**Institution:**

University of Leeds

**Unit of Assessment:**

7, Earth Systems and Environmental Sciences

**Title of case study:**

Case Study 8: Fast petro-physical analysis of unconventional gas reservoirs to assist in improving drilling strategies

**1. Summary of the impact** (indicative maximum 100 words)

Research performed at the University of Leeds allows the petroleum industry to reduce radically the amount of time that taken to estimate the key properties of tight sandstones containing natural gas. These properties largely determine whether gas fields are economically viable. Tests used in the past have taken between six months and two years to complete; with the Leeds research, results can now be obtained in less than one day – a radical improvement. Industry has used the results to justify drilling new prospects and to improve understanding of the controls on gas and water production in existing fields, which has shaped appraisal and production strategies.

**2. Underpinning research** (indicative maximum 500 words)

As conventional (high permeability) petroleum resources are becoming depleted, the petroleum industry is now increasingly turning to unconventional reservoirs, such as tight gas sandstones and shale reservoirs, to meet global energy demands. These reservoirs are difficult and only marginally economic to produce. It is therefore essential to dramatically reduce costs in the exploration, appraisal and development of these reservoirs.

The University of Leeds has established an excellent reputation in industry and academia for conducting high-quality research on the single and multiphase flow properties of low permeability rocks **[1,2,3]**. In response to an industry-led call for future research into unconventional gas reservoirs, **Quentin Fisher** established a joint industry project entitled PEtro-physics of Tight Gas Reservoirs (PETGAS). The initial phase of the project took place from 2009 to 2012 and was sponsored by Aurelian Oil and Gas, BG, BP, EBN, Shell and Wintershall to a cost of £900,000. A second phase of the project started in July 2012. The aim of the project was to improve understanding of the petro-physical properties (porosity, permeability, relative permeability, capillary pressure, elastic moduli, and electrical resistivity) of tight gas sandstone reservoirs to improve predictions of reservoir performance and to reduce costs associated with reservoir characterization in these marginally economic developments.

**Fisher** conducted a wide range of tests on the petro-physical properties of around 150 tight gas sandstone samples provided by sponsors. Analyses included: microstructural and mineralogical assessment, porosity, gas and brine permeability, as well as compressional and shear wave velocity as a function of stress, electrical resistivity, NMR T2 distribution and Hg-injection porosimetry. After rock typing, 40% of the samples were subject to special core analysis including capillary pressure, resistivity and relative permeability as a function of stress, cation exchange capacity, surface area analysis and NMR cryoporometry. In addition, experiments were conducted to address specific issues such as the use of restricted rate practice to enhance production from tight gas reservoirs. These parameters were matched with the microstructure of the samples when viewed in a microscope. The results showed that the key petro-physical properties of the tight gas sandstone can be predicted by a sample's microstructure **[4]**.

A blind test was conducted at the end of the project which attempted to predict a wide range of properties based simply on their microstructure obtained by scanning electron microscopy. The estimates provided proved to be incredibly close to the measured values **[4]**. In other words, simply by inspecting a sample of the sandstone it was possible to gauge its properties and the likelihood that it will be potentially productive or otherwise. This in turn means that it is now possible to provide accurate estimates of reservoir petro-physical properties within a day of them being cored as opposed to waiting six months to two years for the results from laboratory tests. This provides the operators with an early indication of the likely reservoir performance, allowing them to optimise future appraisal and development programmes or in some cases relinquish the asset to avoid more fruitless expense **[4]**.

PETGAS has also conducted specific experiments that should lead to changes in practice within the industry. For example, experiments were conducted to address the impact of stress on absolute and relative permeability of tight gas sandstones. The results suggest that these properties are extremely stress-dependent and that it would be worthwhile implementing restricted rate practice in which lower pressure drawdowns/production rates are used to improve longer-term production **[4]**.

Key researcher

Professor **Quentin Fisher**, Researcher, University of Leeds spin-out company RDR (1992-2008); Principal Researcher (2003-2007) and Professor of Petroleum Geoengineering (2008-present) in the School of Earth and Environment, University of Leeds.

**3. References to the research** (indicative maximum of six references)

The initial foundations for the PETGAS project stemmed from research conducted at the University of Leeds on fault rocks.


1. **Fisher**, Q.J. and Knipe, R.J. (1998) Fault sealing processes in siliciclastic sediments, *Geological Society Special Publication*, **147**, 117-134. DOI: 10.1144/GSL.SP.1998.147.01.08.
2. **Fisher**, Q.J. and Knipe, R.J. (2001) The permeability of faults within siliciclastic petroleum reservoirs of the North Sea and Norwegian Continental Shelf, *Marine and Petroleum Geology*, **18**, 1063-1081. DOI: 10.1016/S0264-8172(01)00042-3.
3. Al-Hinai, S., **Fisher**, Q.J., Al-Busafi, B., Guise, P., and Grattoni, C.A. (2008) Laboratory Measurements of the Relative Permeability of Cataclastic Faults: An Important Consideration for Production Simulation Modelling, *Marine and Petroleum Geology*, **25**, 473-485. DOI: 10.1016/j.marpetgeo.2007.07.005
4. Fisher, Q.J. (2011) PETGAS Report.

   *This research and report have led directly to the impact outline within this case study and are still confidential and only available to sponsors. A username and password will be provided to the reviewers of the case study so they can view the project website (www.see.leeds.ac.uk/petgas), which contains all of the results and reports from the project.*


5. **Details of the impact** (indicative maximum 750 words)

PETGAS created an impact from a very early stage and was viewed as being so successful by the sponsors that it they provided a further £930,000 to fund a second stage of the project. It also led to a £400,000 spinout project, SHAle PErmeability (SHAPE) that is applying the same technology to characterize the properties of shale gas resource plays.

PETGAS proved particularly useful for Aurelian Oil and Gas (now part of San Leon) during their appraisal of the Siekierki project, which is a large tight gas reservoir in Poland. In 2011-2012, Aurelian spent £35 million drilling and hydraulically fracturing two horizontal wells within the Siekierki Field. The well performance was not as good as was hoped for, in that low gas production rates were accompanied by high water production rates. Aurelian and several of their consultants initially thought that the poor performance resulted from the hydraulic fractures intersecting natural fractures that drained the underlying aquifer. A plan was therefore made to drill additional wells in an area less likely to contain natural fractures. However, results from Leeds as part of the PETGAS project provided an alternative explanation for the production behaviour. In particular, based on microstructural analysis of the reservoir rock and comparing these to other rocks on the PETGAS database it was possible to rapidly estimate the key petro-physical properties (permeability, capillary pressure and relative permeability) that controlled gas flow in the reservoir. These properties were then incorporated into a production simulation model and suggested that gas expansion in the reservoir was responsible for the high rates of water production instead of the presence of open fractures. The results from the simulation model indicated that it was possible that the brine production rates would decrease with time. Overall, these results had a very rapid impact on the field development plan. So instead of drilling more wells with the aim of avoiding natural fracture networks, the company decided to conduct longer term well tests to assess how brine and gas production rates evolved with time.

A senior executive of San Leon confirms: "*PETGAS input on our Siekierki core significantly helped in the understanding of water production mechanisms, explaining water production to be from the rock matrix rather than the initial assumption of flow along natural fractures. This informed the technical re-evaluation and dramatically changed the proposed reservoir development plan"* **[A]**.

The executive adds that "*The study showed that by integrating microstructural information with a database of petro-physical properties of tight gas reservoirs, it may be possible to provide reasonably accurate estimates of reservoir properties...within a few days rather than waiting months to years for the results from core analysis*" **[A]**.The results of the PETGAS research have been placed on a web-based database along with wireline log data from the wells analysed **[B]**. The results can be used easily by the sponsors to identify analogues and improve reservoir characterisation. The results have also been divided into rock types so that sponsors can readily obtain the most appropriate properties and relationships for their particular reservoir.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

A. Letter to corroborate impact that PETGAS research has had on appraisal of Siekierki project from Asset Manager, San Leon Energy (dated 20/02/2013).

B. PETGAS website.

*This database is still confidential and only available to sponsors. A username and password will be provided to the reviewers of the case study so they can view the project website (www.see.leeds.ac.uk/petgas), which contains all of the results and reports from the project.*