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REPORT

Energy Geoscience and Geo-Engineering – Collaborative Open Innovation Network (EG-COIN)

Regional Workshops February 23 – March 5, 2015

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Contents

Executive Summary[1]

Shale oil and gas represent a very large and mostly untapped resource for Canada. As conventional oil and gas reserves decline, Canada's ability to develop this next generation of energy resources will be key to maintaining its strong competitive position in the global energy market. Tight reservoir and shale gas development are a growing part of the global energy sector. Canada contains 71.8 trillion cubic feet (tcf) of recoverable natural gas, the 20th largest reserve in the world. In 2013, production of natural gas was 5.15 tcf (5th in the world) with about 50% derived from unconventional gas resources. Tight and shale gas production altogether are expected to increase to 90% of Canada's gas production by 2035. However, shale resources development is facing a number of challenges.

In 2012, the Geological Survey of Canada proposed the development of EG-COIN – Energy Geosciences and Geoengineering - Collaborative Open Innovation Network:

- Collaborative – improving alignment around priority topics of common interest to industry, government and academia;
- Open – having a special mandate to broadly and openly disseminate findings and data;
- Innovative – focusing on pressing national knowledge gaps;
- Network – bringing together partners from across public sectors, industry and academia.

Initially EG-COIN focused on identifying and addressing knowledge gaps related to characterization and extraction of shale oil and gas. To do so, a series of workshops were held in Halifax, Québec City, Winnipeg, Calgary and Vancouver, in February and March 2015, with close to 200 government (Federal/Provincial/Territorial), industry and academia representatives to discuss knowledge gaps and barriers to innovation in the understanding and alleviation of the risks associated with this resource development. The workshops addressed three themes: 1) how to better assess resources and characterize reservoirs; 2) development of geo-engineering best practices; and 3) how to increase understanding and tools/methods to minimize the environmental impact of development. The attached reports present the results of the discussions for each of the five workshops, and the common and unique challenges identified in each region.

The workshops, organized by Natural Resources Canada (the Geological Survey of Canada and the Innovation and Energy Technology Sector) in collaboration with the University of Calgary, consisted of a series of invited talks outlining the regional context, followed by extensive group discussions. The invited speakers, from industry, academia and government, presented a wide range of regional research and knowledge gap issues.

In addition, at each of the workshops, two opening presentations were made. Louise Laverdure (Natural Resources Canada – Geological Survey of Canada) talked about the challenges facing shale oil and gas development (economic competitiveness of shale resource; social consensus on resource development)

[1] **DISCLAIMER**
This document is an informal discussion paper based on the personal views, ideas and concepts of participants attending the EG-COIN workshop, and in some cases, the views of their organization. The observations and recommendations contained herein do not necessarily reflect the opinion of Natural Resources Canada or the Government of Canada, or those of the other departments and organizations identified in the document. Notes from the round-table discussions have not been reviewed by the agencies represented at the workshop; however, the workshop participants were aware the notes would be published. This document is for discussion purposes.

and how a network like EG-COIN could be developed as a coordinated, collaborative and open research program in geoscience and engineering, combined with a novel approach to communicate scientific information, which would have significant impacts on decision making related to shale gas and tight oil extraction in Canada. Bernhard Mayer (University of Calgary) presented some of the key findings of the Council of Canadian Academies' report, Environmental Impacts of Shale Gas Extraction in Canada, released in May 2014, for which he was one of the 16 expert members. The report focused on environmental and health impacts of shale gas development (related to groundwater and surface water contamination; greenhouse gas emissions; land impacts and induced seismicity; and human health) and the need to establish sufficient environmental baseline data to assess, manage and mitigate environmental effects through monitoring and research. The results of a survey completed by the invitees prior to the workshops were also presented. In the survey, the most important issue related to shale oil and gas development was identified as reservoir characterization and resource assessment; the most important environmental issue was groundwater contamination from stray gas, fracking and flow back fluids (use, storage and disposal); and the most important technology and geoscience R&D theme was hydraulic fracturing (improved understanding and monitoring).

During the workshops, it was acknowledged that Canadians have concerns related to potential impacts on water, soil and air (including fluid migration pathways influenced by hydraulic fracturing, seismic events, long-term well integrity). As such, environmental baseline data and methodologies are needed for monitoring and understanding potential impacts on aquifers or associated lands.

Recovery rates for shale oil and gas extraction presently vary between 5-15% and 15-50% respectively, meaning that most of the resource remains underground. A significant R&D effort is thus needed to develop new extraction techniques that will increase those recovery rates, and consequently the return on investments, royalties and potential technology exports. Finally, a better understanding of our resource (where, what kind and how much) will allow governments to make sound decisions (e.g. related to infrastructure development).

The main R&D themes discussed at the workshops were:

- Geological and aquifer mapping needed to support water resources protection and reassure the public that potential environmental impacts are assessed and where necessary mitigated.
- Better understanding of fugitive GHG emissions, wellbore leakage and induced seismicity.
- Enhanced oil recovery; improved secondary/tertiary recovery techniques.
- Rock formation characterisation to better assess location and quantity of oil and gas present, and understand fluid pathways.

Also identified as common innovation barriers were the lack of coordination and access to industry/government data; insufficient, unstable and highly competitive research funding; and the shrinking and aging research communities and difficulties attracting the next generation.

EG-COIN is proposing to leverage industry, government and academic expertise, funding and facilities to address shared research priorities, in order to reduce the risks of development and the adoption of new technologies and practices for shale oil and gas extraction. EG-COIN also plans to take into account related community concerns about development impacts, and to facilitate adoption of socially innovative approaches to expand the reach of scientific innovation.

As an important step toward the formation of the EG-COIN network, a national roundtable entitled "Shale Oil and Gas Development? Opportunities and Challenges for Collaboration in Energy Geoscience

and Geo-Engineering" was hosted by Canada's Public Policy Forum in Ottawa on March 2015, following the regional workshops. Senior leaders from industry, government and academia met to discuss the key issues at a high level and how to enable cross-sector collaboration to solve these issues. A report from this roundtable is forthcoming.

Natural Resources Canada and the members of the EG-COIN Advisory Committee will evaluate the results of the regional workshops and national roundtable and develop a coherent plan for building the cross-sector collaborative EG-COIN network. It is expected that the plan will be in place by fall 2015 and implementation will follow.

The organizers would like to thank the Natural Sciences and Engineering Research Council (NSERC) for their support, as well as Dalhousie University, Laval University, the University of British Columbia and the University of Manitoba for their help in organizing the workshops.

The workshop consisted of two parts: a series of invited talks on the regional context, followed by group discussions. In total, five invited speakers from industry, academia and government presented a wide range of regional research and knowledge gap issues.

Invited talk summaries:

The Atlantic Canada workshop invited participation from various stakeholders from Nova Scotia, New Brunswick and Newfoundland-and-Labrador who outlined the emplacement of the current moratoriums in Nova Scotia and New Brunswick, the expected regulatory challenges that lie ahead for all jurisdictions, the academic research currently being done on hydraulic fracturing and water resources and the challenges faced by industry.

In Atlantic Canada, there is a significant concern about potential environmental impacts of development, particularly with regard to water resources. Presentations from David Besner (NB Energy Institute (NBEI)), Adrian Park (NB Department of Energy and Mines) and Sheri Somerville (Canadian Association of Petroleum Producers, CAPP) all indicated that scientific information has to be developed to support regulations protecting air, water and public health. Concerns about the impact of hydraulic fracturing are widespread and, in general, a better understanding of the subsurface conditions is needed to protect regional groundwater and properly dispose of wastewater. The NBEI has been mandated to provide a forum for discussion on energy-related issues and to bring together researchers to address priority areas of concern (air quality, freshwater resources, seismicity, etc.) amongst government and academic researchers. Work is being done in academic institutions to address water resource use and to document baseline conditions ahead of development. Graham Gagnon (Dalhousie University) pointed out that 15-20% of Nova Scotia wells contain naturally occurring biogenic methane emphasising the need for baseline characterisation studies. He suggested investigating possibilities for using saline or marine waters for operations rather than groundwater resources. It was mentioned (Brad Hayes, Petrel Robertson Consulting Limited) that generally industry recognizes the need for R&D and is willing to provide data, time and resources to support these initiatives. Industry groups, like CAPP, are also willing to step in and work with communities to provide facts and information.

Group discussions on future research avenues, barriers to innovation and opportunities:

In Atlantic Canada, due to the current context no wells are being drilled and hence no data are being collected thus leaving a number of stakeholders with limited possibilities to characterise the shale formations in the region.

Local discussions showed commonality with their colleagues across Canada on insufficient and short-term research funding, the lack of access to industry data, as well as a shrinking and aging research workforce.

Participants mentioned the need to go beyond listing facts and figures and communicate more effectively with the public to build trust and provide information on the science we know, as well as the knowledge gaps currently being looked into. It was suggested that there is a need to build a communication and outreach strategy into future programs/projects, and that the value of this activity be recognised by funding agencies. Communication must be done in plain language and be (and be seen) as non-biased, non-politically-influenced to ensure the best possible policies and decision making.

The priority research areas in Atlantic Canada are centred on ensuring that baseline monitoring and environmental data are collected, and ensure that thorough aquifer and geological mapping are completed ahead of resource development. Work must be done to better understand fracture pathways and aquifer fluid flow, with particular attention to the zone in between fresh water wells and the production zone (a.k.a. the intermediate zone) as well as where freshwater and brines occur. Another priority topic raised was the need to develop wastewater treatment and disposal processes ahead of production. This issue is of specific interest in New Brunswick where no waste disposal sites exist. Can wastewater be disposed of in the ocean? What would the impact be on marine ecosystems? Participants also felt that better natural seismicity, well bore leakage and GHG monitoring are needed in the region, in addition to baseline information. Finally, participants suggested more studies are needed on the potential health impacts of fracking additives and on the mitigation of potential air, water and soil contaminants.

As seen in Annex **1**, other research priorities were brought forward, common to themes that emerged in the other workshops. These cover potential impacts on water, soil and air (including fugitive emissions, seismic events, long-term well integrity). The need exists for better understanding of tight oil and shale rock formation properties (including understanding rock heterogeneity, geomechanics, porosity, permeability etc.), as well as a need to trace and characterize the different gas sources within basins. Researchers agree that modelling from nano-scale observations to reservoir-scale reality posed great challenges and that better models and tools specifically designed for shale and tight reservoirs are necessary. Collectively, industry would like to see more studies of enhanced oil recovery and of secondary and tertiary recovery techniques.

In Atlantic Canada participants felt that there were great opportunities for sectors to work together on existing data, with willingness of industry to share data. Lastly, participants felt that if a pilot test site could be established, it would be beneficial to all sectors.

Participants all agreed that the timing is excellent to establish a collaborative network to tackle issues around shale oil and gas resources while leveraging funding, expertise and data. A number of issues are common through the country and are at the forefront of the public's mind.

Annex 1

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
ATLANTIC REGIONAL STRATEGIC WORKSHOP
HALIFAX, NOVA SCOTIA – FEBRUARY 23, 2015
LORD DALHOUSIE BOARDROOM, HENRY HICKS ACADEMIC BUILDING, DALHOUSIE UNIVERSITY

The Atlantic Regional Strategic Workshop helped on discussing R&D needs on:

1) better resource assessment and reservoir characterization;
2) geo-engineering and best-practices;
3) understanding and tools/methods to minimize environmental impacts; and
4) pooling of existing and future proprietary geoscience information for added value to the entire sector and the public.

They also addressed innovation from social science and humanities research to:

1) better understand how scientific information is transferred to and used by communities, and
2) increase the uptake of this science by citizens.

Participants helped identify any other knowledge gaps from land use, regulatory and industry perspectives, as well as provide regional perspectives on these issues.

Invited presentations

Water: A resource for hydraulic fracturing
Graham Gagnon—Dalhousie University

Shale gas in New Brunswick: Facts and challenges
Adrian Park—Government of New Brunswick

Petroleum industry perspective
Brad Hayes—Petrel Robertson Consulting

Natural gas exploration and development in Atlantic Canada – Communications landscape
Sheri Somerville—Canadian Association of Petroleum Producers

The New Brunswick Energy Institute: Energy Science and New Brunswickers
David Besner—New Brunswick Energy Institute

RESEARCH AND KNOWLEDGE GAPS

Resource Characterization and Resource Assessment

Reservoir characterization (geology)

- Study stress regime to understand how rockmass react to fracturing

- Characterization of rock types (rock mechanics) and baseline regional analysis of basins – using boreholes, drill cuttings, etc.
- Identify pre-existing fractures – baseline and understanding (possible pathways for leakage)
- Understanding of the intermediate zone – pore space
- Information on shallow zones
- Regional standardized geomodels

Reservoir characterization (oil/gas)

- Petroleum borehole data
- Fingerprinting of gases from intermediate zone (biogenic, thermogenic)
- Understand the geochemistry of each plays

Resource assessment

- Develop large regional data models

Geo-Engineering & Extraction

Technologies

- Enhanced oil recovery vs extraction costs
- Geo-engineering properties when multiple layers are encountered
- Secondary fracking

Fracking techniques

- Understand how high hydraulic fracturing propagates up (especially when shallow) – safety buffer
- Modelling for multiple fractures (could help improve public confidence)
- Greener or alternative fracturing fluids
- Substitute for fracking

Well integrity

- Cement and sealing (whether there is a lifetime-cost of remediation)
- Clarity on leakage issues – understand what is happening with wells – baseline and long-term monitoring of well integrity
- Understand how gas comes up from depth – migration – impact – monitoring
- Better practices for surface casings

Environment

General

- Understanding of how baseline methods work – cost effective monitoring practices
- Airborne EM surveys
- National standard for sample collection – QA/QC
- Looking at multiple indicators to differentiate with natural occurrences

Water

- Baseline water quality data

- Targeted environmental hydrogeological assessment – more aquifer mapping (leadership from GSC)
- Best practices/standards/required baseline for deep water injection disposal – cost factor
- Better understand wastewater treatment and injection – no treatment facility in NB – economical waste water management
- Develop monitoring programs for surface and groundwater – regional atlas
- Is marine disposal possible?

Seismicity
- Seismic data and monitoring – background monitoring

GHG
- Gas leakage – collect better data
- Impact of risks of abandonment methane

RESEARCH AND INNOVATION BARRIERS AND OPPORTUNITIES

Barriers to Innovation

General barriers
- Existence of bans prevent collecting more data
- Limited resources and staff in provincial government
- Moratorium prevent any drilling and data collecting – impact on research
- Public acceptance – maybe not enough existing data to convince the 40% against industry

Research-related barriers
- Availability of data to support resource assessment – sharing protocols
- Information not being shared from industry – need proper data management (same platform – one regulator, etc.)
- Due to existing bans, use only of passive seismic monitoring and second order data types
- Need of larger datasets to feed process and best practices for wastewater treatment

Sector-specific barriers
- Industry will not fund research, as risks are high to not produce

Opportunities for innovation

Opportunities within and between sectors
- Share cost of collecting data from the intermediate and the production zones
- Share science information from other jurisdictions
- Data sharing between universities, governments and industry – role for regulators for mandatory data collection – better ways to handle data from acquisition, distribution, and archive
- Improve subsurface monitoring and allow for wells to be drilled, stimulated and collect measured data
- Share past research

- Bring together all stakeholders (academia, regulators, industry, other successful provinces, etc.) – more collaboration between partners
- Review efficient model for focused research funding – funding and cooperation between provincial and federal
- Streamline approvals – one regulatory body
- Success will depend on the champions
- Usefulness of GSC and university research for baseline analysis

Opportunities for outreach

- Develop a test site in an area with known hydrocarbon leakage – also a test site for injection
- Have regional rules (not province by province, community by community)
- Lift ban and moratorium
- Regulations based on science (not emotions)

Science Communication

Communicating science within the research community

- Choose similar jurisdictions (densely populated) to draw comparisons
- Communicating science is the number one issue – not just facts – exercise to earn trust
- Plan studies early to include communication
- Be frank about who is funding research
- Weight of peer-reviewed papers vs consultant reports
- Work with social scientists on how to get the good message out
- Use successful case studies as examples – use examples of the Science advisory board of the NBEI
- Have granting agencies valuing public outreach
- Add soft skills in curriculum – commercialization, communication

Communicating science to broader audiences / public outreach

- Candor is required
- Open science-based communication within the context of current misinformation campaign – need of expertise in formulating messages to be understood and accepted by general public
- Need for trusted agency to communicate science – nee to know who is more credible for the public – universities ? – EG-COIN? - develop communication tools
- Use a language that public is familiar with
- Find ways to better inform the public with existing information
- Take the politics out of discussion
- Be open about what is known and what is still unknown – positive research
- Get more involved in social media
- Multiple people with same message is more convincing
- Need to collaborate with communities – need to be adaptable – early engagement before and after to maintain confidence
- Build local expertise (field studies, peer-to-peer interest)
- Build bridges with indigenous culture and knowledge – engage elders
- Use the consortium approach

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
QUEBEC REGIONAL STRATEGIC WORKSHOP
LAVAL UNIVERSITY
QUEBEC CITY, QUEBEC – FEBRUARY 26, 2015

The workshop consisted of two parts: a series of invited talks, followed by group discussions. In total, four invited speakers from industry, academia and government presented a wide range of regional research and knowledge gap issues.

Invited talk summaries

The Quebec regional workshop was attended by various stakeholders who explained the provincial government's current position in the unconventional resources sector, the industry outlook in Quebec and the need to improve public awareness and acceptance.

Quebec currently has a de facto moratorium on hydraulic fracturing. The public perception of the shale gas industry in Quebec is currently rather unfavourable and environmental concerns must be taken into consideration. Moreover, the resources are located on Anticosti Island, resulting in various specific development challenges. However, assessments of the Utica formation in Quebec and Ohio demonstrate the presence of extensive quantities of shale resources.

Alexandre Gagnon (Petrolia) described Quebec's history of conventional oil and gas exploration. Recent shale gas exploration has raised many environmental concerns among the public, particularly related to climate change, potential environmental risks and the industry's social, economic and environmental sustainability. Quebec does not currently have the infrastructure to be able to bring potential oil and gas resources to market. There is also social opposition to pipeline construction while, in recent years, rail transportation has not been considered safe. Public concerns mainly focus on the potential advantages of this industry as compared with the impact on local communities. Since 2005, $42.5M has been invested in exploration licences, seismic surveys and drilling wells. A consortium estimated resources on Anticosti Island at 34M barrels of oil. In 2016, a hydraulic stimulation test could be conducted. Charles Lamontagne (Quebec Department of Sustainable Development, Environment and the Fight Against Climate Change or MDDELCC) and John Molson (Laval University) referred to the public's concerns about the water resources found in over 80,000 artesian wells in the St. Lawrence Lowlands (almost all at a depth of less than 120 m), and it should be noted that the potential production of the Utica and Lorraine formations would be at a depth of 1.2 to 2.5 km. Major pre-development hydrogeological mapping programs are necessary, however, to understand the fluid pathways in the region, especially since regional aquifers are shallow in the fractured rock. Initial methane studies in wells showed that the gas is mainly of biogenic origin, but more studies and rigorous monitoring are needed to win social acceptance for future projects. Monica Gattinger (University of Ottawa) spoke of the need to educate the public about the energy resource, which could result in better social acceptability. This exercise should include facts about the associated risks and the techniques used to mitigate the potential environmental impacts. More open discussions about the advantages (economic, employment and energy security, etc.) compared with the disadvantages (potential environmental impact, noise, transportation, etc.) of these projects must be initiated with local communities.

Group discussions on future research avenues, barriers to innovation and opportunities

Workshop discussions revealed a number of points in common with colleagues across Canada, mainly regarding the insufficient funding of research and, in the short term, the lack of access to industry data and the shrinking, aging research community.

In Quebec, industry considered the introduction of new regulations as a major hurdle to innovation. Political decisions do not necessarily appear to take scientific evidence into account. Participants also felt that the lack of baseline environmental data posed difficulties for measuring or forecasting the impacts of development. There is an urgent need for updated geological mapping of basins and aquifers. Collaboration between the sectors seems limited and difficult to achieve because of the lack of coordination with regard to scheduling, funding and intellectual property.

Participants referred to the need to delve beyond facts and figures and to communicate more effectively with the public and political leaders to build trust and provide known scientific information together with knowledge gaps currently being studied. University courses in science and engineering should promote better communication and help train future generations of researchers on how to communicate effectively with the public. At the same time, the need to work with the social sciences to develop communication strategies, better understand the public's current perceptions and educate the public on various energy issues was recognized. Participants suggested there is a need to build a communications and awareness strategy in future programs/projects in a potential EG-COIN network, and that the value of the activity must be recognized by funding agencies. Communication must be in clear, open and honest language to ensure regulations and decision-making are as effective as possible.

A unique challenge in Quebec is the potential develop of the industry in an island environment on Anticosti Island, which will pose infrastructure and marketing difficulties. Moreover, there is potentially the issue of marine rather than land extraction. This will require considerable work to ensure development is done in an environmentally sustainable manner. Moreover, the toxicity of fracking additives and the presence of methane and radon in regional aquifers are major concerns in Quebec. What would be done with the waste water and how would the environment be protected? Monitoring and maintaining well integrity were other topics broached. New materials would be necessary to ensure long-term well integrity.

As stated in Annex **2**, other research priorities were discussed that shared the same themes as those that emerged in the other workshops. They covered potential impacts on water, soil and air (including fugitive emissions, seismic events, long-term well integrity). There is a need for a better understanding of the properties of leak-proof reservoirs for the potential elimination of waste water, shale properties (including the understanding of heterogeneity, geomechanical properties, porosity and permeability), and the need to characterize various gas sources in the basins. Researchers agree that modelling on a nano-scale raises significant challenges when extrapolated to the scale of reservoirs, and better models and specially designed tools are required for this type of reservoir. The industry as a whole would like to see more studies on better gas-oil recovery, as well as on secondary and tertiary recovery techniques.

At the Quebec City workshop, participants stressed the importance of creating a test site where researchers could work together on all aspects of shale resource development. In addition, such a site could be used to increase public awareness of development and foster discussion. A network of regional researchers could encourage the sharing of infrastructure, laboratories, equipment and interdisciplinary co-operation. This network could be a vehicle for facilitating data dissemination and sharing, as well as

for attracting new students and researchers in this area. At this time, there is an excellent opportunity to gather baseline pre-development monitoring data.

Participants all agreed that the time has come to establish a collaboration network to address shale resources issues while taking advantage of the pooling of funding, expertise and data. A number of concerns are shared across the country and have captured public attention.

Annex 2

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
REGIONAL STRATEGIC WORKSHOP
ROOM 2326, ALPHONSE DESJARDINS PAVILION, LAVAL UNIVERSITY, QUEBEC CITY, QUEBEC
FEBRUARY 26, 2015

At the regional workshop in Quebec City, R&D needs were discussed, including:

1) better resource assessment and reservoir characterization;
2) geo-engineering and best practices;
3) understanding and tools/methods to minimize environmental impacts; and
4) pooling of existing and future proprietary geoscience information for added value to the entire sector and the public.

They also addressed innovation from social science and humanities research to:

1) better understand how scientific information is transferred to and used by communities; and
2) increase the uptake of this science by citizens.

Participants helped identify other key regional and national knowledge gaps and provided regulatory, industrial and academic perspectives.

Invited presentations

The scientific role of the Geological Survey in the Quebec public debate around exploration and extraction of hydrocarbons
Alexandre Gagnon – Petrolia

Energy Geosciences and Geo-engineering: a Quebec perspective
Charles Lamontagne – MDDELCC (Government of Quebec)

Unconventional geosciences and geo-engineering needs for the development of oil and gas
John Molson – Laval University

Oral presentation by **Monica Gattinger – University of Ottawa**

RESEARCH AND KNOWLEDGE GAPS

Reservoir characterization and resource assessment

Reservoir characterization (geology)

- Fracture propagation under various stress regimes
- Permeability of cap rock, faults
- Basin characterization

- Difference between shale reservoirs – conventional reservoirs – nano/microporosity, permeability, geometry – scaling factors
- Fieldwork – base mapping – update of previous fieldwork

Reservoir characterization (oil and gas)

- Basin characterization (isotopic characterization)

Resource assessment

- Assessment of resources in place, including condensate-gas-oil ratio

Geo-engineering and extraction

Technologies

- Development in an island environment (infrastructure – transport – connectivity – human resources – processing)
- Modelling and optimization of extraction rates

Fracturing techniques

- Optimizing water management
- Eliminating fracturing fluids deep in the ground: possible or not?
- Fracturing fluids (brines, seawater fluid, propane) – management, processing, additives, injection, etc.
- Reuse of drill cuttings

Well integrity

- Sustainability of wells – framework – lack of knowledge
- Migration of gas along wells
- Well inspection and repair (methods, standards, tools)
- New materials (cement, casing)

Environment

General

- Monitoring (**before**, during, after) (all points combined – water, air, seismicity, gas, rock mass, cap rock)
- Knowledge of the intermediate zone between potable aquifers and the production zone (and all points in between)
- Differences between the marine and terrestrial environments
- Need for risk evaluation and social studies

Water

- Depth of aquifers – little data below 150 m
- Groundwater monitoring protocols near producing wells
- Protocols for sampling and variability of methane concentrations in water
- Surface water – Piezometric levels

Seismicity

- Induced seismicity within shale basins
- Micro-seismicity and induced fracture length in the various basins

Greenhouse gases

- Methane and radon in water – What should the standards be?
- Lack of data on methane leakages (wells, soil, water)

RESEARCH AND INNOVATION BARRIERS AND OPPORTUNITIES

Barriers to innovation

General barriers

- How to collaborate with industry – Quebec Department of Energy and Natural Resources (MÉRN) – federal government – universities (maximum sharing of information)
- New regulations – Build-up of regulations following research
- Loss or lack of human expertise in academia and government – further decline in the future
- Competition with communication experts – artists before introverted researchers
- Decisions not taking research into account regularly enough

Research-related barriers

- Realism of research avenues – practical aspects of recommendations
- Lack of standards following numerous analyses of water and excavated material – science can help determine these standards and thresholds
- Direct relationships between engineers (infrastructure) and urbanists
- Access to / use of data
- Nano-porosity tools – expensive
- Need to develop university programs – shortage
- Current curricula – Help develop communications students or include communications training for engineers and scientists
- Relationships with social sciences – compartmentalization of research fields
- Encourage ongoing training

Sector-specific barriers

- Time and resources required for researchers to develop collaborative work
- Industry must train its employees in-house
- Differentiate between intrinsic problems (fracturing) and peripheral problems (noise, trucks)

Opportunities for innovation

Opportunities within and between sectors

- Core logging data – core samples – rarely arising from the cap rock
- Demonstration sites – change the narrative and perceptions
- Laboratory site – aligned with the world of research (CO_2 sequestration – Cenovus – Petroleum Technology Research Centre -– Aquistore)

- Grant program – Create chairs
- Attract students in related fields (geothermics, very deep water, etc.)
- Distribution of knowledge about laboratories, equipment and existing expertise in the region (Natural Science and Engineering Research Council data bank)
- SIGPEG [Oil and Gas Geoscience Information System] to share data – must be updated – need an independent organization to collect data
- Creation of networks? – sharing of benefits
- One-stop shopping for geoscience research
- Transfer of technological and scientific knowledge
- Development of standards for shale gas development
- Major role for governments and the industry – work with British Columbia and Alberta

Opportunities for outreach

- Research and basic data collection before development
- The government could consider giving a contract to a non-governmental organization to measure gas leaks

Science communication

Communicating science within the research community

- Communications training for researchers – ongoing training
- Speakers' program
- Awareness-raising
- Inter-silos forum – pairing science and engineering with other fields
- Interdisciplinary students' energy competition
- Development of a student community in the energy field (all fields combined)
- What to do in the short, medium and long terms?
    - Work in the education system
    - Shale gas sustainable development centre
    - Use of neutral organizations (PollutionProbe)
    - Use of social media (see ResourceWorks – BC) – meeting with opinion leaders

Communicating science to broader audiences / public outreach

- Try to strike a balance with four imperatives: markets – environmental respect – security (resources and markets) – social acceptability
- Improve the public's energy literacy
- Promotion of scientific facts and information – good use of social media
- Promotion of youths and the public (Energy Summit in Montreal)
- What can be done about pseudo-experts?
- Good popularization program
- Communicate risks correctly and be transparent
- Shale gas industry risk study
- Use of other players
    - Examples in the mining industry
    - Major Projects Office (Fédération des chambres de commerce du Québec) – interdisciplinary projects
    - Perception of federal organizations (National Energy Board)

- Organizations similar to watershed agencies – Association francophone pour le savoir (ACFAS)
- Professional associations (geologists, etc.)
- Chief geologist – Hired by the MRNQ – hydrocarbons field
- Organizations such as the Union des producteurs agricoles
- Unions

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
WESTERN REGIONAL STRATEGIC WORKSHOP
UNIVERSITY OF CALGARY
CALGARY, ALBERTA – MARCH 3, 2015

The workshop consisted of two parts: a series of invited talks on the regional context, followed by group discussions. In total, five invited speakers from industry, academia and government presented a wide range of regional research and knowledge gap issues.

Invited talk summaries:

The Western Canada workshop invited participation from various stakeholders from Saskatchewan, Alberta and the Northwest Territories, who outlined the current regulatory environment, the academic research currently being done on hydraulic fracturing and seismicity and the challenges faced by industry. There was also a reflection of successful efforts made in Pennsylvania to convey scientific information to the public while creating a positive R&D and industry environment.

Alberta is currently Canada's second largest producer of gas from shale reservoirs after British Columbia. Extensive production of natural gas, gas liquids and oil from horizontal wells with multi-stage hydraulic fracturing is occurring throughout Alberta in both tight sand and shale reservoirs. Currently shale oil and gas is being extracted in Saskatchewan, but not in the Northwest Territories.

The invited talks were led by Tom Murphy (Marcellus Center for Outreach and Research at Penn State University) who presented the work done in Pennsylvania, on how public outreach efforts on shale gas resources can be highly successful in changing public perception. The Center focused on issues like how waters "above ground" and "below ground" interact. Work focused on mitigation of environmental impacts around shale development to ensure social acceptability and was conducted by talking to the public about the risks involved in development, and breaking down the science for the non-specialist. This talk set the stage for framing the Alberta landscape and thinking about how to improve public perception.

Bob Willard (Alberta Energy Regulator) outlined the regulatory framework in Alberta: how AER is responsible for and how it has evolved to keep up with the changing resource sector, new technologies and the dawn of shale oil and gas resource development. AER is responsible for ensuring regulations are followed through the entire lifecycle of projects to ensure a balance of environmental, economic and social needs are met. The introduction of play-based regulations will change the regulatory framework in Alberta through earlier project based planning enhanced community level engagement, and increased company to company cooperation. The top two challenges in the regulatory process for shale development are the management of water resources, both water use and protection, and gaining public understanding and support. Paul MacKay (Shale Petroleum) highlighted the need to think of shale oil and gas resources as a commodity and as such, from the industry perspective, the greatest risk to development is commodity price. Shale hydrocarbons are expensive to produce and as such, highly sensitive to market price fluctuations because companies are now operating on a cash flow model rather than a reserves and land acquisition model. Furthermore, the shift from vertical to horizontal drilling has resulted in very different, highly diverse teams operating in industry but not necessarily with a better fundamental understanding of what is happening in the ground during fracturing and

extraction. Finally, two talks by Chris Clarkson and David Eaton (University of Calgary) highlighted many of the unknowns surrounding hydraulic fracture characterization and induced seismicity. A great deal of research is happening at universities in the region. Researchers are faced with the challenge of scaling-up their results to the reservoir scale to better understand the system as a whole even knowing that many fundamental laws of fluid dynamics cannot be applied to heterogeneous formations within any given basin system. Academic research is also being done to better understand the micro-seismicity produced by hydraulic fracturing and fluid re-injection into formations. There is a need for improved tools and methods designed for shale oil and gas resources that will enable better resource characterization with respect to shale reservoirs.

Group discussions on future research avenues, barriers to innovation and opportunities:

In Western Canada, as in other regions across the country, participants felt that the lack of stable, long-term funding and access to data were the largest barriers to R&D advancement. Access to data was further limited by strong proprietary IP policies within industry. All sectors in Western Canada noted the lack of HQP available to undertake much needed research, particularly with the poor public perception the industry currently holds, it has become increasingly difficult to attract young professionals and excellent graduate students. Furthermore, due to different timescales of project completion, it can be difficult to collaborate and coordinate efforts between researchers and industry.

All stakeholders (government, academia and industry) felt that there was need for better cross-disciplinary information exchange in Western Canada. Participants stressed the need to go beyond listing facts and figures and communicate more effectively with the public in order to build trust and provide meaningful information on the science we know, as well as the knowledge gaps currently being investigated. Participants felt there is a need to build a communication and outreach strategy into future programs/projects, and that the value of this activity must be recognised by funding agencies. Communication must be done in plain language and be (and be seen) as non-biased, non-politically-influenced to ensure the best possible policies and decision making. Lastly, participants voiced a need for readily available scientific information via websites and social media. Information must be created for public consumption and kept up to date and relevant to promote open dialogue.

An example of successful community engagement was given whereby a company created a community advisory board with people from within a local community, with members representing all aspects and walks of life. The company invested time and money to educate the board on issues around resource extraction and environmental protection. The board heard regularly from the company on operations and when there was a mishap, the board was given access to all records on the incident. The board was then empowered to decide if appropriate measures had been taken. The community felt empowered by this model and it is one that could be used elsewhere.

Not surprising, in Western Canada where shale development is a reality, the priority research topics are centred on improved resource characterization through new or refined tools and techniques. Increased understanding of all aspects of the reservoir and the rocks within it, as well as rock mechanical properties, would improve resource extraction. Better geological models and large-scale aquifer mapping are major areas of need. Work must also be done to understand groundwater behavior and improving well monitoring under fracking conditions to ensure responsible resource development while aiming for maximum recovery. Lastly more work must be done in Western Canada on subsurface stress regimes and the potential for fault reactivation under fracking or underground waste water disposal conditions.

As seen in Annex **3**, other research priorities were brought forward, many of which were common themes that emerged in the other regional workshops. These cover potential impacts on water, soil and air (including fugitive emissions, seismic events, long-term well integrity). There is a need to better understand tight oil and shale rock formation properties (including understanding rock heterogeneity, geomechanics, porosity, permeability etc.), as well to trace and characterize the different gas sources within basins. Researchers agree that modelling from nano-scale observations to reservoir-scale reality poses great challenges and that better models and tools specifically designed for shale and tight reservoirs are necessary. Collectively, industry would like to see more studies of enhanced oil recovery and of secondary and tertiary recovery techniques.

In Western Canada, participants showed a strong will from all stakeholders to work collaboratively towards future R&D goals. Existing umbrella organizations, like the Canadian Society for Unconventional Resources (CSUR) and the Petroleum Services Association of Canada (PSAC), can be invaluable for connecting collaborators. Lastly, participants felt that the time is right for the establishment of a national pilot test site where all researchers could have access to. This would be an excellent opportunity to test technologies and establish standardized best practices to support regulators.

Participants all agreed that the timing is excellent to establish a collaborative network to tackle issues around shale oil and gas resources while leveraging funding, expertise and data. A number of issues are common through the country and are at the forefront of the public's mind.

Annex 3

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
WESTERN REGIONAL STRATEGIC WORKSHOP
CALGARY, ALBERTA – MARCH 3, 2015
BLUE ROOM, DINING CENTRE, UNIVERSITY OF CALGARY

The Western Regional Strategic Workshop led a focused discussion on R&D needs related to:

5) better resource assessment and reservoir characterization;
6) geo-engineering and best-practices;
7) understanding and tools/methods to minimize environmental impacts; and
8) pooling of existing and future proprietary geoscience information for added value to the entire sector and the public.

They also addressed innovation from social science and humanities research to:

3) better understand how scientific information is transferred to and used by communities, and
4) increase the uptake of this science by citizens.

Participants helped identify other key regional and national knowledge gaps, as well as providing regulatory, industrial and academic perspectives.

Invited presentations

Tom Murphy—Marcellus Center for Outreach and Research (Penn State University)
Shale Energy Development: *Finding the Gaps, Conveying the Science*

Bob Willard—Alberta Energy Regulator
AER: A Regulator's Perspective

Paul MacKay—Shale Petroleum
Challenges in Shale Gas: *An Industry perspective*

Chris Clarkson—University of Calgary & Tight Oil Consortium
Challenges in Unconventional Reservoir and Hydraulic Fracture Characterization

David Eaton—University of Calgary
Microseismic Monitoring & Fluid-Injection Induced Seismicity

RESEARCH AND KNOWLEDGE GAPS

Resource Characterization and Resource Assessment

Reservoir Characterization (geology)

- Rock characterization (true porosity, effective permeability, nano-textures, rock heterogeneity, multiphase flow, the effects of scale—lab vs. reservoir
- Improved understanding of reservoir geology (shallow, intermediate and deep zones with respect to stratigraphy, structure, fracture regimes, better understanding of all aspects of black shales, etc.)
- Improved understanding of geochemistry (need for isotope database, organic systems, biogenic vs. thermogenic sources, mud gas logging parameters, baseline values, etc.)
- Water issues (fluid injection and recovery on reservoir stress regime, where does the water go in the reservoir, how does it interact with the formation and what are the resulting geochemical reactions occurring within the formation? what is the overall influence on resource extraction vs. other water use sources like agriculture?)
- Water disposal (where does waste water go? How does it move and does it interact with potable aquifers?)

Reservoir Characterization (oil & gas)

- Geo-mechanics of shale (beyond porosity & permeability, elastic properties, pore pressure requirements, fracture propagation, etc.)
- Improved production modeling (simulation, parameter matching, history matching)
- Improved access to and quality of publically-available, existing information (fracking databases, seismic lines, well logs, etc.)
- Play-based plan needs integration of surface and subsurface data to develop resources and determine how much resource is in the reservoir and what infrastructure is needed to develop the play—how to deal with heterogeneity on a reservoir scale?
- Need better basin models and simulations for better reservoir characterization to maximize productivity and extraction
- Need for well-established definitions of local / regional baseline conditions ahead of development and extraction (for monitoring and regulations)
- Need better understanding of the outliers in the data and their implications in the bigger picture rather than dismissing the 5% that doesn't fit

Resource Assessment

- Scaling factors: how to extrapolate back and forth from nano-scale to rock-scale to reservoir-scale; similarly going from a basin model or simulation to real world well sites
- Conventional logging tools not always appropriate for unconventional wells; need to develop specialized logs / tools
- Lack of understanding of data collected, how to interpret data, lack of standardized collection procedures

Geo-Engineering & Extraction

General

- Understanding the physical properties of the shale crucial to designing optimal extraction techniques
- What degree of scale best characterizes a reservoir that is variable and covers a large area
- Need for a research testing well that could benefit all stakeholders with long-term investigations and monitoring

Reservoir fracturing techniques

- Hydraulic fracturing – determine best approach in each play, examples of different treatments being used and evaluation of each (what fluid, additives etc., what pressure, rate, spacing etc.)-a lot of this exists for purchase already—needs to be fine tuned
- Research needs around concerns in groundwater contamination and how hydraulic fracturing can affect the overburden zone within which potable water occurs
- Evaluation of techniques vs cost effectiveness vs. recovery
- Completion technologies between and in different play types

Extraction Technologies

- Frack fluids – move away from water to other types of (greener) fluids
- Enhanced oil recovery – link between fracking rates and recovery optimization (e.g. well spacing)
- Better understanding of the geochemistry of systems and the interactions within the formations, with respect to mud logging, etc.
- Understanding recoverability and quantifying it, improving rates of extraction
- Evaluation of techniques vs cost effectiveness, Enhanced Oil Recovery opportunities, secondary and tertiary recovery techniques – re-fracking of old wells
- Economics – point of abandonment

Well Integrity

- Monitoring of annular regions of wellbores, cement & casing integrity (ultrasonic, non-invasive techniques rather than sensors)
- Understanding how to re-enter old wells and mitigate risk of loss of integrity
- Wellbore design and migration - well string arrays and well penetration
- Better understanding of the shallow geology to understand natural process that are drawing down water (e.g. agricultural use, potable water)…need for baseline data
- Need more studies on historical data sets as part of the establishment of baseline picture, could be helpful to improve the access to these types of data sets; has big implications for understanding and estimating risk.
- Specialized logs / core – shale, oil gas due to a lack logs, lack of access
- Data interpretation, scale, standardization of collection procedures

Environment

General

- CCA report: water, GHG, seismicity

- Lack of baseline & cumulative effects – important issue – air, ecosystem, groundwater, surface water, land, seismic –important for regulators, need to understand uncertainty
- Intermediate zone—potential leakage zones that need to be characterized
- Need to know what health metrics are going to be in order to inform baseline evaluation / government role
- Management of cumulative sub-surface effects
- Information transparency critical – info currently very siloed – government & industry / need increased collaboration
- Toxicity of fracking additives, breakdown of additives, etc.

Water

- CCA report: water (water availability, groundwater, wastewater, re-injection of water, wastewater remediation and/or disposal, interaction with subsurface formation waters and brines, etc.)
- Lack of baseline & cumulative effects – important issue – air, ecosystem, groundwater, surface water, land, seismic –important for regulators, need to understand uncertainty
- Wastewater – need for closed system – holistic balance of reuse, contamination, disposal, migration
- What exactly is toxicity with respect to all aspects of extraction, fracking chemicals
- Modeling on what happens to the injected water, potential for migration
- Wellbore integrity, new and older wellbores

Seismicity

- CCA report: seismicity / unintentional induced seismicity risks
- Research on fracture treatment strategy and effect on slip
- Can I induce a major seismic event when there is no existing fault?
- Lack of baseline & cumulative effects – important issue – air, ecosystem, groundwater, surface water, land, seismic –important for regulators, need to understand uncertainty
- Fracture propagation, especially between zones even though containment seems to be generally good
- Pressure wave propagation as a result of wastewater re-injection
- Reduction of efforts and development costs by monitoring production area through a seismic network managed by a government body

Green House Gases

- CCA report: GHG
- Lack of baseline & cumulative effects – important issue – air, ecosystem, groundwater, surface water, land, seismic –important for regulators, need to understand uncertainty
- GHG emissions (fugitive, vented, other industry sources, etc.) – very poor data available – life cycle assessment
- CO2 storage (and long-term capping)
- Need for monitoring of air, water, residential water wells with respect to gas fluxes

RESEARCH AND INNOVATION BARRIERS AND OPPORTUNITIES

Barriers to Innovation

General barriers

- Balance research (money coming from industry) and communication with government
- Who's doing what? – nice to know what entities (public & private) do – avoiding duplication – industry may help solving problem – NRCan and others
- Public perception and political drive – focus on evidence base
- CCA report exposes issues – peer reviewed science

Research-related barriers

- Quality of available data is also a barrier; different audiences need different data sets / types, big data sets hard to access and work with
- National dialogue to have governments support to research (in all jurisdictions)
- Open access publication within 12 months – new funding agencies policies – economic impacts
- Access to data – need to wait until info becomes public
- Amount of $$ for research – technology driven government-industry – links with international funding agencies
- Joint IP approach – possible (?) for shale industry when capital cost of research spread across multiple complimentary organizations - using SHRED?
- HQP – support to students
- Frack database - $40k to have access – better access for academia to it
- To have better formatted and accessible database (IHS)
- Competitiveness within industry (keeping info) – and academia
- A lot of research within service industry (copyrights, IP, trade secrets, etc.) – attracting contracts

Stakeholder-related barriers

- Time scale (looking 3-5 years horizon) – not appropriate for service companies – continuity of interest in research projects in industry – possibility to achieve research within 12-24 months
- Lack of meaningful platform for operators – tech companies to interact
- How to commercialize technologies – no incentive to innovate for the companies

Opportunities to Innovation

Opportunities within sectors

- Collaboration within academia (expertise found in other universities)
- Collaboration from industry perspective
- Cooperation between industry (infrastructure, etc.) – about technology – room for that, but not before mineral rights secured

Opportunities for outreach

- National test pilot site – demonstration site (University of West Virginia Morgantown) – why not collaborating – UoC doing one near Brooks, AB
- Gathering baseline info from jurisdictions where industry is ongoing

- Find new pathways to pool money – environmental-wellbore integrity – new vehicles to fund (public scrutiny) – compared to chemicals needed for fracking
- Involvement of government-industry-ENGOs – looking for new models – public dialogue (bringing to new $$ approaches)
- Use Canadian expertise and experience to collaborate with other countries
- Leverage – public entities + education organizations – NSERC – doubling $$
- If Canada breaks its silos, better place of expertise – attract capital markets
- CSUR – PSAC could play important role
- Federal-provincial job grants – try to link training money to current shale needs
- Legal, medical communities, trade – rally them as advocate to the science, not the industry

Science Communication

Communicating science to other researchers

- Learn from colleagues from other disciplines
- Better access to French and English for scientific documentation (and vice versa) - communication

Communicating science to broader audiences / public outreach

- Target should be average citizens who have questions
- NRCan + agencies to have well recognized experts (chief scientists) – to build rapport with media and public
- Update websites – info to be accessible to public
- Learn from colleagues from other disciplines
- Understand social media
- To make our message across – help from social sciences to frame discussions (positive energy UoOttawa & Waterloo)
- Fight against misleading info – education of kids (fact-based science)
- Community advisory panel – first line of info and questions – positive message from stakeholders – train people to understand issues
- Target First Nations – take into account their heritage – living far away – change level of communication (lower grade level)

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
PACIFIC REGIONAL STRATEGIC WORKSHOP
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, BRITISH COLUMBIA – MARCH 4, 2015

The workshop consisted of two parts: a series of invited talks on the regional context, followed by group discussions. In total, four invited speakers from industry, academia and government presented a wide range of regional research and knowledge gap issues.

Invited talk summaries:

The Vancouver workshop invited participation from various stakeholders from British Columbia and the Yukon, who outlined the current regulatory and provincial government involvement in the shale oil and gas resource sector, as well as highlighting the academic research and initiatives currently underway in British Columbia.

British Columbia is currently Canada's largest producer of gas from shale and tight reservoirs. Presently 75% of all gas production from northeast British Columbia comes from shale or siltstone formations (e.g. Horn River, Cordova, Liard and Montney) whereas there is currently no shale resource extraction occurring in the Yukon, but large reserves are expected to be present in the Liard Basin, in southeastern Yukon.

Fil Ferri (BC Ministry of Natural Gas Development) and Ron Stefik (BC Oil and Gas Commission) explained the current government and regulatory responsibilities in British Columbia. Geoscience activities are under the jurisdiction of a series of provincial ministries (Ministry of Energy and Mines, Ministry of Natural Gas Development, Ministry of Environment, Ministry of Forests, Lands, Natural Resource Operations); while industry activity is managed by an independent agency, the British Columbia Oil and Gas Commission. British Columbia is one of the jurisdictions leading the way nationally with the establishment of specific regulations for shale gas resource extraction. In BC, in addition to submission of full well histories, proponents must also submit data on production, injection, disposal, flaring, water use, chemical additive disclosure and fracking data summaries to the regulator. This information, in turn, is then publically available through the BCOGC web portal. British Columbia is also very advanced in terms of setting up collaborative partnerships, as explained by Anton Kuipers (UBC). Erik Eberhardt discussed how UBC is leading the way to train HQP and how knowledge gaps could be addressed by academia.

Group discussions on future research avenues, barriers to innovation and opportunities:

In Pacific Canada (BC), shale oil and gas data are available through the BCOGC web portal; however, there are still many problems related to their accessibility. Data are not always in consistent formats and researchers have problems working with enormous datasets. Participants felt that industry lacks the time and the manpower to address large datasets properly and academia/government lacks the infrastructure to do the same. Collaborations are not sufficiently in place, but participants believe they could/would benefit all parties. Participants also expressed the need for partnerships with the federal

government to tackle large-scale, regional hydrogeology studies and aquifer mapping. Furthermore, all research frameworks must respect the rights of the local First Nations.

Regional discussions showed commonality with their colleagues across Canada with regard to the dependency of research on insufficient and short-term funding, the lack of access to industry data, and a shrinking and aging research community.

Participants mentioned the need to go beyond listing facts and figures in order to communicate more effectively and efficiently with the public (diverse socio-economic, multicultural audiences, including First Nations) to build trust and provide information on the science we know, as well as the knowledge gaps currently being looked into. There is a need to build a communication and outreach strategy into future programs/projects, and the value of this activity must be recognised by funding agencies. Communication must be done in plain language and be (and be seen to be) as non-biased, non-politically-influenced to ensure the best possible policies and sound decision making.

The priority research areas in Pacific Canada are centered on the need for more baseline studies in British Columbia and the Yukon. As shale development is moving full steam ahead, participants felt that such studies need to be undertaken immediately to ensure meaningful environmental monitoring and remediation. BC also faces unique problems of wastewater and solid waste disposal. In order to reduce water use and disposal, many companies in northeastern BC are currently sharing recycled water but problem remains of what to do with the industrial waste when it can no longer be recycled. Similar discussions were heard during the November 2014 BC roundtable on natural gas (Kuipers). The Vancouver workshop highlighted the need for more targeted research North of 60^{o} to understand the effects of shale development on permafrost and what specific regional safeguards are needed ahead of development.

As seen in Annex **4**, other research priorities were brought forward, common to themes that emerged in the other workshops. These cover potential impacts on water, soil and air (including fugitive emissions, seismic events, long-term well integrity). The need exists for better understanding of tight oil and shale rock formation properties (including understanding rock heterogeneity, geomechanics, porosity, permeability etc.), as well as a need to trace and characterize the different gas sources within basins. Researchers agree that modelling from nano-scale observations to reservoir-scale reality posed great challenges and that better models and tools specifically designed for shale and tight reservoirs are necessary. Collectively, industry would like to see more studies of enhanced oil recovery and of secondary and tertiary recovery techniques.

In Pacific Canada, participants felt that British Columbia has already established a strong regulatory framework and there is much in their experience that can be shared with other provinces and jurisdictions. The strong links to the mining industry, as well as the existence of Centres of Excellence in BC universities (e.g. Pipeline Institute), offer a unique opportunity for all stakeholders to partner and work on complimentary issues, as well as to enter into data sharing agreements. Finally, UBC has already begun the roadmapping process with a workshop held in November 2014.

Participants all agreed that the timing is excellent to establish a collaborative network to tackle issues around shale oil and gas resources while leveraging funding, expertise and data. A number of issues are common through the country and are at the forefront of the public's mind.

Annex 4

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
PACIFIC REGIONAL STRATEGIC WORKSHOP
VANCOUVER, BRITISH COLUMBIA – MARCH 4, 2015
SAGE EAST ROOM, PETER WALL INSTITUTE FOR ADVANCED STUDIES, UBC

The Pacific Regional Strategic Workshop led a focused discussion on R&D needs related to:

1) better resource assessment and reservoir characterization;
2) geo-engineering and best-practices;
3) understanding and tools/methods to minimize environmental impacts; and
4) pooling of existing and future proprietary geoscience information for added value to the entire sector and the public.

They also addressed innovation from social science and humanities research to:

1) better understand how scientific information is transferred to and used by communities, and
2) increase the uptake of this science by citizens.

Participants helped identify other key regional and national knowledge gaps, as well as providing regulatory, industrial and academic perspectives.

Invited presentations

Fil Ferri – Ministry of Natural Gas Development

Ron Stefik - BC Oil & Gas Commission

Connecting industry, regulator and researchers to natural gas resource extraction research opportunities
Anton Kuipers - University of British Columbia

A UBC Research Perspective: "Well Pad of Tomorrow" Hydraulic Fracture In-Situ Laboratory
Erik Eberhardt – University of British Columbia

RESEARCH AND KNOWLEDGE GAPS

Resource Characterization and Resource Assessment

Reservoir Characterization (geology)

- Enhance understanding of heterogeneity of rocks, permeability, natural fracture systems – scale issues (samples compared to rock mass – measurements from samples to apply to reservoir performance) - calibration
- Geo-mechanics of faulting and fracturing
- Water and hydrogeology

- Sources of water – water disposal (geo-engineering + environment) – disposal sites (lack of in NE BC) – water life cycle (source, aquifer, use, disposal, contamination, etc.) – north of 60 (take into account permafrost)

Reservoir Characterization (oil & gas)

- Mitigation of induced seismicity - hydraulic fracture parameters, fault identification/stand-off distance
- Development of sophisticated simulation models – doing fundamental research from both simple and complicated models – modelling important – comparison between software, based on data recorded via instrumentation (induced fracturation)
- Gas definition and migration within reservoirs
- Still using conventional approach – develop unconventional ones for resource assessment
- Links between porosity, permeability, seismicity – modelling

Resource Assessment

- General resource assessment
- Natural gas characterization – isotopic analysis
- Regional understanding of the resource
- Still using conventional approach – develop unconventional ones for resource assessment

Geo-Engineering & Extraction

Technologies

- Maximize gas recovery - wellbore spacing, fracking spacing, stimulation – best practices - instrumentation
- Enhanced resource recovery – knowing gas composition – how to retrieve liquid state in reservoir
- Onsite flow back water treatment (membrane) – discharge – economics of treatment compared to disposal
- Use of non-potable water – water reuse
- Play-specific trial and error approach – difficult to pinpoint specific parameters affecting extraction

Fracturing techniques

- Hydraulic fracturing – bringing it more effective
- Frac fluid flow back water chemistry - management
- Refrac – second generation of fracturing - soaking
- Link between microseismicity and fracking (fracture growing) – modelling towards increasing recovery (time variability of properties – behaviour change)
- Chemicals used in fracking (info already known in BC)

Well Integrity

- Well bore integrity – research into the short and long terms fate of casing and cement – connections within wells

Environment

General

- More focus on the downstream sites, not just the upstream sites
- Baseline data (seismic, water, air, etc.)
- Reclamation – saving money for reclamation process
- Legacy wells (liability to whom? – protocols-regulation) – difficult to locate older wells (subsurface wells)
- Complete life cycle (GHG) – form production
- Economics of these environmental issues (How big? How to remediate? How much??)
- Cumulative effects (study issues together) of different issues
- Try to be more efficient – better understanding of what we do
- Big-global picture of the social license

Water

- Baseline groundwater mapping and monitoring - facilitate aquifer protection – water contamination-quality – supply—dynamic between the groundwater and the surface water (to avoid chronic water shortages)—
- Better understanding groundwater zones and fractures connecting them
- Baseline data (seismic, water, air, etc.)

Seismicity

- Induced seismicity

Green House Gases

- Gas leakage (temporal patterns to GHG emissions)
- Baseline data (seismic, water, air, etc.)

RESEARCH AND INNOVATION BARRIERS AND OPPORTUNITIES

Barriers to Innovation

General barriers

- Lack of awareness / access to data (byzantine?)
- Leadership from industry and regulator needed – bring all partners together
- Research funding – paperwork – time to develop proposals – flexibility and stability of funding
- Public perception, education/training a growing workforce
- Industry has a lot of data (what is available ?) but no time – Academia needs data
- Catch 22 – need industry to collect-provide data – how to satisfy environmental requirements

Research-related barriers

- Lack of seismic, well, water, thermal maturity data
- IP issues – corporation benefits – academia publishing – lawyers
- Managing data (large amount, no cohesion of approach, etc.)

- Disappearing funding from corporate head offices – no link between researchers and corporate research efforts

Sector-specific barriers

- Lack of seismic, well, water, thermal maturity data (Academia)
- Skepticism from population about research funded by industry (better? Being stewarded by Govt)
- Research capacity in academia (to solve problems) – bring researchers as industry sabbatical (embedded in academia) – interaction with students (opportunity)
- Access to good students (work at PhD level) – difficult to attract and retain bright minds – public perception around work in some of these fields
- Fugitive emissions – too much overlapping research (duplication) – more communication – need coordination - who does what?

Opportunities for innovation

Opportunities within and between sectors

- Formal collaboration agreements
- Enhance collaborations between regulator, industry and university
- Enhanced data sharing
- Well integrity center of excellence, Pipeline Institute, BC research test site, Geohydrology Network of Excellence
- Water sharing
- Interchange regulator-industry-academia program(s) – BC Government program exists for secondment
- Service sector – key to move forward technologies
- Link with nanotechnologies – as we're dealing with nanostructures-network (imaging, etc.)
- Build diverse teams – cross-fertilization
- Lot of opportunities for funding (Genome BC, NSERC, MITACS, etc.)
- Engaging engineering students in conference=association (social development) or address industry on these issues
- Bring stakeholders to help mobilizing efforts and resources: tax regime – hiring professionals-organizations for fund raising – aiming raised funds to appropriate fields

Opportunities for outreach

- Web service/portal showing links to all pertinent data sets (geoscience groups)
- SCEK (Science and Community Environment Knowledge) Fund
- Public perception, education/training a growing workforce
- Necessity to link with social sciences and humanities – to articulate issues
- Engage stakeholders groups in research

Science Communication

Communicating science within the research community

- Experts (trusted leads) to disseminate scientific facts
- Messaging science is important (shorter version)

- Disseminate outputs in formats understandable by diverse audiences

Communicating science to broader audiences / public outreach

- Experts (trusted leads) to disseminate scientific facts
- Messaging science is important (shorter version)
- Define social license
- Disseminate outputs in formats understandable by diverse audiences
- Educate public to digest information – energy literacy
- Use social media – information coming from one side
- Increase public outreach
- Looking at other jurisdictions - better wealth distribution - solve First Nations' situation - cultural culture

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
CENTRAL REGIONAL STRATEGIC WORKSHOP
UNIVERSITY OF MANITOBA
WINNIPEG, MANITOBA – MARCH 5, 2015

The workshop consisted of two parts: a series of invited talks on the regional context, followed by group discussions. In total, four invited speakers from industry, academia and government presented a wide range of regional research and knowledge gap issues.

Invited talk summaries:

The Winnipeg workshop invited participation from various Ontario and Manitoba stakeholders who outlined the respective current provincial regulatory structure, provincial government involvement in the shale oil and gas resource sector, academic research and initiatives currently underway in Central Canada, the industry perspective and lastly, a post-mortem perspective on the Wheeler Report in Nova Scotia.

Currently in Central Canada there is a small, limited oil and gas industry located in southern Ontario, producing from Ordovician formations and oil production in Manitoba, from Devonian to Jurassic-aged formations. The advent of shale gas has brought interest in the Cretaceous formations in the Manitoba portion of the Williston Basin. One of the most significant challenges Central Canada's hydrocarbon industry faces is the lack of infrastructure to transport resources to market.

In Central Canada, there is concern about potential environmental impacts from shale gas development, particularly with regard to water resources. Pamela Fulton-Regula (Manitoba Mineral Resources Department) explained that the Manitoba government faces challenges in regulating the emerging shale gas industry due to an overall lack of: staff, research funds and availability of environmental monitoring. She also highlighted concerns regarding groundwater contamination. Provincial aquifers are mainly in the upper 100 m, oil producing formations are much deeper (430-1050 m), but naturally occurring biogenic gas can be present in shallow Cretaceous formations, some of them in proximity of water aquifers. In order to address public concerns, Maurice Dusseault (University of Waterloo) suggested that facts be explained and balanced with better industry standards and regulations, particularly in the areas of hydraulic fracturing, water protection and waste disposal. Furthermore, it was mentioned that shale oil and gas extraction typically has a smaller surface footprint (though the local development can be much more intense); and methane is a cleaner resource than coal which releases CO_2, particulates, mercury and other heavy metals into the atmosphere when burned. Erik Nickel (Petroleum Technology Research Centre) spoke on tight oil extraction and the challenges of extracting it from fractures rather than using conventional porosity. In the former case, recovery is dependent on fluid migration pathways along fractures, and modelling how fluids move or where they are coming from is not yet entirely understood. Industry still faces many R&D challenges to improve understanding of what is happening beneath the ground. Grant Wach (Dalhousie University) explained how the Wheeler independent review panel, in Nova Scotia, was faced with understanding many of these challenges, particularly with respect to hydraulic fracturing impacts on groundwater, surface water, land impacts, waste management and site restoration. The report also assessed the potential economic impacts of shale development against the potential negative impacts on health (air & water quality), the socio-economic and ecological impacts and the potential impacts on water availability in the province.

Ultimately, it was deemed that the public concerns could not be dispelled based on available information and a moratorium on hydraulic fracturing was enacted. Other provincial jurisdictions can learn from the Wheeler Report experience.

Group discussions on future research avenues, barriers to innovation and opportunities:

In Central Canada, the lack of energy infrastructure (i.e. pipelines), technologies and expertise seem to be limiting shale oil and gas development. Participants also felt that the local regulatory framework is not ready for the industry expansion in these jurisdictions.

Local discussions showed commonality with their colleagues across Canada with regard to dependency on insufficient and short-term research funding, the lack of access to industry data, as well as a shrinking and aging research workforce.

Participants emphasized the need to go beyond listing facts and figures and communicate more effectively and efficiently with the public to build trust and provide information on the science we know, as well as the knowledge gaps currently being looked into, to overcome the existing wealth of misinformation. There is a need to incorporate a communication and outreach strategy into future programs/projects, where funding sources should be clearly identified to improve public trust. Communication (through champions or the scientific community at large) must be done in plain language and be (and be seen) as non-biased, non-politically-influenced to ensure the best possible policies and decision making.

The priority research areas in Central Canada are centered on the need for large-scale regional mapping and comprehensive resource assessments. Such federal-provincial programs would be beneficial ahead of resource development. Development of better tools is needed to characterize and assess shale oil and gas reservoirs. As in many parts of Central Canada freshwater resources are limited, more research should be done on using brines from depth for resource extraction, followed by reinjection of wastewater back into the deep aquifers. Finally, participants expressed concerns about particulate matter emissions, particularly in newly industrialized areas, and wellbore integrity.

As seen in Annex **5**, other research priorities were brought forward, common to themes that emerged in the other workshops. These cover potential impacts on water, soil and air (including fugitive emissions, seismic events, long-term well integrity). The need exists for better understanding of tight oil and shale rock formation properties (including understanding rock heterogeneity, geomechanics, porosity, permeability etc.), as well as a need to trace and characterize the different gas sources within basins. Researchers agree that modelling from nano-scale observations to reservoir-scale reality posed great challenges and that better models and tools specifically designed for shale and tight reservoirs are necessary. Collectively, industry would like to see more studies of enhanced oil recovery and of secondary and tertiary recovery techniques.

In Central Canada participants felt that there were great opportunities for stakeholders to create multidisciplinary teams with representatives from science and engineering, social sciences, health professions etc. who are willing to tackle complex scientific and societal issues. There is also a need to create dialogue between regulators and the research community to have the soundest data and information fed into the regional regulatory process. A single data portal for work done across Canada would be an excellent tool of making research and data available to all interested parties. Lastly, the

creation of networks of centres of expertise could improve collaboration, idea exchange and advance research efforts in the region quickly.

Participants all agreed that the timing is excellent to establish a collaborative network to tackle issues around shale oil and gas resources while leveraging funding, expertise and data. A number of issues are common through the country and are at the forefront of the public's mind.

Annex 5

ENERGY GEOSCIENCE AND GEO-ENGINEERING
COLLABORATIVE OPEN INNOVATION NETWORK (EG-COIN)
CENTRAL REGIONAL STRATEGIC WORKSHOP
WINNIPEG, MANITOBA – MARCH 5, 2015
ROOM 108, ST. JOHN'S COLLEGE, UNIVERSITY OF MANITOBA

The Central Regional Strategic Workshop helped on discussing R&D needs on:

1) better resource assessment and reservoir characterization;
2) geo-engineering and best-practices;
3) understanding and tools/methods to minimize environmental impacts; and
4) pooling of existing and future proprietary geoscience information for added value to the entire sector and the public.

They also addressed innovation from social science and humanities research to:

1) better understand how scientific information is transferred to and used by communities, and
2) increase the uptake of this science by citizens.

Participants helped identify any other knowledge gaps from land use, regulatory and industry perspectives, as well as provide regional perspectives on these issues.

Invited presentations

Mechanisms for Gas Seepage Outside of Cased Wells
Maurice Dusseault—University of Waterloo

The Shale Challenge
Pamela Fulton-Regula - Government of Manitoba

The "Wheeler Report" - A Summary of the Report of the Nova Scotia Independent Review Panel on Hydraulic Fracturing
Grant Wach—Dalhousie University

Tight Oil Production: Some Industry Perspectives
Erik Nickel - Petroleum Technology Research Centre

RESEARCH AND KNOWLEDGE GAPS

Resource Characterization and Resource Assessment

- Important to realize that all issues mentioned below are interconnected

Reservoir characterization (geology)

- Mapping (aquifers, geology – including characterization of the intermediate zone)

- Geological heterogeneity
- 3D fault assessment, fracture characterization
- Anisotropic and multiple permeability – knowing time-dependent properties (clays) - multiphase fluid behaviour in low permeability formation (when using water flood method)
- Understanding scaling (from nanoporosity – macroscale – to full rock mass)
- Merge all datasets after quality of them is verified, in order to have better models

Reservoir characterization (oil/gas)

- Isotopic characterization of gas-methane (surface-intermediate-production zones)
- Organic matter characterization

Resource assessment

- Location of sweet spots (maturity, TOC)

Geo-Engineering & Extraction

Technologies

- Specifics on well geometry-spacing – lengths - number of phases-frac – distance from water reservoirs and faults (hydraulic fracking and salt water disposal operations) – modelling (using statistical components of the rock properties)
- Ad hoc empirical approach – to achieve best practices – rigorous data analysis (data 'mining') to develop best practices instead – using public datasets (hidden datasets)
- Recovery optimization
- Recovery from horizontal well (20 stages) – deterioration of wells and their frac conductivity

Fracking techniques

- Hydraulic fracturing, fracture length analysis compared to plays geometry (use of microseismicity)
- Fluid pressures and volumes in proximity to faults
- Precipitation of different solids reducing permeability – within refrac process
- Methods to reduce fresh water use (abandoned mine, liquid propane, saline-brackish aquifers (problem of salinity), municipal water, etc.) – impacts of fluids on formations + impacts on aquifers
- Mechanism for transferring gas from your production zone to water into wells
- Secondary and tertiary recovery (water flood)

Well integrity

- Well integrity (short and long term behaviour)
- Best ways to seal new wells and reseal old wells

Environment

General

- Predrilling baseline datasets and monitoring (soil, gas, water (and its levels), seismicity)
- Knowledge about cumulative impacts on environment
- Knowledge about best approaches-procedures on environmental monitoring
- Population density impacts

Water

- Groundwater cross-contamination – baseline groundwater
- Baseline gas levels in water reservoirs
- Water use, source, volume, treatment, etc.
- Disposal of waste water (salt water disposal wells – MB; disposal well (no deep anymore, but allowed) – ON)

Seismicity

- Induced seismicity (triggered by HF) – magnitude vs ground acceleration-velocity – sensitive surface infrastructures (events vs sequences) – fluid reinjection

GHG

- Gas leakage – fugitive gas – well integrity (long term – legacy wells)
- Particle matter emissions in newly industrial rural areas – cancer rates (and others)

RESEARCH AND INNOVATION BARRIERS AND OPPORTUNITIES

Barriers to Innovation

General barriers

- Lack of infrastructures (pipelines)
- Lack of human resources in government
- Misinformation disseminated
- Datasets legally public but inaccessible – data collected (proprietary or owned by broker), but not shared
- Regulatory framework from elsewhere (maybe only guidelines) – but take into account geological settings

Research-related barriers

- Lack of dialogue between disciplines – lack of true interdisciplinary studies/issues, but very challenging
- Access data (who has what, if collected – data suitable for research)
- More flexible funding processes – for multidisciplinary groups (good example – CCS)
- Access to samples, sites
- Restriction with current GSC research programs – need of more regional studies
- Expensive pieces of specialized equipment (and-or access to them) – need to operate them (fund service contracts and technicians – funding more than 5 years)
- Lacking geochemistry specialists – need to develop expertise, instrumentation and infrastructure in Canada
- Industry wants students with skills - limitations in curriculum to have courses in other disciplines
- Funding

Sector-specific barriers

- Complex environmental regulations

- Incentive to study intermediate zone
- Understand why fracking works or doesn't work
- Fear of companies on science – mistrust of public face to companies
- Regulation enforcement – expensive
- Willingness from companies to share data

Opportunities for innovation

Opportunities within and between sectors

- Use of Fracfocus database and Petrinex Information Network
- Taking an optimized multidisciplinary approach – incentive to do interdisciplinary research (if risk in proposal title, add social science)
- Link geoscientists with engineers (adding social scientists, medical people)
- Enabling dialogue between scientists and regulator
- Need for more regional studies from government agencies
- Centres of expertise – good management structure

Opportunities for outreach

- Webpage to inform the public on government best and current practices, provide links to pertinent information
- Gather, collect, share and have accessible reports and work done across Canada
- Encourage students-faculty to open their minds to alternate fields

Science Communication

Communicating science within the research community

- Include communication as a theme in your project
- Development of series of people that became good communicators (communication specialists) – use them
- Identify champions in scientific community as good communicators and award-recognize them – have access to professional communication experts
- Have a professional communication expert in any national network
- Industry has a role in communicating (Ohio model) – build on good examples
- Database of expertise in organizations linked to communication departments
- Research organization, independent from industry
- Interdisciplinary research team-panel (CCA report)

Communicating science to broader audiences / public outreach

- Let people know that series of safeguards already exist
- Educate public that we learn about risks from trial and error
- Use excerpt of appropriate documents (like "Last 1B years" and "Last 4B years") and disseminate in schools (Fed-provincial geological surveys) – education at all levels
- Link with reporters – literacy of media – try to have meaningful coverage
- Database of hazards – definition, probability, consequence, management, what we don't know, reference to literature – but 'disclaimer' issue – find someone(s) to take responsibility – take responsibility and have guts to communicate risks

- Communicate using the right media with young people – web-based, media – capture their attention
- How to combat fear-based emotions with logical science
- Engage ministries of education and professors to relate with issue
- Inform people about good cases
- Scientists constraints by facts, not the opposition
- Educate the decision-makers – adapt communications to the specific-targeted audiences
- Jurisdictions are at different maturity levels – again adapt communications
- Engage community associations (ON farmers association) – use existing channels – enlightened self-interest
- Conflicting information – challenging for people to understand
- Advocating science (not in a vacuum – political side, etc.), not the industry