Revealing **rocks**

Dr Doug Schmitt explains his team's work on rock physics, which aims to uncover the seismic alterations which highlight subtle changes in the subterranean material complexity

DR DOUG SCHMITT

To begin, can you explain the premise of your latest research into the temporal and spatial analysis of subsurface fluids?

Rocks are incredibly complex materials, and their behaviour is intimately tied to their internal architecture of minerals and pore space. Seismic waves are sensitive to this stiffness and also to the rock density. However, the stiffness actually depends on a number of factors, such as tectonic stresses, pore fluid pressures, temperatures, and the character of the fluid in the pore spaces. When we change any of these, by injecting or extracting fluids, we cannot avoid changing the seismic properties, and this means that we correspondingly alter the character of the seismic echoes that we record. Hence, tracking the changes in the observed seismic responses with time gives us clues as to where fluids are, or are not, moving because of our disruption. In effect we seek to track changes in the three spatial and one time dimension.

What are the main objectives of this project? What makes this project unique?

My group studies Rock Physics ~~such~~ issues from a number of different perspectives. We of course carry out controlled laboratory measurements to gain a basic understanding of the changes produced in a rock sample from varying the extrinsic conditions it is subject to~~o~~. My group is further unique in that we are also actively involved in field campaigns that allow us access to real field data particularly from boreholes. This range of studies forces my students to try to

Power waves

Seismic technologies are at the forefront of understanding the effects of energy technologies, from geological sequestering of CO_2 to fracking. A pioneering team from the **University of Alberta** is leading the field

THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE has predicted that CO_2 trapped using geological sequestration could provide 1,000 years' worth of safely removed carbon worldwide. Furthermore, in the US alone, there are 6,000 square miles of rock formations which would be able to store the equivalent of 500 years' CO_2 production.

As the levels of carbon dioxide continue to increase in our atmosphere and waters, the geological sequestration of the greenhouse gas will become more attractive. The work of a team at Canada's University of Alberta is set to demonstrate the potential of this technology. With worries about whether the CO_2 will stay in place, and whether we are even able to accurately assess the condition of the trapped greenhouse gas from the surface, the team's 4D seismic monitoring can begin to answer these issues. Led by Dr Doug Schmitt, the team has been producing laboratory experiments on a fully CO_2 saturated porous ceramic rod, which they then subjected to a range of pressures and temperatures. By measuring how this rod altered P- and S-wave velocities, they have been able to provide information which will assist in this important process.

The research group is at the forefront of developing these 4D seismic technologies, which will be able to accurately describe captured carbon. Yet there are a number of issues centring on sequestered CO_2 given that the temperatures and pressures to which it is exposed can cause it to change states, from gas to liquid or supercritical fluid. This means that accurately measuring the interaction of seismic waves travelling through the P-T space must take into account the differences caused by these shifts. The team's work, believed to be the first of its kind in the world, has been able to detect phase changes in the CO_2 stored in rocks. The study will integrate the laboratory results with real field measurements in order to best understand a given situation.

You have been working with leading scientists to develop a state of the art laboratory. What is your ambition for the venture?

There are three things that really drive me and my work. The first is that I find rocks fascinating and even dynamic materials, and I am excited by discovering new things about their behaviour. Secondly, my laboratory is not confined within the walls of our building but extends out into the real world, so making measurements of the Earth itself using seismic or borehole techniques adds dimension to our laboratory work. Finally, at this point in history, with the growth of the world economy, our search for energy and mineral resources is pushing the boundaries of what we can actually accomplish safely, and I find the fact that our work could have some impact on addressing very real environmental and resource problems very satisfying.

As a member of the Canadian Research Chairs (CRC), how is the programme improving our depth of knowledge in the sciences?

The CRC programme has been very good for my group. Although the programme does not fund much in the way of direct research support, having the Chair has given me access to additional opportunities and collaborations, both nationally and internationally, that I do not think would have existed otherwise. This allows me to maintain and grow an active rock physics laboratory that can carry out some higher risk measurements that would not otherwise be possible within the Canadian support systems.

What are your hopes for the future of rock physics? What is needed to further advance understanding?

As noted, rock is an incredibly complex material and its behaviour in the Earth is influenced by numerous factors. From the academic side, we need to better understand issues such as the non-linearity of rock properties, the effects of the frequency of observations, and the influence of the scale and heterogeneity of the geological structures on geophysical observations. At this time, too, our computational powers are just reaching the point where we can begin to carry advanced numerical calculations to support our laboratory observations and I see a great deal of growth in this modelling.

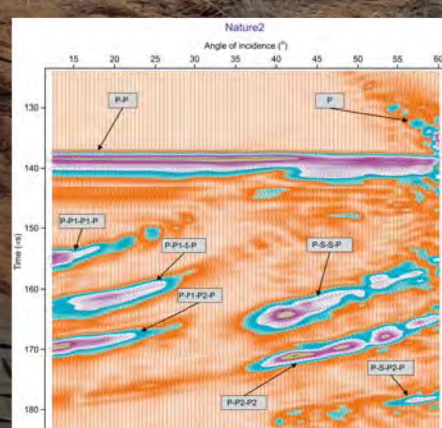
How do you see the nascent discipline of rock physics developing in the coming years?

I am probably biased, but despite the fact that the field of rock physics is still quite small, I see a great potential because it holds the multidisciplinary key to linking engineers, geologists, hydrologists, and geophysicists together. Differences in the training of these various disciplines, even geophysicists, is a limiting factor in the use of rock physics knowledge. Consequently, a challenge for the rock physics community at the present time is to try to better inform our colleagues of the value of such studies.

be able to provide accurate seismic monitoring, demonstrating that subsurface changes can be detected by the available technologies, thereby opening up geological sequestration as an option. As this improves, more accurate models of this trapped greenhouse gas will be produced, providing the opportunity to monitor the incremental shifts in the condition of trapped gas. It is hoped that these advances will encourage the use of this form of CO_2 removal, allowing the team to provide the technology which will help to combat one of the major causes of climate change.

FRACKING PROBLEMS

The sequestering of CO_2 is not the only environmentally controversial process the work of the team hope to have an impact on. Fracking involves the injection of highly pressurised fluids into rock formations in order to break new channels in them, thereby allowing the faster and more efficient extraction of oil and gas. However, fracking has come under international scrutiny, with the process being suspended or banned in some countries due to unknown or under-researched environmental impacts. Critics claim that these could include the contamination of groundwater, the migration of gases and fracking chemicals and risks to air quality. Yet fracking may cause none of these, and could solve the impending energy crisis as fossil fuels become harder to extract. Schmitt is balanced in his outlook: "I think that such production is going to be necessary, however the industry risks its social licence to carry it out, and it needs to be more transparent with regards to its activities". The fracking fields are unlike traditional and more highly permeable fields, and the active 4D methodologies will be incredibly important in conducting new studies into the nature of these areas.



THE RESULTS OF ULTRASONIC LABORATORY EXPERIMENTS THAT SHOW THE REVERBERATIONS AND CONVERSIONS BETWEEN MANY DIFFERENT KINDS OF WAVES IN A PLATE OF SYNTHETIC SANDSTONE.

INTELLIGENCE

ROCK PHYSICS IN THE LAB AND THE FIELD

OBJECTIVES

- To gain valuable insight to improve production strategies for the oil industry, and to better monitor greenhouse gases in subterranean reservoirs
- To carry out controlled laboratory measurements to gain a basic understanding of the changes produced in a rock sample from varying the extrinsic conditions
- To integrate the laboratory results with real field measurements in order to best understand a given situation

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DOUGLAS SCHMITT holds the Canada Research Chair in Rock Physics and is a Professor of Geophysics and Physics at the University of Alberta, Edmonton. His research team carries out a variety of field and laboratory based measurements with research focussed in Rock Mechanics and Physics, and is active in scientific drilling programmes on six continents.

RESEARCH AND INDUSTRY

The team's investigations demonstrate the way in which their association with the energy industry is changing through time, moulding their relationship and their technological capabilities. Schmitt has spent much of his career working on highly viscous heavy oils and bitumens derived from deposits in Western Canada. However this is set to change. Over the course of his career, seismic monitoring has progressed from being an often overlooked science, to a widely used tool of the industry. A good example is the injection of steam into heavy oil, something which dramatically alters the seismic properties. As a consequence, studies are able to almost instantly determine where the steam has travelled to, providing a low cost way of demonstrating the underground mapping of the area. Despite this, uptake is still somewhat limited because of a number of factors, ranging from a lack of absolute need, to an avoidance of studies as a whole. By transferring their technology towards new techniques and green innovations, the team are able to maintain the applicability of their work, hopefully making a close examination of the seismic properties of rocks an essential part of any large energy project.

STUDY TOOLS

The advances being made by the team are particularly impressive when compared to the complexity of their subject matter. Rock is a densely variable substance, creating a difficult situation for study replication. The structure, composition and pore configuration of rock varies spatially and at a range of dimensional scales, meaning that the team are forced to find accurately representative materials. Schmitt utilises a range of techniques once these subjects are selected: "We carry out an extensive material characterisation using tools that range from micro-scale X-ray computer tomography imaging through to advanced mercury injection porosimetry".

> The study will be able to provide accurate seismic monitoring, demonstrating that subsurface changes can be detected by the available technologies, thereby opening up geological sequestration as an option

The information can then be processed by the team, providing the knowledge needed to understand rock behaviour. With the CO_2 experiments, a test case is conducted before the gas is imbibed, with a wide range of pressures and temperatures helping to investigate the ranged behaviours of the sample. Afterwards, the same benchmarks are returned to, but now with the gas present. Finally, the gas is evacuated, and the rock once again tested in order to detect changes. Through these processes, the group are able to begin to move towards an accurate knowledge of the ways in which sequestration will change the readings which they produce.

ENTERING THE FIELD

Advances made in the laboratory are to be placed against the incredible complexity of the field subject which they will eventually be applied to. The samples are, almost through necessity, biased towards a more competent material. They lack the heterogeneity through space, and also miss the fractures and joints of natural rock. Furthermore, the frequency of the ultrasonic laboratory measurements exceeds the field seismic measurements by four to five orders of magnitude. The team from the University of Alberta are working to counteract these, and thorough lab work is a natural precursor to field experiments. It is hoped that their portfolio of samples will assist them in their understanding of the changes which occur in rocks. Their investigations mean that they will continue to be at the forefront of world energy issues, providing the measurements which will make or break the cutting edge green innovations and energy technologies.

DOUG SCHMITT EXPLORING ONE OF THE DRY VALLEYS IN ANTARCTICA