UNIVERSITY OF LEEDS

Advanced fractal modelling of heterogeneous and anisotropic geological hydrocarbon reservoirs

A PhD studentship to be run by the Petrophysics Research Group in the School of Earth and Environment at the University of Leeds.

Supervisors: Dr. Piroska Lorinczi & Prof. Paul W.J. Glover.
School of Earth and Environment, University of Leeds.

Start date: October 2019

Summary

- Opportunity to fully implement and test an exciting new approach to geological reservoir modelling for geoscientists, mathematicians, physicists or computing graduates.
- Opportunity to take a novel and ground-breaking research method to the edge of commercialisation.
- The project is a blend of geophysics, mathematics and advanced coding, which is a stepping stone to both IT and Geoscience-based industries.
- Join a diverse research group covering all aspects of rock physics with an international reputation and links to industry.
- Attend international conferences in Europe, the US and elsewhere.
- The project is supported by successful pilot studies with the potential to generate early publications and consequent option of PhD assessment by publications alone.
- Tutoring in career development (academia, industry and beyond).

Motivation. The modern oil and gas industry is refocussing its efforts. Most of the large and simple conventional reservoirs have now been found and exploited. New reservoirs are discovered regularly, but most are small, complex and difficult to produce. Reservoir modelling has always provided the industry with a way to predict hydrocarbon production over the lifetime of the reservoir, as well as a method of testing changes to reservoir production, e.g., drilling more wells, with no risk. However, this key tool struggles to be relevant in the new complex heterogeneous and anisotropic reservoirs. Another approach is needed.

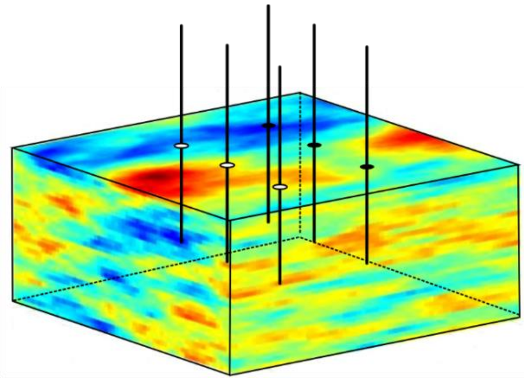


Fig. 1. A 3 injector-3 producer well pattern arranged in an AFRM for reservoir simulation testing (Glover et al., 2018).

Fractal-based methods allow the complexity of the reservoir to be accounted for in the reservoir model over a large range of scales. Research at the University of Leeds has already made significant progress in creating these state-of-the-art models (Al-Zainaldin et al., 2017; Glover et al., 2018). Initial coding exists that allows us to make generic Advanced Fractal Reservoir Models (AFRMs), and some research has examined how hydrocarbon production depends on the spatial and directional distribution of critical reservoir properties, such as porosity and permeability (Fig. 1). Initial work has also been able to use the new method on real reservoirs.

Aims and Objectives. The aim of the research is to develop the advanced fractal modelling technique to the edge of commercialisation. Its objectives include:

- To convert existing AFRM code into a consistent set of procedures, including the development of QA and statistical tools.
- To develop methods for extracting reservoir fractal dimensions and anisotropy factors from 3D seismic data cubes.
- To carry out a full study of how the heterogeneity and anisotropy of reservoirs affects reservoir production.
- To further develop methods for carrying out fractal interpolation for conditioning AFRMs to real reservoirs.
- To carry out full AFRM and conventional modelling on a limited number of type reservoirs.
- To develop, test and validate a pre-commercial beta version of the AFRM code including a UX-rich UI.

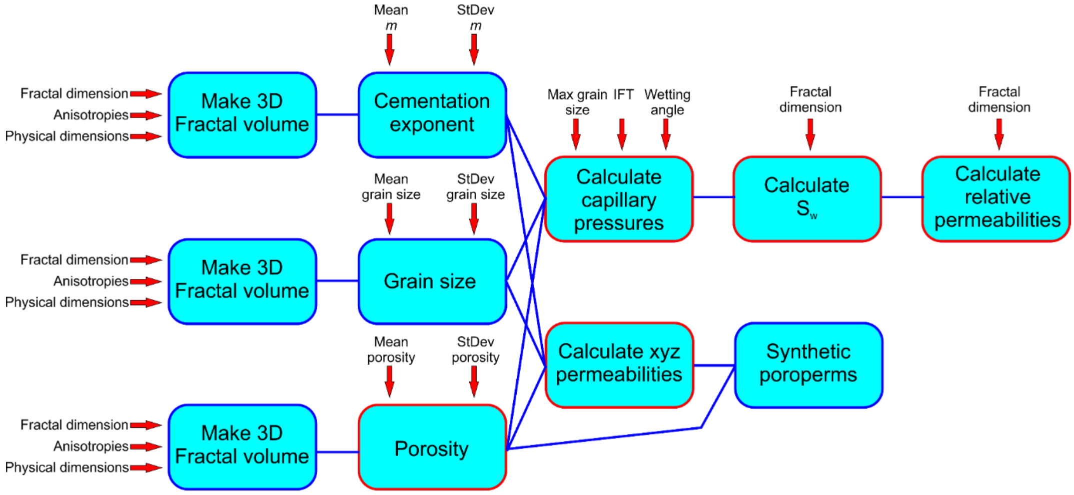


Fig. 2. Current procedure for constructing an AFRM (Glover et al., 2018).

Methodology. The PhD will progress in 5 consecutive, but overlapping strands.

- The first strand will involve familiarisation with and modification to the existing code for creating generic AFRMs using the procedure in Fig. 2, followed by its use to examine how changing reservoir heterogeneity, anisotropy and well placement affects hydrocarbon production over time. Pilot studies on these effects have already been done and will act as a guide (Fig. 3). The candidate will be expected to expand the studies on a statistically valid number of implementations, which will lead to at least one publication.
- The second strand concerns the analysis of 3-D seismic data cubes. In this strand the candidate will develop methodologies for extracting fractal dimension and anisotropy data from raw seismic and seismic attribute data. This strand will also lead to at least one publication.

- The third strand involves the further development and testing of the fractal interpolation method that will be used to condition AFRMs to represent real reservoirs. This is a critical step that we know from pilot studies to be possible, as the data in Fig. 4 shows.
- The fourth strand is dedicated to a full comparative testing of the conditioned AFRMs and conventional reservoir models on a limited number of well-characterised reservoirs (clastic and carbonate) for which production is well-known. Consequently, we should be able to show whether the AFRM approach is statistically significantly better than what conventional modelling currently provides. This strand has the potential for producing a publication with great impact for the industry.
- The fifth and final strand to the PhD involves the implementation of existing coded procedures within a clear and easy to use UI that takes account of expected user experience. This strand effectively produces a pre-commercial beta testing version of the software for making advanced fractal models.

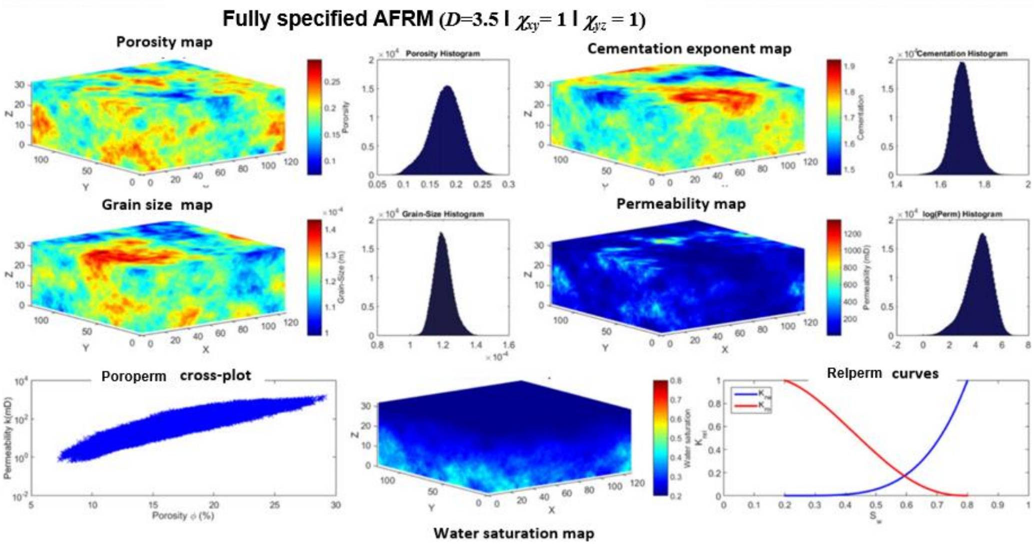
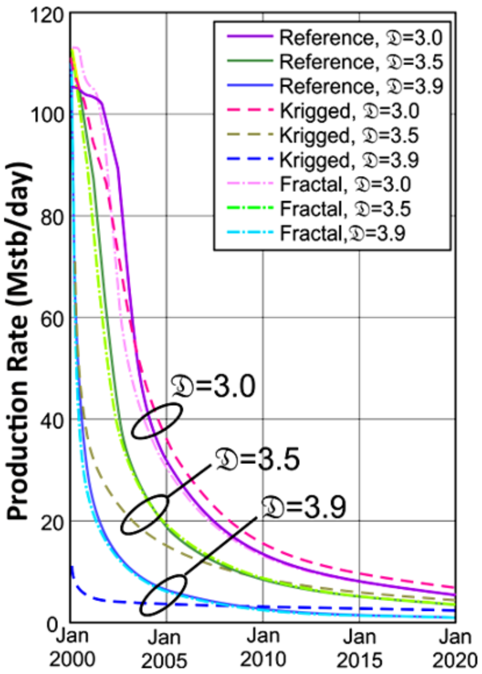


Fig. 3. A fully specified generic AFRM showing the distribution of various rock properties within a cubic portion of a reservoir (Glover et al., 2018).

Scope. This PhD proposal is unusual in that it combines (i) geophysics, (ii) the elaboration of a new analytical approach, (iii) software development, and (iv) pre-commercialisation in one piece of work, making it ideal for an industry-focussed student with the right qualities. The software development is prefigured by a number of successful pilot studies which have already led to scientific papers (Al-Zainaldin, 2017; Glover et al., 2018), and which need to be expanded upon in order to provide early publications. All of the AFRM development and subsequent reservoir modelling will be carried out using the extensive computer facilities and state-of-the-art software of the School of Earth and Environment. The supervisory team is extremely experienced in petroleum engineering, petrophysics and reservoir modelling, and has an excellent track record in PhD supervision. All relevant health, safety and technology-specific training will be provided. It is expected that the student will present scientific papers at conferences in at least two years of the PhD, and will submit multiple scientific papers to journals before the PhD finishes. Fast-track submission of publications, as envisaged, opens the possibility of being examined on a collection of published papers rather than by thesis.



◀ *Fig. 4. The discrepancy between the conventional approach (Krigged) and the actual production rate (Reference), compared with how well the AFRM (Fractal) performs. The improvement of AFRMs over the conventional approach is very strong for heterogeneous reservoirs (Glover et al., 2018).*

Eligibility. Applicants should have a BSc degree (or equivalent) in mathematics, computer science, physics, geology, earth sciences, geophysics, petroleum engineering or a similar discipline. An MSc, MGeol or MEng in one of the aforementioned disciplines would be an advantage. The applicant must be competent in handling discrete mathematical equations and be able to code in common languages effectively. Some experience of UX/UI design is desirable.

Training. The successful applicant will work within the inter-disciplinary Petrophysics Research Group, which is part of the wider Institute of Applied Geosciences at the School of Earth and Environment, University of Leeds. The Petrophysics Research Group has graduated 13 PhD students since 2012, and has 5 on-going research sections related to (i) tight carbonate petrophysics, (ii) advanced fractal reservoir simulation, (iii) gas shale research, (iv) reservoir nanoflooding, and (v) the electrical/electro-kinetic properties of rocks.

The mixed pure- and applied-science nature of this research project will enable the student to consider a future career in either academia or a range of different industries. The project will provide specialist scientific training, as appropriate, in: (i) the existing code; (ii) training in coding languages as required, (iii) UX/UI design; (iv) statistical analysis; (v) FEM and reservoir modelling; (vi) seismic attribute analysis. In addition, the student will have access to a broad spectrum of training workshops provided by the Faculty that include an extensive range of training workshops in statistics, through to managing your degree, to preparing for your viva (http://www.emeskillstraining.leeds.ac.uk). The successful candidate will be strongly encouraged and supported to publish the outcomes of their research in leading international journals.

References and bibliography

AL-ZAINALDIN, S., GLOVER, P.W.J. and LORINCZI, P., 2017. Synthetic Fractal Modelling of Heterogeneous and Anisotropic Reservoirs for Use in Simulation Studies: Implications on Their Hydrocarbon Recovery Prediction. Transport in Porous Media, 116(1), pp. 181-212.

GLOVER, P.W.J., LORINCZI, P., AL-ZAINALDIN, S., AL-RAMADAN, H., DANIEL, G. and SINAN, S., 2018. Advanced fractal modelling of heterogeneous and anisotropic reservoirs, SPWLA 59th Annual Logging Symposium 2018 2018.

Further Information

For more information about this project and other Petrophysics Research Group activities contact: Piroska Lorinczi, +44 (0)113 34 39245, earpl@leeds.ac.uk
http://www.see.leeds.ac.uk/people/p.lorinczi & http://www.see.leeds.ac.uk/people/p.glover