Thermally Enhanced Gas Recovery and Infill Well Placement Optimization in Coalbed Methane Reservoirs

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Alireza Salmachi, B.Sc., M.Sc.

A thesis submitted for the degree of

Doctor of Philosophy (Ph.D.)

Australian School of Petroleum

Faculty of Engineering, Computer and Mathematical Sciences

The University of Adelaide

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Table of Contents

Abstract

The aim of this thesis is to investigate innovate approaches that can help to improve methane recovery and production rate from coalbed methane (CBM) reservoirs. The results of two following subjects are presented and discussed. First, *thermally enhanced gas recovery* from gassy coalbeds is introduced. Second, an integrated reservoir simulation-optimization framework is developed and employed to optimize infill well locations across coalbed reservoirs.

When coalbed methane and geothermal activities coexist in the same field, coalbeds can be thermally treated prior to the gas production using available underground geothermal resources. Feasibility of this method is investigated both using methane sorption tests on Australian coal samples at different temperatures and also reservoir simulation.

The impact of temperature elevation on methane sorption and diffusion in coal is investigated by running sorption experiments on two the Australian coal samples using a manometric adsorption apparatus. Experiments are performed to indicate that how the difference between original reservoir pressure and critical desorption pressure is decreased at elevated reservoir temperatures. Lower pressure gradient is required to extract methane from coalbed when it is thermally treated prior to gas production.

Following the experimental study, the feasibility of thermally enhanced gas production from coalbeds is studied by coupling of coalbed methane and thermal simulators. The coalbed methane simulator of Computer Group Modelling (CMG) and the thermal simulator of CMG known as STARS are loosely coupled to study the effect of temperature elevation on total gas and water production. Both gas rate and ultimate gas recovery from the reservoir are increased by thermal operation.

In the second part of this thesis, an integrated reservoir simulation-optimization framework is developed to intelligently obtain locations of new infill wells in a way to maximize profitability of the infill plan. This framework consists of a reservoir flow simulator (Eclipse E100), an optimization method (genetic algorithm), and an economic objective function. The objective function in this framework is to maximize discounted net cash flow of infill project.

The importance of optimization is magnified when cost of water treatment is increased. When optimization approach is compared with standard five spot pattern well arrangements, the impact of water treatment cost is observed. When cost of water treatment is high, there is a large difference between the profit of the infill project calculated using the optimization approach and the standard five spot pattern. Simulation results indicate that at higher cost of water treatment, infill wells are preferably located either on the front of the water depletion zone or close to existing wells. On the other hand, when water treatment cost is low, infill wells are located in virgin sections of the coalbed where both gas content and cleat water saturation are high.

Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Alireza Salmachi and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Alireza Salmachi   Date

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There are a number of people I learned a lot from them during my PhD life in the University of Adelaide; my dear friends **Abbas, Justin, Ernest, Reza, and Dave** who were great sources of joy and encouragements.

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Alireza Salmachi

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List of Publications

I. Salmachi, A., M. Haghighi, et al. (2011). Combined Energy Recovery from Coal Seam Gas Reservoirs and Geothermal Resources (Simulation Study). SPE 14847, presented at International Petroleum Technology Conference (IPTC), Bangkok, Thailand, February 7-9.

II. Salmachi, A. and M. Haghighi (2012). "Temperature Effect on Methane Sorption and Diffusion in Coal: Application for Thermal Recovery from Coal Seam Gas Reservoirs." Journal of APPEA **52**: 291-300.

III. Salmachi, A. and M. Haghighi (2012). "Feasibility Study of Thermally Enhanced Gas Recovery of Coal Seam Gas Reservoirs Using Geothermal Resources."Energy & Fuels **26**(8): 5048-5059.

IV. Salmachi, A., M. Sayyafzadeh, and M. Haghighi (2012). "Infill well placement optimization in coal bed methane reservoirs using genetic algorithm." Fuel **111**(0)**:** 248-258.

V. Salmachi, A., M. Sayyafzadeh, and M. Haghighi (2013). "Optimization and Economical Evaluation of Infill Drilling in Coal Seam Gas Reservoirs Using a Multi Objective Genetic Algorithm." Journal of APPEA 53: 381-390.

Statement of Authors' Contribution

This thesis is submitted for the partial fulfilment of the requirement for the degree of Doctor of Philosophy (PhD) in petroleum engineering at the University of Adelaide, Adelaide, Australia. The thesis comprises of both publications and written narratives in accordance with 'Academic Program Rules and Specifications 2012'. All the journal papers published and/or submitted are indexed in the 'ERA 2012 Journal List' database. This research was conducted in Australian School of Petroleum, the University of Adelaide, from February 2010 until January 2013. The sorption experiments for coal samples were performed in the laboratory of the school of chemical engineering, the University of Queensland under the supervision of **Doctor Greg Birkett** in June 2011. The following chapters and all the 5 papers attached to the thesis are the outcomes of this research. All the papers in this thesis are co-authored and detailed statements of their contributions are endorsed by the co-authors.

STATEMENT OF AUTHORSHIP

Infill well placement optimization in coal bed methane reservoirs using genetic algorithm

Fuel, 2013, volume 111(0), pages: 248-258

Alireza Salmachi (candidate)

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the optimization framework, performing the simulations and the comparative study, data interpretation and writing the manuscript

Certification that the statement of contribution is accurate

Signed... .... *Date*...14/08/2013...

Mohammad Sayyafzadeh

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the optimization framework, development of the GA code for the framework, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signeu *Date*...14 – 08 – 2013

Manouchehr Haghighi

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Supervision of the work, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed. .... *Date*...14 – 8 – 2013...

STATEMENT OF AUTHORSHIP

Feasibility Study of Thermally Enhanced Gas Recovery of Coal Seam Gas Reservoirs Using Geothermal Resources

Journal of Energy and Fuels, 2012, volume 26, pages 5048-5059

Alireza Salmachi (candidate)

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Performing the simulations and the comparative study, data interpretation and writing the manuscript

Certification that the statement of contribution is accurate

Signed. .... *Date*...14/08/2013...

Manouchehr Haghighi

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Supervision of the work, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed. .... *Date*...14-8-2013...

STATEMENT OF AUTHORSHIP

Temperature Effect on Methane Sorption and Diffusion in Coal: Application for Thermal Recovery from Coal Seam Gas Reservoirs

APPEA journal, volume 52, pages 291-300

Alireza Salmachi (candidate)

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Performing the experiments, data analysis and interpretation, and writing the manuscript

Certification that the statement of contribution is accurate

Signed .... *Date*....14/08/2013....

Manouchehr Haghighi

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Supervision of the work, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed.. .... *Date*....14/8/2013

STATEMENT OF AUTHORSHIP

Optimization and Economical Evaluation of Infill Drilling in Coal Seam Gas Reservoirs Using Multi Objective Genetic Algorithm

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Alireza Salmachi (candidate)

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the optimization framework, performing the simulations and the comparative study, data interpretation and writing the manuscript

Certification that the statement of contribution is accurate

Signed... .... *Date*....14/08/2013....

Mohammad Sayyafzadeh

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the optimization framework, development of the GA code for the framework, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signea *Date*..14 - 8 - 2013

Manouchehr Haghighi

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Supervision of the work, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed. .... *Date*........14 - 8 - 2013

STATEMENT OF AUTHORSHIP

Combined Energy Recovery from Coal Seam Gas Reservoirs and Geothermal Resources (Simulation Study)

SPE conference, SPE 14847, IPTC, Bangkok 2012

Alireza Salmachi (candidate)

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Developing the idea of thermal method, data interpretation and writing the manuscript.

Certification that the statement of contribution is accurate

Signed.... .... *Date*......14-08-2013

Manouchehr Haghighi

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Supervision of the work, manuscripts evaluation and participating in the manuscript writing

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed .... *Date*.....18/1/2013.....

David Dixon

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the Eclipse model, performing the simulations

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed................................ .... *Date*......18/01/2013

Peter Hart

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the Eclipse model, performing the simulations

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed........ *Date.....*20/11/2013.....

Ashley Jackmann

Statement of contribution (in terms of the conceptualization of the work, its realization and its documentation)

Construction of the Eclipse model, performing the simulations

Certification that the statement of contribution is accurate and permission is given for the inclusion of the paper in the thesis

Signed.. .... *Date.*...