Meeting Agenda

Meeting title **JOINT M4SHALEGAS – EERA ANNUAL MEETING**	MEETING ORGANISER **Michael Bradshaw, Warwick Business School**

DATE **1-2 Feb 2017**	VENUE **Imperial College, Beit Quadrangle, Prince Consort Rd, Kensington, London SW7 2BB**

Attendees (estimated)

- ca. 10 persons (EERA)
- ca. 30 persons (M4ShaleGas)

Meeting agenda

Wednesday 1 February 2017, 10:00 – 23:00 h London time		
10:00 – 10:30	**Arrival and welcome coffee/tea**	
10:30 – 11:00	**Welcome words EERA / M4ShaleGas**	**R. Peters / M. Bradshaw**
11:00 – 12:30	***Hydraulic fracturing and induced seismicity***	
11.00 – 11.30	*What controls the direction of hydraulic fractures and can fault reactivation be predicted?*	*Robert Cuss (BGS)*
11.30 – 12.00	*Fault reactivation and induced seismicity caused by shale gas operations*	*Brecht Wassing (TNO)*
12.00 – 12.30	*From shale to surface: best practice for microseismic reservoir monitoring*	*Marco Bohnhoff (GFZ)*
12:30 – 13:00	***Impact of shale gas on air quality and global climate***	
12.30 – 13.00	*Monitoring methane leaks from a European shale gas industry*	*Hugo Denier van der Gon (TNO)*
13:00 – 14:00	**Network lunch**	
14:00 – 15:00	***Impact of shale gas well site infrastructure and transport***	
14:00 – 14:30	*Assessment of the footprint and carrying capacity of oil and gas well sites: the implications for limiting hydrocarbon resources*	*Sarah Clancy (Durham Univ.)*
14:30 – 15:00	*Assessing fugitive emissions of CH4 from high-pressure gas pipelines in the UK*	*Fred Worrall (Durham Univ.)*
15:00 – 16:00	***Shale gas drilling risks***	
15:00 – 15:30	*Minimizing risks and impacts of shale gas drilling, completion and production*	*Malin Torsæter (SINTEF)*
15:30 – 16:00	*Drilling through shale: instabilities, fallouts, and lost circulation*	*Alexandre Lavrov (SINTEF)*
16:00 – 16:30	**Coffee break**	
16:30 – 18:00	***Monitoring geochemical species, groundwater and flowback water***	
16:30 – 17:00	*Review of geochemical species to monitor in a shale exploitation context*	*Bruno Garcia (IFPEN)*
17:00 – 17:30	*Composition of flowback and productive water – reality and simulation*	*Andrea Vieth-Hillebrand (GFZ)*
17:30 – 18:00	*Shale gas development in Denmark with special reference to groundwater protection*	*Ole Stig Jacobsen (GEUS)*
20:00 – 23:00	**Dinner (sponsored by M4ShaleGas)**	

Thursday 2 February 2017, 09:00 – 22:00 h London time		
9:00 – 9:30	**Arrival and welcome coffee/tea**	
9:30 – 13:00	**Special meeting session: Social license for shale gas exploration: reality or wishful thinking?**	**Michael Bradshaw (organizer)**
9:30 – 10:00	*The UK's Shale Gas Trilemma*	*Michael Bradshaw (WBS)*
10:00 – 10:30	*Social License to Operate in the (Shale) Gas Industries*	*Darrick Evensen (Cardiff Univ.), Aleksandra Lis (AMU)*
10:30 – 11:00	*Q & A and Discussion*	
11:00 – 11:30	**Coffee break**	
11:30 – 12:00	Can fracking be fair?	*Matthew Cotton (York University)*
12:00 – 12:30	*Fracking: Has the public really had enough of experts?*	*Joanne Hawkins (Univ. of Leeds)*
12:30 – 13:00	*Panel Discussion*	
13:00 – 14:00	**Network lunch (EERA and M4ShaleGas)**	
14:00 – 18:00	**EERA Steering Committee (on invitation only)**	**M. Halter / R. Peters**
19:00 – 22:00	**Dinner (sponsored by EERA)**	

ABSTRACTS 1 February 2017

HYDRAULIC FRACTURING AND INDUCED SEISMICITY

Robert Cuss

WHAT CONTROLS THE DIRECTION OF HYDRAULIC FRACTURES AND CAN FAULT REACTIVATION BE PREDICTED?

Hydraulic fractures in rock will propagate in the direction of the maximum stress direction, which is usually vertically. Yet considerable lateral migration of fractures is seen, mainly due to fractures becoming lithologically bound. As part of M4ShaleGas a series of analogue experiments have been conducted in order observe and quantify the restriction of fractures in geological layers. Additional experiments have also looked at controls on fault strength and when fault reactivation is likely. The outcomes of the work will give an understanding of the operational limits that hydraulic fracturing operations can safely operate without inducing fault reactivation and aid understanding of the risks of hydraulic fracture propagation out of the prospective shale horizon into overlying aquifers.

Brecht Wassing

FAULT REACTIVATION AND INDUCED SEISMICITY CAUSED BY SHALE GAS OPERATIONS

Fluid injection plays a major role in shale gas operations and there are a number of cases worldwide where the injection operations associated with shale gas production, related either to hydraulic stimulation or waste water injection, are believed to have caused earthquakes. The increase in pore pressures caused by fluid injection results in stress changes on faults and fractures, which can lead to a reactivation of faults and fractures and related seismicity. The induced seismicity is expected to be a function of the pre-existing site conditions and geology and the injection operation itself. We performed a review of injection-induced seismicity reported worldwide, and performed an extensive analysis on the data obtained to further our understanding of the underlying mechanisms of injection-induced seismicity. In addition, we used numerical modelling studies to identify the key factors controlling fault reactivation and seismicity during fluid injection and shale gas operations.

Marco Bohnhoff

FROM SHALE TO SURFACE: BEST PRACTICE FOR MICROSEISMIC RESERVOIR MONITORING

The high induced seismicity rates in certain regions of low natural seismic activity have recently become a growing public safety issue. This resulted in a call for independent seismic reservoir monitoring before, during and after hydrocarbon production as well as for underground storage activities. To date no uniform regulations for case-dependent seismic monitoring exists and only few reservoir operations are locally monitored at all. Local seismic monitoring is a pre-requisite to detect low magnitude events that in many cases have foreshadowed potentially damaging ones. Here, we provide a best practice procedure for seismic reservoir monitoring with focus on shale gas reservoirs describing a modular construction kit and its stepwise implementation. We provide a workflow to help organize the associated technologies, starting with a single surface or downhole sensor in order to establish a baseline state. Each subsequent step in the workflow is then used to help decide on the most cost-effective way to proceed during reservoir treatments and the subsequent production period. We also include concepts for monitoring waste-water disposal and long-term underground storage as well as along-well leakage detection.

IMPACT OF SHALE GAS ON AIR QUALITY AND GLOBAL CLIMATE

Hugo Denier van der Gon

MONITORING METHANE LEAKS FROM A EUROPEAN SHALE GAS INDUSTRY

The M4ShaleGas program focuses on measuring, monitoring, mitigating and managing the environmental impact of shale gas exploration and exploitation in Europe. One of the main concerns surrounding shale gas exploitation is the leakage of methane, a strong greenhouse gas, second only to CO2 in terms of contribution to global warming. In this context we investigate how atmospheric monitoring could be used to detect and identify any significant leakages from a potential future shale gas industry. Any future European shale gas production will occur in a complex landscape with many different sources of methane present such as animal husbandry or wetlands. This complicates the monitoring and timely recognition of potential high methane leakage rates during shale gas production. This problem can be solved by using unique tracers such as isotopes or co-emitted (hydrocarbon) species. We will present an outline and the first steps towards such a system including the identification of suitable tracers in (shale) gas based on a gas composition database and a scenario for locations of a potential European shale gas industry and potential loss rates.

IMPACT OF SHALE GAS WELL SITE INFRASTRUCTURE AND TRANSPORT

Sarah Clancy

ASSESSMENT OF THE FOOTPRINT AND CARRYING CAPACITY OF OIL AND GAS WELL SITES: THE IMPLICATIONS FOR LIMITING HYDROCARBON RESOURCES

We estimated the likely physical footprint of well pads if shale gas or oil developments were to go forward in Europe and used these estimates to understand the impact upon existing infrastructure; the carrying capacity of the environment and how this may limit the proportion of resources that are accessible. Conventional well pads in UK, The Netherlands and Poland were examined. For the existing UK conventional well pads the current minimum setback from a building for a currently producing well was measured. To assess the carrying capacity of the land surface, well pads of the average well pad footprint, with recommended setbacks, were randomly placed into the licensed blocks covering the Bowland Shale, and the extent to which they would interact or disrupt existing infrastructure assessed.

When the surface and sub-surface footprints were considered the carrying capacity of the currently licensed blocks covering the Bowland Shale was between 5 and 42%, with a mean of 26%. This surface carrying capacity would mean that the predicted recoverable reserves estimate of 8.5 x 10^{11} m^3 for the Bowland Basin would be limited by the surface carrying capacity to 2.21 x 10^{11} m^3.

Fred Worrall

ASSESSING FUGITIVE EMISSIONS OF CH_4 FROM HIGH-PRESSURE GAS PIPELINES IN THE UK

Estimates of fugitive emissions from transmission, storage and distribution have been criticized for reliance on old data from inappropriate sources (1970s gas pipelines). Here, we investigated fugitive emissions of CH_4 from the UK high pressure national transmission system. The study took two approaches. Firstly, CH_4 concentration is detected by driving along roads bisecting high pressure gas pipelines and also along an equivalent distance along a route where no high pressure gas pipeline was nearby. Five pipelines and five equivalent control routes were driven. Secondly, 5 km of a high pressure gas pipeline and 5 km of equivalent farmland, were walked and soil gas was analysed every 7 m using a tunable diode laser. The smallest leak detectable was 3% above ambient. The number of leaks detected along the pipelines correlate to the estimated length of pipe joints, inferring that there are constant fugitive CH_4 emissions from these joints. When scaled up to the UK's National Transmission System pipeline length of 7600 km gives a fugitive CH_4 flux of 62.6 kt CH_4/yr – this fugitive emission from high pressure pipelines is 0.14% of the annual gas supply.

SHALE GAS DRILLING RISKS

Malin Torsæter

MINIMIZING RISKS AND IMPACTS OF SHALE GAS DRILLING, COMPLETION AND PRODUCTION

There are several unique technological challenges related to shale gas drilling, completion and production operations. We here provide an overview of these, together with a collection of operational recommendations for how to best prevent and mitigate problems. Maintaining shale gas well integrity from drilling to abandonment requires understanding of how various parameters/choices impact safety. Topics that are discussed are: shale gas drilling procedures, well cementing methods and materials, completion materials, and choice of operating parameters during well stimulation. Major knowledge gaps are pointed out, and we draw up a roadmap for future research and development on this topic.

Alexandre Lavrov

DRILLING THROUGH SHALE: INSTABILITIES, FALLOUTS, AND LOST CIRCULATION

Accessing shale-gas reserves requires that wells can be drilled safely and efficiently from the surface to the reservoir. A number of risks are associated with drilling such wells. In naturally-fractured rocks like gas-bearing shales, some drilling problems, e.g. borehole instabilities (collapse, fallouts, etc.) and lost circulation, are usually exacerbated. All rocks contain natural fractures. The difference between formations is not whether there are fractures or not, but how dense the fracture system is, how well-connected the fractures are, what are the fracture apertures, are the fractures sealed or open, etc. In some rocks, including gas-bearing shales, natural fractures are essential for storage of hydrocarbons and production from such reservoirs. Natural fractures effectively reduce the strength of the borehole wall. As a result, borehole instabilities may occur in form of e.g. fallouts. Rock debris falling into the well during drilling may lead to packoffs near the bottomhole, thereby impairing circulation of the drilling fluid and cuttings transport to the surface. Excessive torque and build-up of the bottomhole pressure are some of the consequences of a packoff. Build-up of BHP above the lost-circulation pressure may result in severe losses of the drilling fluid into the fractures (see below). Fallouts create enlargements in the borehole wall, which is detrimental not only for drilling but also, at a later stage, for cementing the well. When cement is pumped up the annulus during a cement job, fallouts (or washouts, as they are commonly referred to in the context of well cementing) might not be fully filled with cement. As a result, pockets of undisplaced drilling mud (drilling fluid + cuttings) or formation fluids may remain captured as "pockets". During subsequent lifetime of the well, such pockets represent a risk since they may (a) jeopardize zonal isolation of the well and (b) act as stress concentrators if downhole temperature or in-situ stresses change (Lavrov and Torsæter, 2016). When drilling with overbalance, natural fractures represent escape routes for the drilling fluid. If the fractures are wide enough (i.e. sufficiently opened), drilling fluid may enter even if the bottomhole pressure is below the fracture reopening pressure. Losses are likely to stop in this case, after the fluid has propagated a certain distance into the fracture. Losses stop because of non-Newtonian, yield-stress rheology of the drilling fluid. If the fracture is closed or its aperture is below a certain threshold (typically 100-200 μm), the bottomhole pressure must exceed the fracture reopening pressure for the fluid to enter (Lavrov, 2016). Combatting lost circulation in shales is a challenge since most materials sealing fractures and, thus, preventing or stopping losses, require fluid leakoff through the fracture wall. Such leakoff enables deposition of particles inside the fracture, on which then a filter cake can be built that prevents further losses. In shales, permeability is so low that there is effectively no leakoff on the time scale of a lost-circulation incident. This prevents sealing of the fracture and reduces the effectiveness of loss-prevention and lost-circulation materials. New products (additives to the drilling fluids) designed to prevent or combat lost circulation are introduced to the market every year. Development of more effective lost-circulation and loss-prevention materials will reduce the risk of occurrence and negative consequences of lost circulation in gas shales in the future. References: Lavrov, A. 2016. Lost Circulation: Mechanisms and Solutions, Oxford, Elsevier. Lavrov, A. & Torsæter, M. 2016. Physics and Mechanics of Primary Well Cementing, Springer.

MONITORING GEOCHEMICAL SPECIES, GROUNDWATER AND FLOWBACK WATER

Bruno Garcia

REVIEW OF GEOCHEMICAL SPECIES TO MONITOR IN A SHALE EXPLOITATION CONTEXT

Shale plays contain organic matter with mineral phases (clay, silt and also carbonate and sandstone) with presence of oil and/or gas. In a geological context, aquifers are always present in the environment of these shale formations (from deep aquifers (near the shale formation) to sub-surface and potable (surface) aquifers). That's why 3 main sources of geochemical species can be identified:

(1) The first one is composed from the geochemical species naturally present in the shale itself. Indeed, source-rock reservoirs are fine-grained petroleum source rocks from which liquid and gaseous hydrocarbons may be produced following fracture stimulation. A recent publication written

by Curiale and Curtis (2016) reviewed published literature to assess the current status of geochemical measurement and data interpretation of organic matter in these reservoirs. Their discussions of published studies focus on three areas: (a) source rock characteristics – organic matter quantity, quality and maturity; (b) thermally-induced cracking of kerogen, oil, condensate and gas; and (c) natural gas stable carbon isotopic anomalies often observed in shale plays. From these points discussed, (i) organic matter and hydrocarbon's species (in liquid and gaseous forms) can be described from a geochemical point of view. And, moreover, in addition to these hydrocarbon's species, (ii) non-hydrocarbon's species have to be considered too, especially in terms of monitoring.

(2) The second one from the aquifers present around it.

The various aquifers present are usually the most sensitive target in terms of environmental issues (Ancre, 2016). Deep aquifers are first exposed in case of uncontrolled migration of fluids through natural discontinuities which could exist, fracturing after the production process that can be present. Geochemical monitoring in these deep aquifers can be an interesting option for use as an early alarm trigger that's why monitoring and detection of specific geochemical species is very important in these locations. Moreover, because they are not containing potable water and generally have a high salinity, mitigation and remediation are conceivable even if they are impacted by leakage. Superficial aquifers, on the contrary, may be used as a source of potable water or water used for human activities (e.g., irrigation, industrial use). Some exploitation wells are present in these superficial aquifers for exploitation but nevertheless, they are quite far from the source rocks and the main objective to monitor these aquifers would be to detect leakage occurring on longer timescales. At that point significant impact on aquifer water quality may be expected.

That's why, considering the aquifers present (deep or superficial), a strategy in term of geochemical species monitoring can be envisaged. Some key elements (geochemical species) have to be identified and adopted in monitoring campaigns to design the best methodology to detect leakage as soon as possible.

(3) The last source is composed by the geochemical species used/present in the fluids that are used for hydraulic fracturing operations.

The chemical composition of the fracturing fluids used in shale exploitation can be very complex, locally depending on (a) specific fluid properties required for the fracturing and production of the formation, and (b) the local availability of a source of base fluid.

From these 3 sources, different geochemical species are present and induce a specific strategy/methodology that will be proposed, to have the best practices to monitor this process.

Andrea Vieth-Hillebrand

COMPOSITION OF FLOWBACK AND PRODUCED WATER – REALITY AND SIMULATION

Black shales are a heterogeneous mixture of minerals, organic matter, and formation water and little is actually understood about the fluid-rock interactions during hydraulic fracturing and their effects on composition of flowback and produced water. On the one hand, "real" flowback water samples were investigated for their chemical composition and on the other hand, interactions of different black shales with different artificial stimulation fluids were studied in lab experiments under ambient and elevated temperature and pressure conditions. These lab experiments showed clearly that fluid-rock interactions change the chemical composition of the initial stimulation fluid and that geochemistry of the fractured shale is relevant for understanding flowback water composition. This approach will be followed in setting up of a chemical process model for shale gas reservoirs.

Ole Stig Jacobsen

SHALE GAS DEVELOPMENT IN DENMARK WITH SPECIAL REFERENCE TO GROUNDWATER PROTECTION

Extraction of shale gas has in recent years attracted increasing interest internationally and in Denmark. A shale gas developed runs though different stages from exploratory and horizontal drilling; hydraulic fracturing; production of gas and closure of the well. The composition of hydraulic fracturing liquids that may be used in Denmark is at present unknown, but may contain the same 14-40 chemicals that have been used in Poland. A screening identified many potential risks, of which groundwater contamination, waste water and waste management and radioactive substances are classified as the major. The international literature reports a water demand with an average of about 18,000 m3 / well. Further, a set of monitoring and remedial measures should be implemented to minimize possible environmental impacts, including a baseline for the relevant inorganic substances and hazardous organic substances in surface water and groundwater, which from the previous studies have potentially been affected by the activities. Finally, the produced water from deep formations contains large amounts of salt which is expected to pose a significant problem for discharge.

ABSTRACTS 2 February 2017

SOCIAL LICENSE FOR SHALE GAS EXPLORATION: REALITY OR WISHFUL THINKING?

Michael Bradshaw

THE UK'S SHALE GAS TRILEMMA

This presentation sets the scene for a more detailed discussion of the shale gas debate in the UK. It does not examine the case for and against shale gas development. Rather, it uses the notion of the energy trilemma, which still informs the UK's energy and climate policies, to examine two areas that are critical points of disagreement in the shale gas debate. The first is the issue of UK gas security and the role that might be played by a domestic shale gas industry. The second is the future role of gas in the UK's energy mix and its compatibility with the UK's Climate Change Act (2008) and its associated carbon budgets. The presentation reports on recent UKERC-funded research on UK gas security and the future role of gas to demonstrate the complexities around these areas in relation to the shale gas debate.

Darrick Evensen, Aleksandra Lis

SOCIAL LICENCE TO OPERATE IN THE (SHALE) GAS INDUSTRIES

Shale gas as well as the method used for its extraction - hydraulic fracturing - can be seen as a highly controversial topic within the EU. In this presentation, we review the concept of “Social Licence to Operate” and methods prescribed by it to balance out public concerns with industry interests. To this end, we provide a short overview on the concept's origins in the mining sector, current interpretations and the involvement of stakeholders. In addition, we critically explore what “Social Licence to Operate” means to the oil and gas sector with a special focus on the shale gas industry and how it could practically be achieved. In particular we address the challenge of understanding what ‘the community’ is, whether a SLO is a ‘single-project achievement’ of a ‘sectoral achievement’ and the need for a long term engagement with communities rather than employing a defensive strategy to prevent protest.

Matthew Cotton

CAN FRACKING BE FAIR?

The development of unconventional fossil fuels using hydraulic fracturing and horizontal drilling techniques raises issues of environmental and public health risks to water management, climate change, traffic congestions, air, noise and light pollution, and seismic activity. It also has the potential to create technological stigmatisation, identity disruption and social decline in the communities it affects. Such impacts are unevenly distributed between host communities, land-owners, and fracking developers; alongside uneven decision-making powers and unequal economic benefits. This paper discusses the distributive and procedural justice dimensions of fracking in the United Kingdom, drawing upon qualitative and normative philosophical work on fracking justice. I examine the discourses of fracking threat and opportunity, recent developments relating to regulatory systems and institutional arrangements, changes to the powers of local authorities and the adequacy of industry-led community compensation and consultation processes with recommendations for future policy directions.

Joanne Hawkins

FRACKING: HAS THE PUBLIC REALLY HAD ENOUGH OF EXPERTS?

This paper presents findings from an empirical study that asked ‘what makes a regulatory decision regarding fracking/shale gas exploration legitimate to the public?’ This paper highlights that members of the public affected by shale gas exploration had a clear and comprehensive view of the factors that influenced their perceptions of decision making legitimacy. This consisted of the dominance of experts in regulatory decision making (in both planning and other regulatory decisions) and the imposition of extra strong controls to address the risks interviewees were concerned about. The term ‘expert’ had a very specific definition which diverged from the common use of the term to describe those with the relevant qualifications. Although interviewees’ definition was initially founded upon the possession of scientific qualifications the definition extended much further to include broader considerations such as the goal to which said experts were committed and the predictability of their behavior in pursuing such a goal. These broader considerations can help account for the perceived lack of expertise in current decision making procedures despite the presence of qualified scientists. The findings discussed in this paper contest the assertion in both STS and regulatory literature that there is a need to move away from expert dominance in decision making. The findings highlight that expert led decision making is actively desired by the public in the context of fracking and challenges the assumption that public participation plays a central/desired role in establishing the legitimacy of fracking related decisions. What is clear however is that there is a fundamental need to engage with the way in which an expert is defined, by the public, and the reasoning behind it if such a model of decision making is to be considered legitimate.