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Extended Abstract

Petroleum Congress 2018: Next generation reservoir engineering- Klaus Regenauer-Lieb- University of New South Wales Sydney

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Abstract

Our mission is to advance knowledge about energy in transition with the aim to aid the industry in the imminent energy transformation. To this end we use an approach based on developing a fundamental physics based understanding of the chemical, mechanical, thermal and hydrological processes and their interactions that operate over long time scales to form and characterize the porosity/fracture networks in conventional and unconventional oil and gas reservoirs. we apply that understanding to engineer that structure for the purpose of energy extraction and resource discovery. Interdisciplinary approach links geoscience, engineering and computational science disciplines with the result of providing a step change in exploration and exploitation technologies with significant reduction in onshore gas improvement costs without compromising OHSE or environmental protection and assurance. Numerical simulation has played a pivotal role in the dynamic reservoir modeling and for testing competing hypotheses in complex, typically data-poor environments. Through our ability to rigorously describe key processes in petroleum reservoirs is still imperfect (in particular Unconventional Plays), there have been substantial advances over the past several decades. These advances owe mainly to the steady growth of computational power and the concomitant development of numerical models that have gradually minimized various simplifying assumptions. They include incorporation of more accurate description of the fluid chemistry and its multiphase evolution and fluid flow rock interaction, an increased ability to represent geometric complexity and heterogeneity and faster and more accurate computational schemes.

In collaboration with international partners we have prototyped a multiphysics, multiscale simulator based on the Open Source Massively Object Oriented Simulation Environment (MOOSE), originally designed for running synchronous multiphysics calculations for a nuclear power plant. The Multi App framework allows coupling processes at grain level through to the fission in the reactor core, including the large-scale fluid flow in the pipe network of the heat exchangers of the power plant. In this presentation, we will show the first results that allow incorporation of important processes in Unconventional Plays. Diagenetic processes such as the smectite-illite transition are found to create natural fractures under tectonic load that form the permeable reservoirs in shale gas/oil reservoirs. Consequences indicate that the fractures triggered by natural fluid release reaction on geological time scales are supported by a critical fluid pressure that must not be crossed to avoid sudden loss of the reservoir. Simultaneous crossing this threshold reservoir damage can be substantial. No amount of proppant or other engineering interaction can rescue the reservoir on a human time-scale. Our novel framework allows linking the long-time scale geological processes with the design of an injection-extraction protocol to maintain critical fluid pressure. We are also able to incorporate microstructural changes and fluid-solid interaction at grain scale. The latter has only been benchmarked for conventional carbonate plays, but the multiscale results are encouraging for the entire spectrum of conventional and unconventional traps/source rocks. Our theoretical framework and the forward simulator are specifically designed to interface with geophysical inversion techniques for multi-scale geophysical data. Complete this data-assimilation step in the future will define next generation reservoir engineering.

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Exploitation of unconventional resources in shales has boomed the US economy over the last decade, while decreasing significantly its carbon footprint (Considine et al., 2010). Because of their abundance and low carbon footprint, shale gas resources have been identified as the key player in the energy landscape and the current century has been labelled the "golden age of gas" (IEA, 2011). To support these claims, the production from USA unconventional shale in the early 90's has led to an abrupt decline in conventional gas resources development. More importantly, the commercial production from shale plays in the United States has caused the CO2 emission to be significantly reduced from almost 6000 Metric Tons (MT) a year to just over 5000 MT (Fig. 1). Therefore, unconventional shale plays indeed seem to be a way forward for securing the energy needs for any nation. In particular, Australia is well-known to host enormous unconventional oil and gas resources, and has been recently recognised as one of the emerging key exporters of natural gas resources worldwide (EIA, 2015). Despite the obvious benefits, hydrocarbon production from unconventional resources - in particular shales - has not lived up to expectations. The apparent success of exploitation of shale gas in the US revealed that their environmentally friendly CO2 emissions are accompanied by high risk of contaminating groundwater resources and induced seismicity due to the poorly constrained stimulation techniques used (e.g. hydraulic fracturing) (Johnson and Greenstreet, 2003). The induced risks are mainly related to poor understanding of the rock behaviour at in-situ conditions and, correspondingly, the lack of advanced, custom-made and environmentally respectful exploration and stimulation protocols. The drilling risk is exponentially increasing in the case of Australia, where the shale gas resources are dominantly found at great depth, below 3 km. On top of that, Australia is in an extreme tectonic environment where – unlike the tensile case of the US - it is subjected to a highly compressional tectonic environment (Sandiford and Quigley, 2009). Figure 1: The CO2 emission in the US is curbed by massive proliferation of Shale Gas use after 2006. AEGC 2018: Sydney, Australia 2 The greater depth of the Australian reservoirs reduces groundwater contamination risk. However, the unconventional response of materials at these extreme conditions constitutes a formidable challenge for geomechanics and reservoir engineering. In this contribution, we aim to bridge this gap and understand the formation, geometry and fluid connectivity of high-temperature and high pressure Shale Gas reservoirs using a multiphysics approach. By looking at the processes underpinning the formation and connectivity of oil and gas resources in these unconventional rocks we provide a better understanding of how shales respond at in-situ conditions. The application of this knowledge will allow a rigorous assessment of the future potential for the recovery of unconventional reservoirs under Australia's extreme in-situ conditions.

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