Oil and Gas CDT

NERC DOCTORAL TRAINING

Prediction of flow through fractures and maximising recovery under geological uncertainty and geomechanical constraints
Heriot-Watt University (Institute of Petroleum Engineering

Supervisory Team

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Key Words fracture modelling, geological realism, flow simulation, uncertainty quantification, production optimisation

Overview

Fractured reservoirs contain the majority of the world's hydrocarbon reserves but are extremely challenging to produce and require complex development decisions. These challenges include: difficulty in simulating flow through fractured porous media accurately, uncertainty in predicting fracture network distributions, and non-uniqueness in the modelling choices. Altogether this renders building geologically consistent models of fractured reservoirs difficult and development decisions need to be optimised over a range of possible models.

We can reduce risks in developing fractured fields if we can ensure (a) all models are geologically consistent, (b) the best simulation method for that fracture pattern is selected and (c) that all the models match the real reservoir production. By ensuring that all models we produce honour these 3 issues we can be sure that model forecasts are "possible".

The project contributes to 3 out of the 4 CDT research themes:

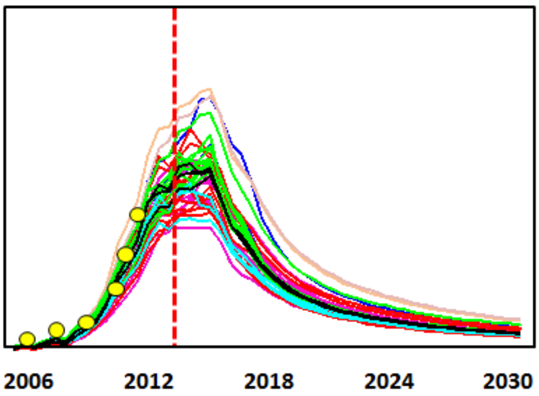
a) Extending life of mature fields is achieved through optimisation of development decisions for brown fractured reservoirs;
b) Exploitation of challenging environments is addressed as the project aims to tackle the problem of lower recovery from fractured fields including carbonates.
c) Effective production of unconventional hydrocarbons theme is also linked to the project since realistic uncertainty in fracture model description can be used to optimise hydraulic fracking.

Fractured carbonate formation in Morocco

The project aims to tackle the problem of quantifying uncertainty of fractured fields where multiple possible geological scenarios, requiring different reservoirs models, are possible.

This will be achieved by the following:

1) Provide an accurate and computationally efficient way to assess the spread of uncertainty in the flow response for a sub-set of discrete fracture network (DFN) model realisations across possible geological scenarios for spatial fracture distribution and with respect to different upscaling techniques.
2) Ensure geological consistency of the selected fracture scenarios by using realistic geological prior information elicited from geomechanical modelling and experiment.
3) Maximise oil recovery across possible field development scenarios based on the quantified geological uncertainty and model errors.

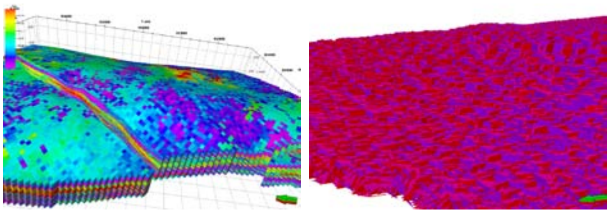


Simulated production rates for multiple geological models which all match past production data (yellow dots) but lead to different forecasts and hence different optimisation and development strategies.

Methodology

The project bridges across several reservoir modelling disciplines: geomechanics (G. Couples), flow simulation through fracture network models (in collaboration with S. Geiger) and uncertainty quantification and optimisation (V. Demyanov and D. Arnold). A new workflow that incorporates all these disciplines would generally be as follows.

1. The reservoir will be modelled using a DFN and suitable simulation grids.
2. Geomechanics (lead by G. Couples) will be used to ensure the generated DFN models are consistent with nature and reservoir geological conditions.
3. The most appropriate method for upscaling and simulating the DFN will be analysed and chosen (with input from S. Geiger) and a simulation model created.
4. Uncertainty in reservoir productivity will be estimated from matching the fracture simulation model to real production data based on an ensemble of geological (DFN) scenarios (lead by V. Demyanov and D Arnold).
5. Optimisation of the reservoir development (e.g. well placement) over the subset of the most probable realistic geological scenarios is carried out on the calibrated simulation models. The choice of the most robust and reliable development decision based on the evaluated uncertainty will help to manage the economic value and risk.



Example well placement in a fracture reservoir model with matrix permeability (left) and fracture network (right)

Timeline

The project will capitalise on some of the outcomes of the recent (2013) and ongoing PhD research in geological realism in history matching, fractured reservoir simulation, and improving the effectiveness of reservoir description for history matching and field development optimisation.

Year 1: Training academy courses (10 weeks), literature review, introduction to stochastic optimisation and history matching, geological data and knowledge collation, fractured reservoir simulation, DFN modelling and upscaling.
Year 2: Training academy courses (5 weeks), pilot studies of parts of the methodology: history matching, presentation coaching at internal meetings and CDT workshops.

Year 3: Training academy courses (5 weeks), application of the integrated workflow, to a realistic synthetic case study, field development optimisation, conference presentations
Year 4: Real field examples, thesis completion, preparation of mansucripts for international journals

Training & Skills

You will become a part of the Uncertainty group, which is a multidisciplinary team of engineers, geologists and mathematicians, where you will master advanced prediction modelling and uncertainty quantification statistical methods. The project will also involve close collaboration and input from geomechanical expertise (Prof G. Couples) and fractured reservoir simulation (Prof. S. Geiger and Carbonates Reservoirs Group). A doctoral graduate upon completion of this PhD will become a highly sought-after specialist for the industry, with state-of-the-art skills in both geosciences (fracture modelling and geomechanics) and reservoir engineering (model uncertainty and optimisation).

As part of a CDT cohort, you will receive 20 weeks bespoke, residential training of broad relevance to the oil and gas industry: 10 weeks in Year 1 and 5 weeks each in Years 2 and 3. Instructors will be both from expert academics from across the CDT and also experienced oil and gas industry professionals.

You will be expected to present posters and talks at conferences and will also have an opportunity to get exposure of your work to industry practitioners at consortium steering group meetings.

References & Further Reading

Hierarchical benchmark case study for history matching, uncertainty quantification and reservoir characterisation, D. Arnold, V. Demyanov, D. Tatum, M. Christie, T. Rojas, S. Geiger, P. Corbett Computers & Geosciences, Vol. 50, 2013, pp. 4–15

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Further Information

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