Unconventional resource recovery

Foundation CMG Chair in Reservoir Geomechanics Professor Rick Chalaturnyk provides insight into his unique developments in the field of reservoir geomechanics, with a particular focus on the extraction of unconventional resources such as bitumen and shale gas.

Could you begin by discussing your professional and academic background as well as how your research interests have developed over time?

My undergraduate degree is in Civil Engineering and my PhD, during which I worked on the very first field test of steam-assisted gravity drainage, is in Geotechnical Engineering. This test was conducted at what was then called Alberta Oil Sands Technology and Research Authority’s Underground Test Facility. In 1994, I co-founded a reservoir surveillance company that installed real-time, down-hole temperature and pressure gauges for the oil and gas industry. Finally, in 1997 I joined the University of Alberta. My research here has included a range of topics, particularly work on oil sands tailings management, reservoir geomechanics, geological storage of CO2 and numerical simulation.

How has the establishment of a Foundation CMG Research Chair, supported by a Natural Sciences and Engineering Research Council of Canada Collaborative R&D Grant (NSERC CRD), assisted your research endeavours?

It will allow the development of an extensive research programme that a collection of companies will commit their time and funding to support. Having the Chair recognised by our main national funding body – NSERC – is also a real honour. One of the most important things the Chair research programme allows you to do at a university is create a critical mass of very smart people all the way from undergraduate and graduate students through to postdocs and research engineers, enabling everyone to work towards a common goal.

The Foundation CMG Research Chair is also a very positive mechanism for bringing together multiple industrial sponsors and partners to discuss and focus research on what are often challenging issues. The programme provides an ideal framework for researchers and industrial partners to collaborate.

Which research fields and organisations are you collaborating with to develop a unique perspective on unconventional resource recovery?

Our research links the worlds of geomechanics or geotechnical engineering and reservoir engineering, and we continue to improve our integration with petroleum engineering. We draw very heavily on the geoscience world – geophysics, rock physics, etc. – as well as experimental science as we are pushing the boundaries of testing. Materials science also helps us to characterise materials.

About 60 per cent of the Chair research programme is focused on bitumen-related unconventional resources, specifically oil sands, carbonates, shale caprocks and intraformational shales. The remaining 40 per cent is related to tight oil and gas, such as shale gas. The industrial partners therefore span the full range of those assets and include Suncor Energy, Nexen, Athabasca Oil Corporation, Cenovus Energy, Shell, ConocoPhillips, Statoil, Canadian Natural Resources Ltd, BP Canada, Brion Energy and Foundation CMG. We also receive support from two Alberta-based government organisations, namely Alberta Innovates – Energy and Environmental Solutions and Alberta Innovates – Technology Futures.

Could you expand on the type of resource recovery methods you are in the process of developing?

We try to focus on prediction of how the reservoirs and rocks will respond, as opposed to just focusing on different recovery methods. When a particular recovery technique is applied, such as thermal or hydraulic fracturing, we want to know how the geomechanics and other processes impact it and how that, in turn, can help to optimise the process.

There is concern over the safety of shale gas extraction, particularly hydraulic fracturing. How does your knowledge in geomechanics limit risk?

Hydraulic fracturing is controlled by the geomechanical behaviour of the formations; the properties of the formations, the in-situ stresses and, of course, operational aspects. Our research tries to make improvements in the understanding of how those reservoir materials behave. We concentrate on determining how they respond to hydraulic fracturing conditions and how better to model them in order to control or manage those risks and therefore develop a model for more sustainable shale gas extraction.

What methodologies do you utilise to develop more environmentally friendly models for shale gas extraction and your other operations?

We look at the complete life cycle of risk management around environmental impact. However, there are numerous other aspects that are even more important; air, water and human health impacts deserve more attention – there are lots of documented cases where fracking has caused serious health concerns. While it is our job to worry about geomechanics, there is a real need for more experts to assess and minimise these environmental impacts.
A reservoir geomechanical future

Leading-edge research at the University of Alberta is making significant progress toward developing new models and mechanisms for the extraction of unconventional resources with reduced environmental impact.

In the face of climate change, carbon storage and alternative energy extraction are crucial, not only to maintaining a healthy economy, but also human and environmental wellbeing. The Government of Alberta’s Climate Change Strategy includes plans to store 15 million tonnes of CO₂ every year, starting in 2015, in an attempt to reduce emissions during the period of transition from nonrenewable to renewable or alternative energy. Providing a one-of-a-kind research environment, the Geomechanical Reservoir Experimental Facility (GeoREF) at the University of Alberta has received over CAD $4 million in support from the Canada Foundation for Innovation (CFI) and the Alberta Science and Research Infrastructure Program (ASRIP). The university has played a key role in the development of the Canadian energy sector for a number of years by supplying world-leading research and technologies.

Integral to the establishment of this unique research facility is Professor Rick Chalaturnyk, newly appointed Foundation CMG Industrial Research Chair (IRC) in Reservoir Geomechanics for Unconventional Resources and supported by a Collaborative R&D award from the Natural Sciences and Engineering Research Council of Canada (NSERC). Since 2010, Chalaturnyk and his group have been busy buying, renovating, installing and commissioning equipment for GeoREF; the facility was officially declared complete in December 2013. Exclusively designed for high-temperature and high-pressure testing, the Facility will also contain Western Canada’s first geotechnical beam centrifuge.

Their research focuses on understanding the properties and behaviour of unconventional resources such as oil sands and shale gas. Through developing a complete understanding of the flow of these materials through a rock, the team will develop new methods and improve existing ones with the primary goal of increasing extraction efficiency. This increased efficiency will allow substantial reductions in the energy required for extraction, which in turn will lead to a reduction in greenhouse gas emissions.

To achieve this, it is important to develop models – both physical and computational – that can give accurate and testable predictions. Modelling has a number of challenges; for example, as heterogeneities in the rock matrix vary across different length scales, modelling a small area – typically a cylindrical core – and simply extrapolating these small-scale effects to full industrial-scale often proves to be inaccurate.

There are two opposing theories regarding the most accurate way to model materials being transported through subsurface rock. One involves the use of a discrete fracture network (DFN) approach that enables the efficient modelling of rock fractures while capturing the connectivity and stochastic nature of their formation. Conventional continuum models, on the other hand, allow flow through the surrounding rock matrix as well. This leads to a dual continuum with flow occurring through fractures at a defined rate, but also through the rock matrix which has a determinable permeability. The DFN approach tends to capture the connectivity and scale-dependent heterogeneity of fractured reservoirs more accurately than dual continuum models.

DIGITAL FABRICATION

Traditional fabrication technologies use a bonding catalyst and sand to form porous 3D structures to develop physical models; however, finding appropriate materials that can be removed once the model is complete is an ongoing area of research. Furthermore, the use of these technologies is limited due to internal discontinuities in the model.

A key tool for the production of physical models at GeoREF is state-of-the-art digital fabrication technology. These techniques, which include laser cutting and 3D printing, allow the construction of detailed models with which to test theories. For example, using a precise 3D printing technique called fused deposition modelling, Chalaturnyk and his team are able to build models using water-soluble materials to reinforce the internal discontinuities that are easily washed away in post-production.

Due to the gap in fundamental knowledge regarding intermediate range between core size and field scale, verification of the dynamic behaviour of a DFN model is usually carried out numerically. The cutting-edge digital technology and beam centrifuge available at GeoREF will enable Chalaturnyk’s group to obtain results from physical modelling that can be used to validate these numerical assumptions of DFN behaviour.

CARBON CAPTURE AND STORAGE

One of the central elements of this research is to limit the potentially large environmental impacts that arise from extracting these
unconventional resources. A key strategy in environmentally conscious development is carbon capture and storage (CCS), which constitutes a chain of technologies that allow CO₂ emissions to be collected at the source and transported to geological formations suitable for long-term storage. Much of the work previously carried out in this field relates to the use of CO₂ for enhanced oil recovery, but in the last 15 years, there has been an increased interest in permanently trapping the gas in underground reservoirs.

It is hoped that within the next few decades global energy demands will be met by renewable energy sources. In the short and medium term, however, fossil fuel-based resources will remain the primary source of fuel. With this in mind, it is vital to minimise the environmental impact of these resources and the technologies developed to extract them. It is for this reason that Chalaturnyk and his group are developing CCS strategies, as well as improving the efficiency of extraction.

Primarily focused on reservoir geomechanics, the team is predominantly concerned with the storage aspect of CCS; this involves identifying potential sites and gathering data on the reservoir. The storage volume must be determined so as not to over-pressurise the subsurface. Finally, they must gain an acceptable level of certainty with regards to the reservoir’s ability to retain the gas – it is vital that there is minimal long-term leakage. “We have been working in CCS for a long time – since the beginning of the International Energy Agency Greenhouse Gas (IEA GHG) Weyburn-Midale CO₂ Storage and Monitoring Research Project,” explains Chalaturnyk. As each programme transfers knowledge to the public, they can share in the process as the projects unfold. “In Canada, even if you just consider Alberta, there are still some very significant learnings to happen out of our commitment to the Enhanced Energy’s carbon trunkline (a pipeline for CO₂-enhanced oil recovery) and Shell’s Quest project (a pure, integrated CO₂ storage that transports and injects CO₂ from a hydrogen production unit into the deep subsurface).”

HIGHLY QUALIFIED PERSONNEL

To ensure the continuation of their work in the long-term, Chalaturnyk is also dedicated to training highly qualified personnel. GeoREF aims to provide an innovative and exciting research environment for graduate students, postdoctoral fellows, research engineers and junior and senior research professors. Not only will this high quality research space attract the brightest minds, the team hopes that it will also enable them to develop an improved model for training the next generation of academic and industrial leaders. Chalaturnyk considers this educational outreach to be fundamental to his work: “The programme is all about the people – the highly qualified personnel and their interaction with industry”.

Although initially difficult and time consuming due to the absence of permanent research engineering support and the time required for students to become accustomed to the use of equipment and safety procedures, the training offered at GeoREF has dedicated technical support and individual safety procedures for each independent and self-contained testing system. This is another area where close ties with local industry play an important role. Beyond sharing technology and research, these industrial partners will help facilitate student internships, onsite seminars and hands-on courses. It is also anticipated that there will be a number of industry members able to act as co-supervisors for graduate students.

The Energy Information Agency foresees that the energy requirements of developing countries will double by the year 2030. Canada is recognised as having the second-largest crude oil reserves in the world; the country has a clear opportunity to develop these resources and not only increase its self-reliance, but to take economic advantage of its position. The substantial support this project is receiving from large, significant sources such as the CFI, ASRIP, NSERC, Foundation CMG and the industrial partners highlights the potential impact of this research on the future of energy production in Canada, although there are also clear global benefits possible from this kind of leading research.

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Numerical Studies

Geomechanical behaviour is often seen as complex, but with improved modelling, GeoREF will be able to more accurately predict deformations within a reservoir to optimise production and improve safety.

In depth, calibrated, numerical simulations designed by GeoREF are proving to be powerful tools that provide insight into the physical significance of geomechanical behaviour. The centrifuge facility is able to verify the accuracy of its models with field performance data from *in situ* thermal recovery pilots, thereby scaling up evaluations to reservoir scale and determining the fundamental mechanisms controlling the production processes.

Issues relating to scale are tested numerically to predict rock mass behaviour based on the construction and testing of 3D synthetic rock mass (SRM) samples which simulate rock as an assembly of bonded spheres (intact rock) with an embedded discrete network of disc-shaped flaws (joints). “The combination of the SRM numerical modelling approach and the capability of GeoREF represents a significant step forward in reservoir geomechanical modelling, as it is impossible, at present, to obtain representative *in situ* samples of discontinuous rock masses for laboratory testing,” explains Chalaturnyk.

**A CLOSED LOOP**

The life cycle of reservoirs can be optimised if models, production measurements, time-lapse seismic and other data are optimised. Applying closed-loop reservoir management in real-time can better predict unconventional reservoir formations, such as oil sands, shales and bitumen carbonates and help answer a number of questions. As Chalaturnyk elaborates, these include: “What is the optimal frequency for the updating of numerical models and production strategies; what are the observable and controllable variables in reservoir-geomechanical models and which parameters can be identified from data; and what are the most important decisions, and how can they be used to focus measurement strategy and modelling efforts to support those decisions?”

This knowledge is crucial for carbon capture and storage projects and will be invaluable for the many programmes GeoREF is actively supporting.