**THE UNIVERSITY OF ADELAIDE**

# COUPLED FLUID FLOW-GEOMECHANICS SIMULATIONS APPLIED TO COMPACTION AND SUBSIDENCE ESTIMATION IN STRESS SENSITIVE & HETEROGENEOUS RESERVOIRS

A THESIS SUBMITTED FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

by
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**ABSTRACT**

Recently, there has been considerable interest in the study of coupled fluid flow – geomechanics simulation, integrated into reservoir engineering. One of the most challenging problems in the petroleum industry is the understanding and predicting of subsidence at the surface due to formation compaction at depth, the result of withdrawal of fluid from a reservoir. In some oil fields, the compacting reservoir can support oil and gas production. However, the effects of compaction and subsidence may be linked to expenditures of millions of dollars in remedial work. The phenomena can also cause excessive stress at the well casing and within the completion zone where collapse of structural integrity could lead to loss of production. In addition, surface subsidence can result in problems at the wellhead or with pipeline systems and platform foundations.

Recorded practice reveals that although these problems can be observed and measured, the technical methods to do this involve time, expense, with consideration uncertainty in expected compaction and are often not carried out. Alternatively, prediction of compaction and subsidence can be done using numerical reservoir simulation to estimate the extent of damage and assess measurement procedures. With regard to reservoir simulation approaches, most of the previous research and investigations are based on deterministic coupled theory applied to continuum porous media. In this work, uncertainty of parameters in reservoir is also considered.

This thesis firstly investigates and reviews fully coupled fluid flow – geomechanics modeling theory as applied to reservoir engineering and geomechanics research. A finite element method is applied for solving the governing fully coupled equations. Also simplified analytical solutions that present more efficient methods for estimating compaction and subsidence are reviewed. These equations are used in uncertainty and stochastic simulations. Secondly, porosity and permeability variations can occur as a result of compaction. The research will explore changes of porosity and permeability in stress sensitive reservoirs. Thirdly, the content of this thesis incorporates the effects of large structures on stress variability and the impact of large

structural features on compaction. Finally, this thesis deals with affect of pore collapse on multiphase fluid and rock properties. A test case from Venezuelan field is considered in detail; investigating reservoir performance and resultant compaction and subsidence.

The research concludes that the application of coupled fluid flow – geomechanics modeling is paramount in estimating compaction and subsidence in oil fields. The governing equations that represent behaviour of fluid flow and deformation of the rock have been taken into account as well as the link between increasing effective stress and permeability/porosity. From both theory and experiment, this thesis shows that the influence of effective stress on the change in permeability is larger than the effect of reduction in porosity. In addition, the stochastic approach used has the advantage of covering the impact of uncertainty when predicting subsidence and compaction.

This thesis also demonstrates the influence of a large structure (i.e. a fault) on stress regimes. Mathematical models are derived for each fault model to estimate the perturbed stress. All models are based on Mohr–Coulomb's failure criteria in a faulted area. The analysis of different stress regimes due to nearby faults shows that effective stress regimes vary significantly compared to a conventional model. Subsequently, the selection of fault models, fault friction, internal friction angle and Poisson's ratio are most important to assess the influence of the discontinuity on the reservoir compaction and subsidence because it can cause a significant change in stress regimes.

To deal with multiphase flow in compacting reservoirs, this thesis presents a new method to generate the relative permeability curves in a compacting reservoir. The principle for calculating the new values of irreducible water saturation ($S_{wir}$) due to compaction is demonstrated in this research. Using coupled reservoir simulators, fluid production due to compaction is simulated more comprehensively. In the case example presented, water production is reduced by approximately 70% compared to conventional modeling which does not consider changes in relative permeability. This project can be extended by applying the theory and practical methodologies developed to other case studies, where compaction and stress sensitivity dominate the drive mechanism.

**PUBLICATIONS**

Ta, Q. D., S. P. Hunt and C. Sansour (2005). Applying fully coupled geomechanics and fluid flow model theory to petroleum wells. The 40th U.S. Symposium on Rock Mechanics-USRMS, Anchorage, Alaska.

Ta, Q. D. and S. P. Hunt (2005). Investigating the relationship between permeability and reservoir stress using a coupled geomechanics and fluid flow model. 9th Conference on Science and Technology, held in Ho Chi Minh City University of Technology, Viet Nam.

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Ta, Q. D. and S. P. Hunt (2006). Stress variability around large structural features and its impact on permeability for coupled modeling simulations. 4th Asian Rock Mechanics Symposium (ARMS), Singapore.

Ta, Q. D., M. Al-Harthy, S. Hunt and J. Sayers (2007). The impact of uncertainty on subsidence and compaction prediction. First Sri Lankan Geotechnical Society (SLGS) International Conference on Soil and Rock Engineering, Colombo, Sri Lanka.

**STATEMENT OF ORIGINALITY**

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

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signed:………………………………..Date………………………..

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