water, make estimation of saturation controversial through conventional methods. Due to complex nature of shale, an accurate simulator is necessary that can achieved by revising existing methods and provide remedial approaches because conventional

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capillary equilibrium and Darcy fluid model are not suitable for unconventional reservoirs in the following areas i.e. Darcy Law in describing flow, relative permeability is not depend on rate and presumption of instantaneous capillary equilibrium [4-5]. Due to hydraulic fracturing for increasing permeability, fractures generated should be under control. Fracture growth need special care to not to contaminate water zones in subsurface and also not to extend toward the fault zone, which may activate seismic activity.

Water Saturation

Water saturation estimation is important parameter, either conventional or unconventional reservoirs. As compare to conventional, it is quite challenging task in unconventional reservoirs due to high percentage of clay contents in shale. Direct method to determine water saturation through core samples are Retort method and Dean stark method can be applied to both conventional and unconventional reservoirs. In dean stark method, main drawback in estimating water saturation is overestimation of saturation due to process of dehydration of clay minerals while retort method is destructive method to determine saturation [6]. Other resistivity methods like Archie, Simandox and Indonesian models also over or under estimate water saturation in unconventional reservoirs due to presence of some conductive mineral like pyrite. Also, in shale, water attached to the surface of the clay mineral surface and so much water is store in small pores, act as clay bound water. Classical methods do not determine this water, and at the time of production huge amount of this water is produce, which cause so much problems. NMR technique calculate saturation in shale gas reservoirs more accurately as compare to other methods as it directly detect fluids in the rock, independent of the rock matrix. NMR tool detect hydrogen nuclei in the fluids, which are more in water and hydrocarbon. It basically calculate time relaxation for the polarization of the proton and then their dephasing and rephrasing of these nuclei's and on the basis of this relaxation and dephasing bound water and free water in the rock can be separated.

Micro Seismic Mapping

Due to ultra-low permeability of shale, hydraulic fracturing is used for stimulation. Fractures propagation prediction is very difficult and challenging task. Micro seismic mapping of such reservoirs for characterization is more reliable technique to minimize the effect of any undesirable activity. Micro-Seismic has vital role in hydraulic fracturing technique to monitor the growth of fractures. It works basically on the same principle of earthquake seismology [7]. Micro seismic mapping determines the fault or any water zone near the reservoir, which may get effected due to fracturing. Using micro seismic mapping, many parameters like pressure, proppant concentration and pump rate of proppants for hydraulic fracturing can be monitored to control fracturing as it is shown in Figure 1. When through micro seismic mapping, it is predicted that fracture propagate towards the fault, pump rate of proppants was then kept low to avoid hazards.

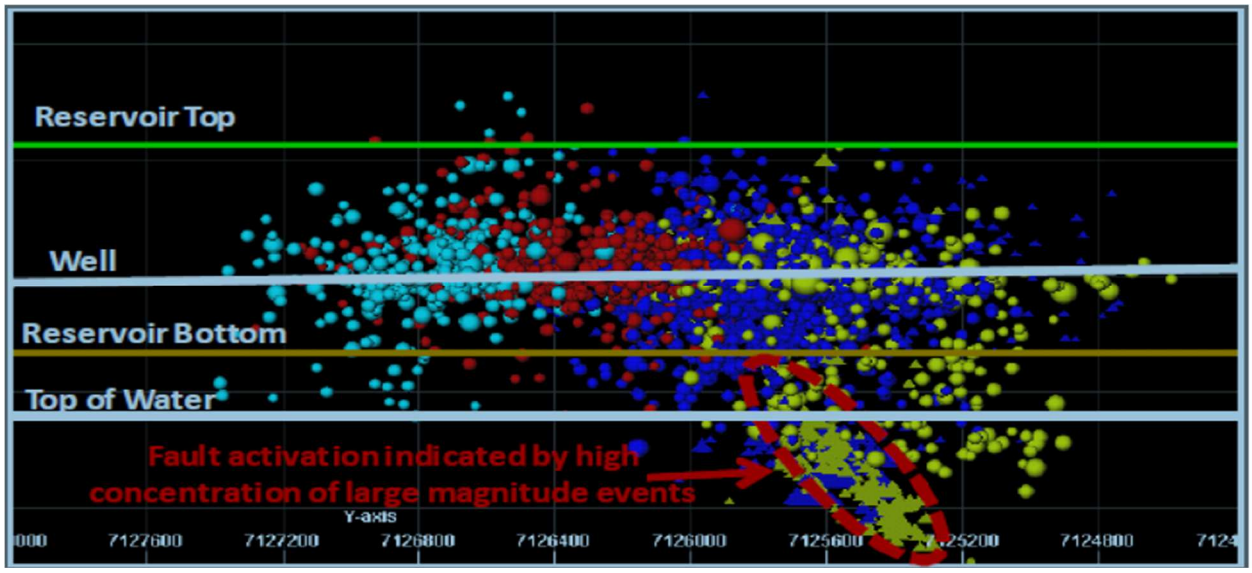

Figure 1: illustration of fault activation [7]

DISCUSSION

The instantaneous capillary equilibrium model is not valid for modelling of unconventional reservoirs because fluid redistribution from one steady state to other take much time e.g. suppose we have small radius conical tube, in which interminable water with reservoir pressure Pwr at small while interminable gas with reservoir pressure Pgr at large end as shown in Figure 2. When we drained some water from small conical side, the pressure will reduce and gas occupy the voids because of its high compressibility and attain new equilibrium and capillary pressure. In this case, the instantaneous capillary pressure model is valid. While on other side, gas on low compressibility and reduction in pressure will have different consequences from above. However, water will not move instantaneously towards large conical side to fill the voids and negative pressure will be experienced [8]. Hence, we will have to revise the instantaneous capillary pressure.

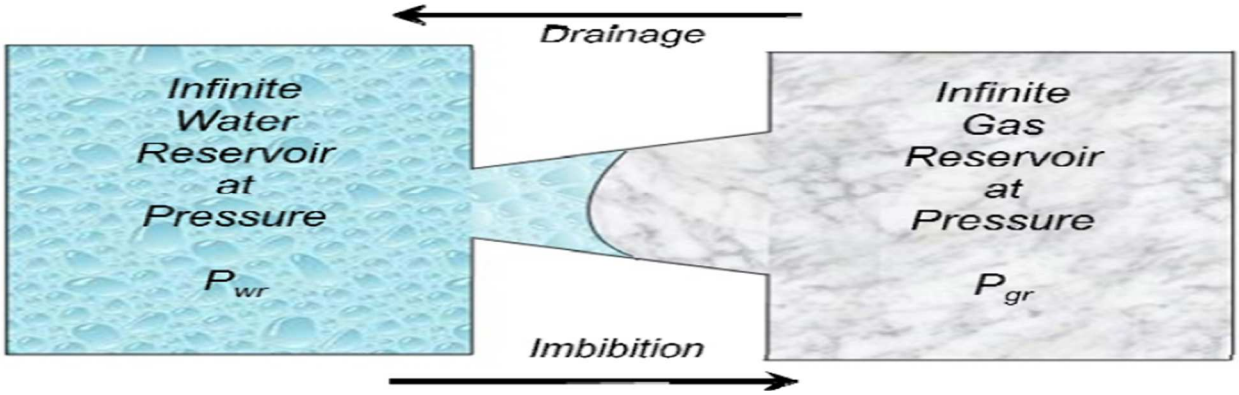

Figure 2: Illustration of instantaneous capillary pressure [8]

Water saturation is another very controversial parameter in shale gas reservoirs because of high clay contents present in them. Clay minerals have much affinity for water and hold brine in their structure and this water is clay bound water, which creates so much problems in estimation when it is calculated through conventional methods. The classical methods show significant variation because water saturation became more challenging in shale gas because some heavy minerals also present in it, which are conductive and resistivity methods used to determine the brine, show under or over saturation and hence hydrocarbon saturation effected. So, lab base NMR technique will be best for measurement [8-10]. Because NMR detect directly hydrogen contents present in the fluids irrespective of the matrix material. On the basis of the relaxation time used in the calculation of hydrogen contents, clay bound water and free water are measured (Figure 3).

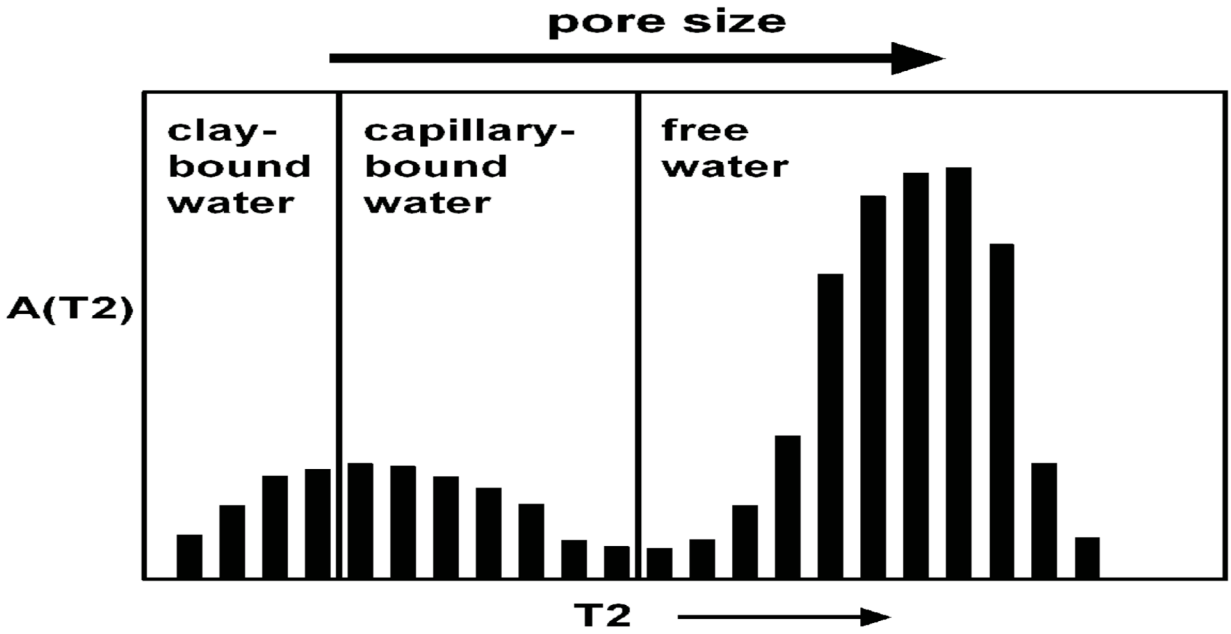

Figure 3: NMR calculated water saturation according to pore size [11]

The extraction of hydrocarbon from shale gas requires hydraulic fracturing, in which proppant with fluid is injected at high pressure into formation that creates fractures [12]. It depends on geomechanical properties such as brittleness/ductility and produce inefficient fractures on ductile at high pressure due to its low Brittleness Index, while efficient fractures in brittle behaviour at comparatively low pressure due to its high Brittleness [13-14]. The importance of brittleness can be understand by the concept that brittle shale contain several pre-existing natural fractures that are closed, and therefore can make a well distributed fracture network by stimulation and also mineralogical characterization of the formation is compulsory for fracability. The percentage and amount of quartz, carbonates and clay minerals effect fracture gradient, so some zones are more fractured during stimulation than others. Furthermore, brittle shale is much easier to frac than ductile shale because more energy is required to create fractures in highly ductile rock [15] and several researchers has been proved this concept from laboratory experiments, seismic and well logs [16]. Different researcher provide different models for the fracturing of shale but their models are proposed by their research on any specific formation, which cannot be used in other formation have different geological environment.

Micro seismic mapping is vital in fracturing monitoring in order to stop intersection between water zone and fracture, it involve sensing, locating and processing of small seismic events, arrival time of P-waves and S-waves indicate distance of fracture while time the waves take to arrive on sensors indicate depth of event. This technology is famous in North America while ignored in other countries because it is expensive but increased production [17-19].

According to Canadian Association of Petroleum Producers, the shale gas is found in unconventional reservoir which differs from conventional by geological characteristics and location that in turn affect the process, cost and level of ease for the extraction of gas. In unconventional like shale gas act both the source and reservoir rock itself. The gas is stored in shale gas by following ways i.e. gas trapped on the surface of organic material, free gas in matrix porosity, free gas in micro fracture porosity, hydraulic fractures as a result of stimulation and free gas in pre pore networks within organic matter [20]. There are certain challenges still remain in shale gas exploration that need accurate methods for the measurement like permeability, water saturation etc. different than conventional reservoir's methods. The results vary by using different methodology that result in unreliability of methods. So, there must be some specific methods for the exploration of shale gas due to its complex nature. Some commercial simulation software is best for shale gas simulation and also gives accurate results in modelling, but still the exploration and production companies will have to face the challenges like instantaneous capillary pressure where negative pressure may encounter and find its solutions.

The extraction of oil/gas from shale gas on commercial scale became possible because of hydraulic fracturing technique. Although Micro-seismic mapping is expensive, but it is vital and progressive technology for the complete

understanding of hydraulic fractures distribution and subsurface dynamics and this technology can reduce the cost of implementation without having offset well [21].

Case History: Application of Micro-Seismic-Mapping to Avoid Geo-Hazards

The most common geo-hazard is faults which can be identified with magnitude and location on micro-seismic map, fracture growth into fault is very deleterious because fault can be reactivated e.g. Fracture growth observed in Haynesville shale and intersection of faults and fracture also observed in Haynesville shale [22-23] as shown in Figure 4.

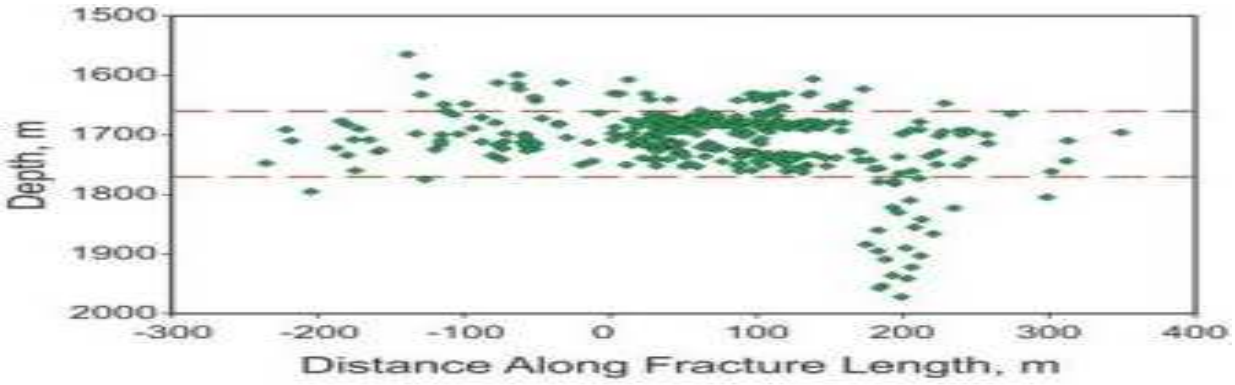

Figure 4: Fracture growth in Haynesville shale [26]

CONCLUSION

The instantaneous capillary pressure must be re-evaluated for the unconventional reservoir simulation. Currently, the use of laboratory base NMR gives the accurate results of water saturation as compared to other methods like Dean-Stark and retort method and other resistivity models. Micro-seismic mapping is the only way to get clear picture of subsurface fractures distribution. So, all the companies must adopt this technology for progressive production.

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REFERENCES

1. Chopra, S., R. Sharma and K. Marfurt, 2013. Workflows for Shale Gas Reservoir Characterization. In the Proceedings of the 2013 75th EAGE Conference and Exhibition incorporating SPE EUROPEC, pp: 1-5.
2. Fazelipour, W., 2011. Innovative Reservoir Modeling and Simulation of Unconventional Shale Gas Reservoirs Powered By Microseismic Data. In the Proceedings of the 2011 SPE Middle East Unconventional Gas Conference and Exhibition, pp: 1-14.
3. Curtis, J.B., 2002. Fractured Shale-Gas Systems. AAPG Bulletin, 86(11): 1921-1938.
4. Langmuir, I., 1918. The Adsorption of Gases on Plane Surfaces of Glass, Mica and Platinum. Journal of the American Chemical Society, 40(9): 1361-1403.
5. Shelley, R.F., M.J. Mullen and W.A. Minner, 2013. A North American Review of Commercial Shale Plays; Have We Learned Anything Besides Serendipity? In the Proceedings of the 2013 SPE Annual Technical Conference and Exhibition, pp: 1-13.
6. Clarkson, C.R., J.L. Jensen and T. Blasingame, 2011. Reservoir Engineering for Unconventional Reservoirs: What Do We Have to Consider? In the Proceedings of the 2011 North American Unconventional Gas Conference and Exhibition, pp: .1-45

7. Cipolla, C.L., M.G. Mack and S.C. Maxwell, 2010. Reducing Exploration and Appraisal Risk in Low-Permeability Reservoirs Using Microseismic Fracture Mapping. In the Proceedings of the 2010 Canadian Unconventional Resources and International Petroleum Conference, pp: 1-14.

8. Perdomo, J.F.A., F.Civan, D. Devegowda and R.F. Sigal,2010. Accurate Simulation of Shale-Gas Reservoirs. In the Proceedings of the 2010 SPE Annual Technical Conference and Exhibition, pp: 1-11.

9. Xie, J., S.H. Lee, Z. Wang and X.H. Wen, 2013. Uncertainty Assessment of Production Performance for Shale Gas Reservoirs. In the Proceedings of the 2013 International Petroleum Technology Conference, pp: 1-15.

10. Biswas, D., 2011. Shale Gas Predictive Model (SGPM)-An Alternate Approach to Model Shale Gas Production. In the Proceedings of the 2011 SPE Eastern Regional Meeting, pp: 1-15.

11. Fan, L., J.W. Thompson and J.R. Robinson, 2010. Understanding Gas Production Mechanism and Effectiveness of Well Stimulation in the Haynesville Shale through Reservoir Simulation. In the Proceedings of the 2010 Canadian Unconventional Resources and International Petroleum Conference, pp: 1-15.

12. Freedman, R. and N. Heaton, 2004. Fluid Characterization Using Nuclear Magnetic Resonance Logging. Petrophysics, 45(3): 241-250.

13. Arogundade, O. and M. Sohrabi, 2012. A Review of Recent Developments and Challenges in Shale Gas Recovery. In the Proceedings of the 2012 SPE Saudi Arabia Section Technical Symposium and Exhibition, pp: 1-31.

14. Barenblatt, G.I., T.W. Patzek and D.B. Silin, 2003. The Mathematical Model of Nonequilibrium Effects in Water-Oil Displacement. SPE Journal, 8(4): 409-416.

15. Javadpour, F., D. Fisher and M. Unsworth, 2007. Nanoscale Gas Flow in Shale Gas Sediments. Journal of Canadian Petroleum Technology, 46 (10): 55-61.

16. Jarvie, D.M., R.J. Hill, T.E. Rubleand R.M. Pollastro, 2007. Unconventional Shale-Gas Systems: The Mississippian Barnett Shale of North-Central Texas as One Model for Thermogenic Shale-Gas Assessment. AAPG Bulletin, 91(4): 475-499.

17. Perez, R. and K. Marfurt, 2013. Brittleness Estimation from Seismic Measurements in Unconventional Reservoirs: Application to the Barnett Shale. In the Proceedings of the 2013 SEG Technical Program Expanded Abstracts, pp: 2258-2263.

18. M. Zoback, S. Kitasei and B. Copithorne, 2010. Addressing the environmental risks from shale gas development. Worldwatch Institute.

19. Norton, M., W. Hovdebo, D. Cho, M. Jones and S. Maxwell, 2010. Surface Seismic to Microseismic: An Integrated Case Study from Exploration to Completion in the Montney Shale of NE British Columbia, Canada. In the Proceedings of the 2010 SEG Technical Program Expanded Abstracts, pp: 2095-2099.

20. Vermylen, J. and M.D. Zoback, 2011. Hydraulic Fracturing, Microseismic Magnitudes, and Stress Evolution in the Barnett Shale, Texas, USA. In the Proceedings of the 2011 SPE Hydraulic Fracturing Technology Conference, pp: 1-15.

21. Miller, C., R. Lewis and K. Bartenhagen, 2007. Design and Execution of Horizontal Wells in Gas Shales Using Borehole Images and Geochemical Data. In the Proceedings of the 2010 SEG Denver 2010 Annual Meeting.

22. Friehauf, K.E. and M.M. Sharma, 2009. Fluid Selection for Energized Hydraulic Fractures. In the Proceedings of the 2009 SPE Annual Technical Conference and Exhibition, pp: 1-17.

23. Dunn, D.E., L.J. LaFountain and R.E. Jackson, 1973. Porosity Dependence and Mechanism of Brittle Fracture in Sandstones. Journal of Geophysical Research, 78(14): 2403-2417.

24. Luffel, D.L. and F.K. Guidry, 1992. New Core Analysis Methods for Measuring Reservoir Rock Properties of Devonian Shale. Journal of Petroleum Technology, 44 (11): 1-184.