



Understanding Shale Gas in Canada



INFORMATION ABOUT CANADA'S
EMERGING ENERGY RESOURCES

What is Shale Gas?

Shale gas is natural gas, no different than what you currently use to heat your home or cook with or use to generate electricity. The gas is naturally trapped within very fine grained sedimentary rocks called shale or mudstone. Millions of years ago, the mud and silt that was deposited in ancient oceans and lakes often contained plant and animal debris. Over time, these sediments containing the organic material, were compacted and solidified through burial. With increasing temperature and pressure to form shale and mudstone.



The organic material through the same pressure and temperature processes generated oil and gas which in many cases migrated into other rock types such as sandstones and limestones to form conventional oil and gas reservoirs. The natural gas that is retained within the shale is referred to as shale gas.

Shale and mud rich rocks often vary in colour as well as grain size. Colours may vary from dark brown or grey through to black shale (a), like the Utica Formation in Quebec or the shales of the Horn River Basin in British Columbia. In some basins, often the fine grained shale rocks are interbedded with coarser grained siltstones (b). Where structural processes have been at work, the shale rocks can be fractured (c) creating natural pathways for natural gas or oil to flow to the wellbore.

(a)



(b)



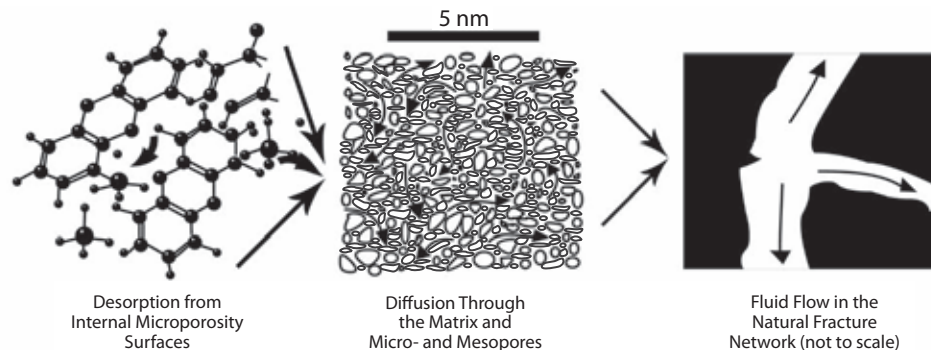
(c)

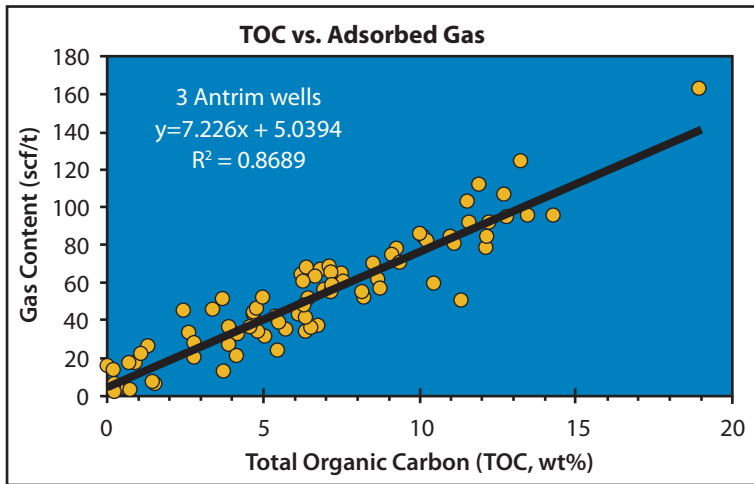


How is Natural Gas Stored in Shale?

Shale rocks contain very fine grains of minerals separated by very small spaces called “pores”. Natural gas or oil molecules that have been created from the organic material in the rock are trapped within the numerous micro-pores or are attached to the organic material by a process called adsorption. The amount of pore space within the shale usually ranges between 2-10% allowing a large volume of natural gas to be stored within the rock.

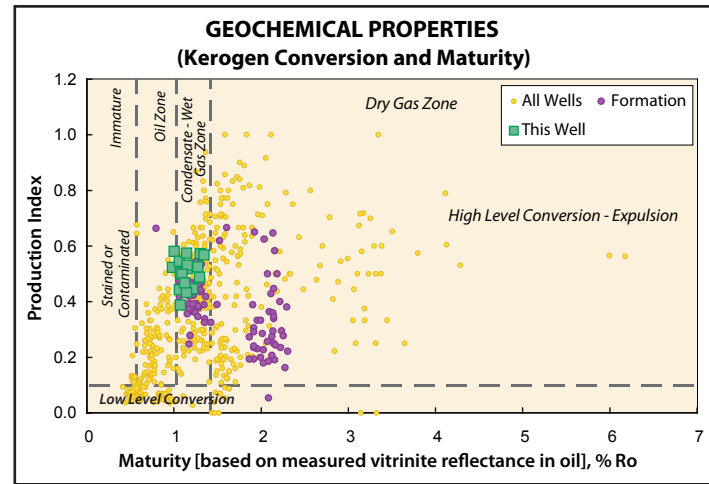
The amount of natural gas that is stored within shale is variable depending on the amount of open pore space, amount of organic material present, reservoir pressure and thermal maturity of the rock. Thermal maturity is a measure of how much pressure and temperature the rock has been subjected to. It also measures whether oil or gas has been generated during the process. Core samples are often collected to allow laboratory tests to be taken that will measure the amount of organic material present as well as the thermal maturity.





From Jarvie, 2007

Organic material is referred to as TOC or Total Organic Carbon and is measured as a percentage of the rock weight. The amount of gas that can be stored by adsorption within the rock is dependent on the amount of organic carbon present.



Thermal maturity is measured on a vitrinite reflectance scale (% R_o). Maturity of the rock is controlled by pressure and temperature burial conditions over time. Maturity of the organic kerogen in the rock will control the type of natural gas or oil that is created.

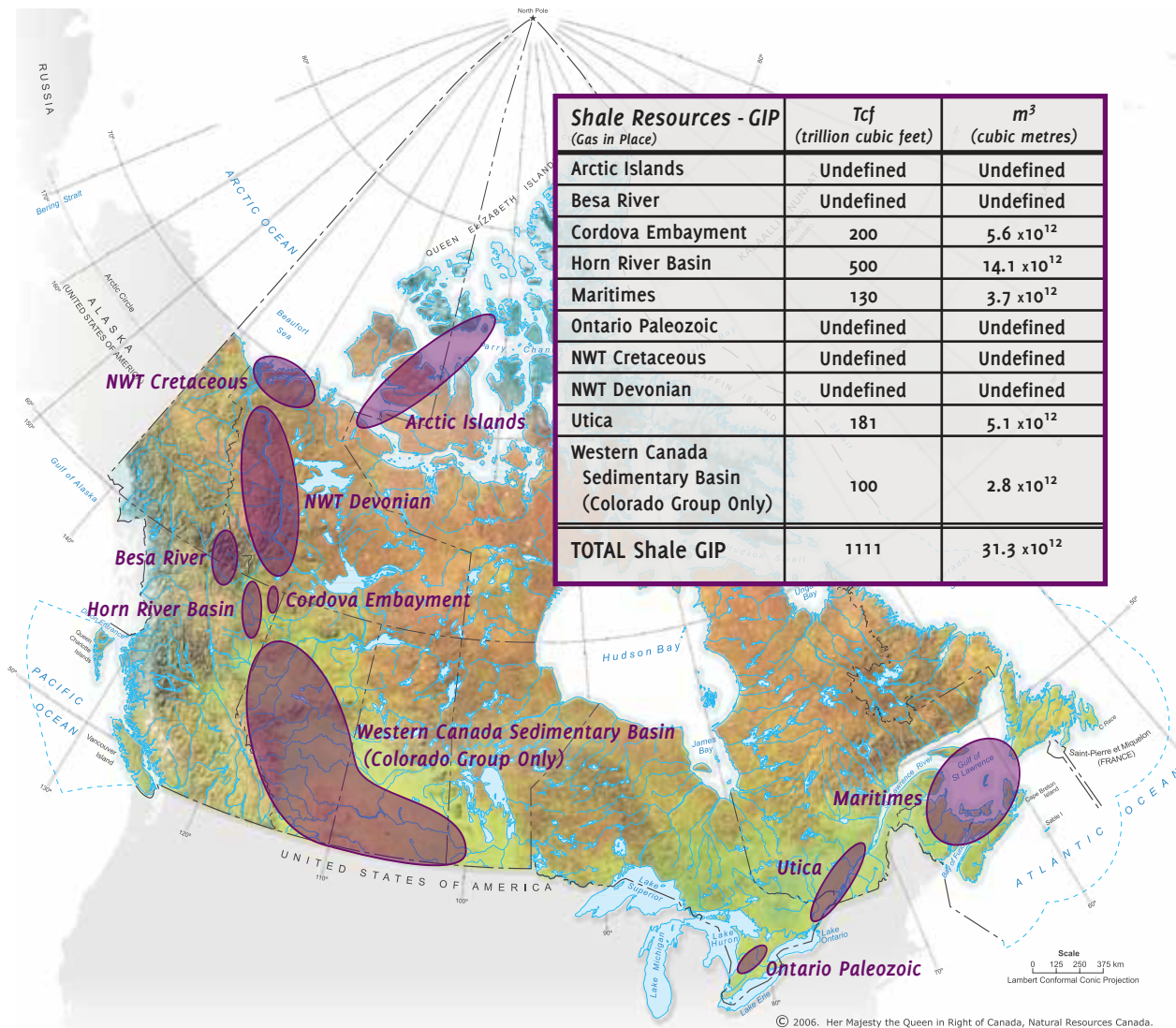
Both of these measurements can be used to help determine the amount of natural gas that is present in the rock.

Where is Shale Gas Found in Canada?

Shale rocks containing natural gas can be found in most sedimentary basins across the country. The largest concentration lies within the Western Canada Sedimentary Basin (WCSB) which extends from northeast British Columbia to southwest Manitoba. Other basins are located in the Arctic, Northwest Territories, Yukon, Quebec, southern Ontario, New Brunswick and Nova Scotia.

Shale gas resources in Canada are estimated to be greater than 1 100 Tcf (trillion cubic feet) or $31 \times 10^{12} \text{ m}^3$ (cubic meters) with the majority residing within the WCSB.

Marketable resources, as defined by CSUG, represent the amount of gas that may be recovered from production operations. These estimates account for a defined recovery factor for each basin as well as discounting for natural gas used in the production process. In addition, marketable resources also reflect regions where access to resources may be difficult due to potential stakeholder, technical, or other issues. Marketable resources for shale gas in Canada are estimated to range from 128 to 343 Tcf (3.6 to $9.7 \times 10^{12} \text{ m}^3$). To put this number in context, in 2009 Canada produced 5.26 Tcf ($149 \times 10^9 \text{ m}^3$) of natural gas. Roughly 50% of the natural gas produced in Canada is exported. The other 50% is used within the country to heat homes and businesses and by industry as a clean energy source for wellsite operations.



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Adapted with the permission of Natural Resources Canada 2010, courtesy of the Atlas of Canada.

Distribution of major shale gas basins in Canada

Stages of Shale Gas Exploration and Development

A decision to proceed with commercial development of a shale gas project is the culmination of a process requiring several years of exploration, experimentation and data collection. These stages of exploration require significant investment by the company with no assurance of success. While each company has their own processes for development, in general, shale gas development requires five stages of exploration and evaluation to reach commercial development. Each of these stages is designed to gather technical information that is then analyzed and used in the development of the next stage. A summary of these stages and the types of activities that may take place are presented in the adjacent figure.

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Stage 1: Identification of the Gas Resource

Land Acquisition and the securing of seismic and drilling location permits and land use agreements.

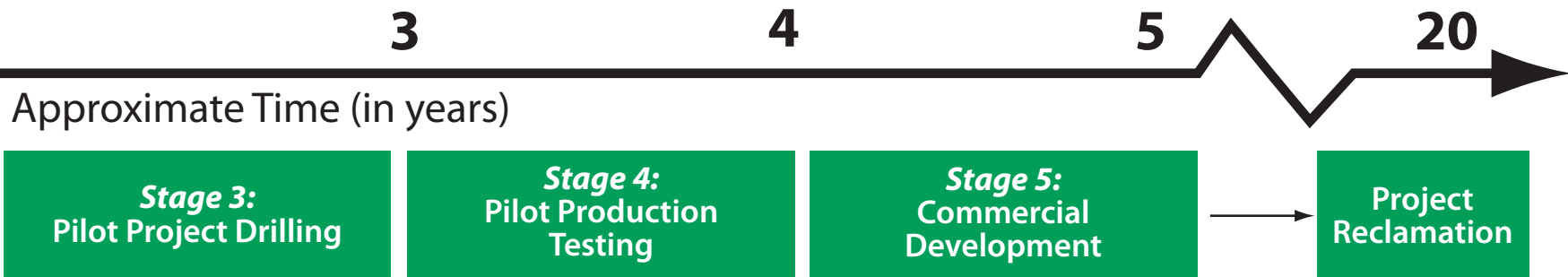
Initial geophysical and geochemical surveys in some regions.



Stage 2: Early Evaluation Drilling

Seismic surveys to map the extent of gas bearing formation(s) and geological features such as faults or discontinuities that may impact the potential reservoir.

Initial vertical drilling to evaluate shale gas resource properties - commonly core samples are collected.



Drilling of initial horizontal well(s) to determine reservoir properties and completion techniques (includes some level of multi-stage fracturing).
Continued drilling of vertical wells in additional regions of shale gas potential.
Initial production tests.

Drilling of multiple horizontal wells from a single pad as part of a full size pilot project.
Optimization of completion techniques including drilling and multi-stage fracing and microseismic surveys .
Pilot production testing.
Planning and acquisition of pipeline right of ways for field development.

Commercial decision to proceed and government approvals for construction of gas plants, pipelines and drilling.



All stages of development include stakeholder dialogue and consultation

Pace of development is largely dependent on resource complexity, technical success, local circumstances and market conditions

How Do You Get the Gas From the Shale?

Most unconventional natural gas reservoirs tend to have lower permeability and require some method of increasing the amount of reservoir in contact with the borehole. In shale gas, the two most common methods are horizontal drilling and hydraulic fracturing.

Horizontal Drilling

Horizontal drilling first entails drilling a vertical well to a predetermined depth above the shale gas reservoir. The well is then drilled at an increasing angle until it meets the reservoir interval in a horizontal plane. Once horizontal, the well is then drilled to a selected length, which could extend to as much as 2500m. This portion of the well, called the horizontal leg, allows significantly increased contact of the wellbore with the reservoir compared to a vertical well.

Upon completion of drilling, production casing is placed in the wellbore. A perforating gun is used to create a series of holes in the casing to connect the rock formation to the wellbore.

Hydraulic Fracturing

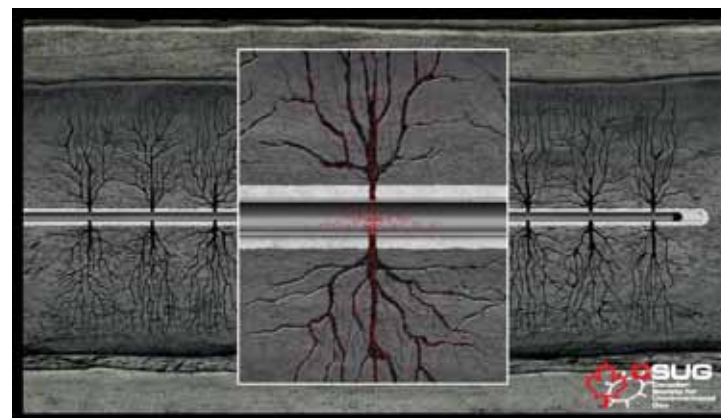
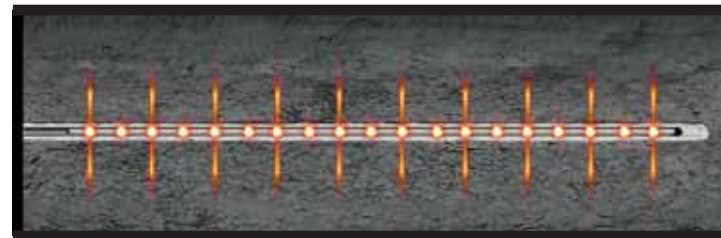
The purpose of the hydraulic fracturing or “fracing” is to either intersect and open existing natural fractures or create new fractures in the reservoir. This fracture system is necessary to create pathways by which the natural gas can flow to the wellbore.

The hydraulic fracturing process consists of pumping a fluid, either a gas or a liquid, with a suspended proppant (usually sand or ceramic beads) down the wellbore at a high rate and pressure through the perforations which causes the surrounding rock to fracture or crack. The suspended fluid/proppant mixture fills the open fractures keeping them open after the fracture pressures are removed. After the fracture stimulation is completed, the proppant stays within the fracture while the fluid is flowed back to surface.

*Right: Multi-stage horizontal well
Top far right: Perforating the well
Middle far right: Fracing the well
Bottom far right: Gas flow into the well*

Multi-Stage Fracing

In most horizontal wells that have an extended horizontal leg section, multiple fracturing operations are necessary in order to effectively stimulate the reservoir rock. This process is called “multi-stage” fracing and consists of dividing the horizontal leg into sections which are then fractured independently. During the fracing operation, each “stage” is isolated from the rest of the wellbore using various types of plugs or packers (seals). Upon completion of all fracture stages, the plugs or packers are removed and all stages of the wellbore are allowed to flow back to the surface.



Fracture Fluids and Water

Developing shale gas resources requires water for drilling and typically also requires the use of water for hydraulic fracturing before the well can produce natural gas. Water is the most common fracturing fluid, although in some shale gas reservoirs where the reservoir rock is not compatible with water, carbon dioxide, nitrogen or propane are used. Potentially tens of thousands of cubic meters of water could be required to properly frac a deep horizontal shale well. However, this operation typically takes place only once per fractured well, at the beginning of the well operation. Most wells then produce for 20 to 30 years without requiring any further fracturing and related water use.

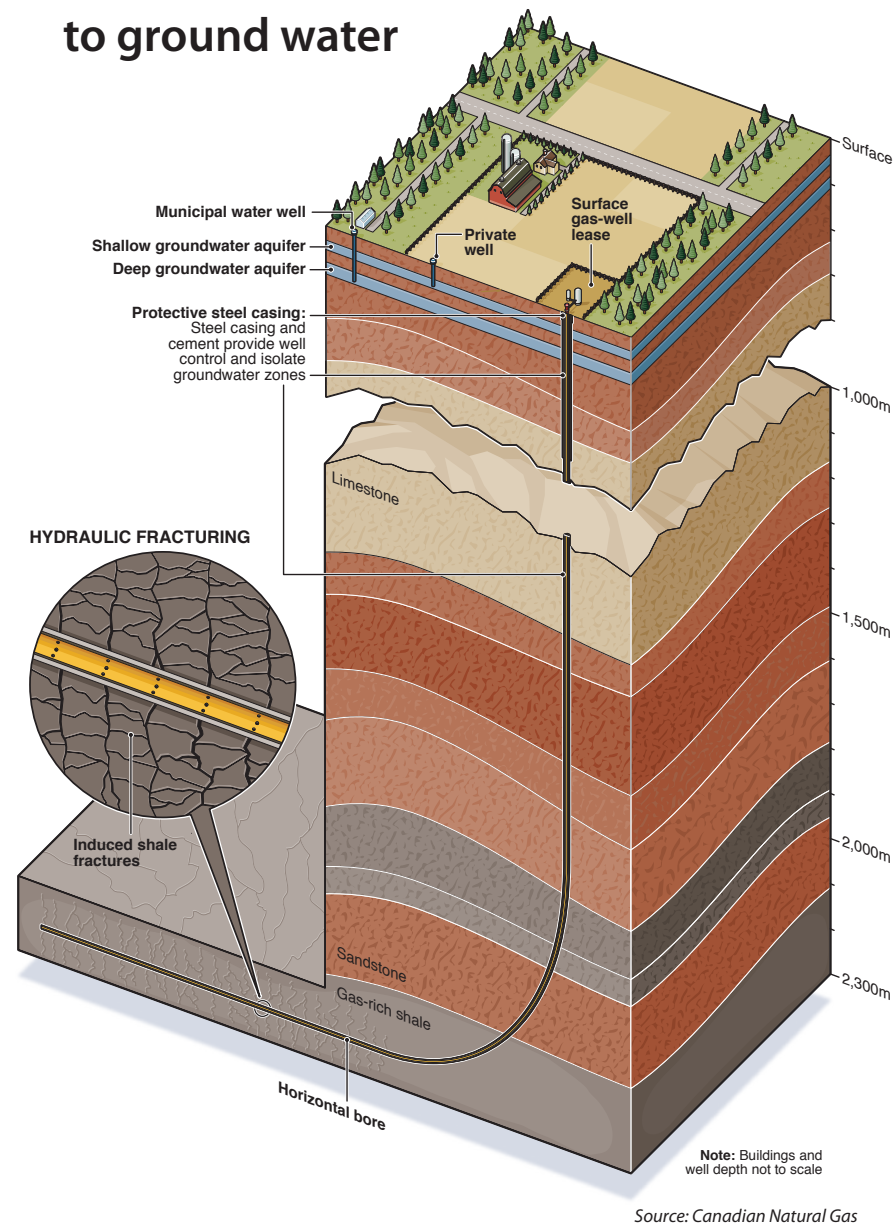
In the early stages of shale gas development, the water used is typically withdrawn from fresh water sources. Natural gas producers, however, are increasingly using methods such as water recycling techniques or fracturing with non-potable brackish water to offset increased demand for water and to reduce impacts on surface water and aquifers. Water used is usually

trucked or piped to the well site where it is stored either in large ponds or tanks.

To help the fluid carry the proppant and to ensure that the proppant is being carried as far into the fractures as possible, a number of chemicals may be added to the fluid/proppant mixture. Individual companies will have their own proprietary combination of these chemicals but the combined concentrations are usually less than 1% of total volume of the fluid proppant mixture. During the flowback stage as much as half of the fluid is recovered. The water used for oil and gas production is considered to be consumed water, since it comes into contact with hydrocarbons and other contaminants and cannot be returned to the environment without additional treatment. Increasingly companies are looking to treat the fluids used for fracturing and recycle them. If the fluid is not recycled, it is recovered and disposed of as required by provincial regulations.

Schematic of a horizontal well relative to ground water

Drinking water - referred to as potable water - is an abundant resource in Canada, but not an infinite one. Protection of drinking water is a key priority for both regulators and the natural gas industry. Canadian natural gas production takes place in a way that isolates the natural gas production zone from drinking water resources, including wells, groundwater and waterways. All drilling and well construction operations adhere to rigorous regulations to isolate and protect potable groundwater from natural gas operations through installing, and cementing in place, steel surface casing before proceeding to drill to greater depths. In some areas, mandatory pre-drill testing of local water wells provides additional assurance of drinking water protection. Pre-testing of water wells has the added benefit of discovering contamination that predates any oil and gas industry activity, which might not have been previously known to exist.



Optimizing Production of Shale Gas

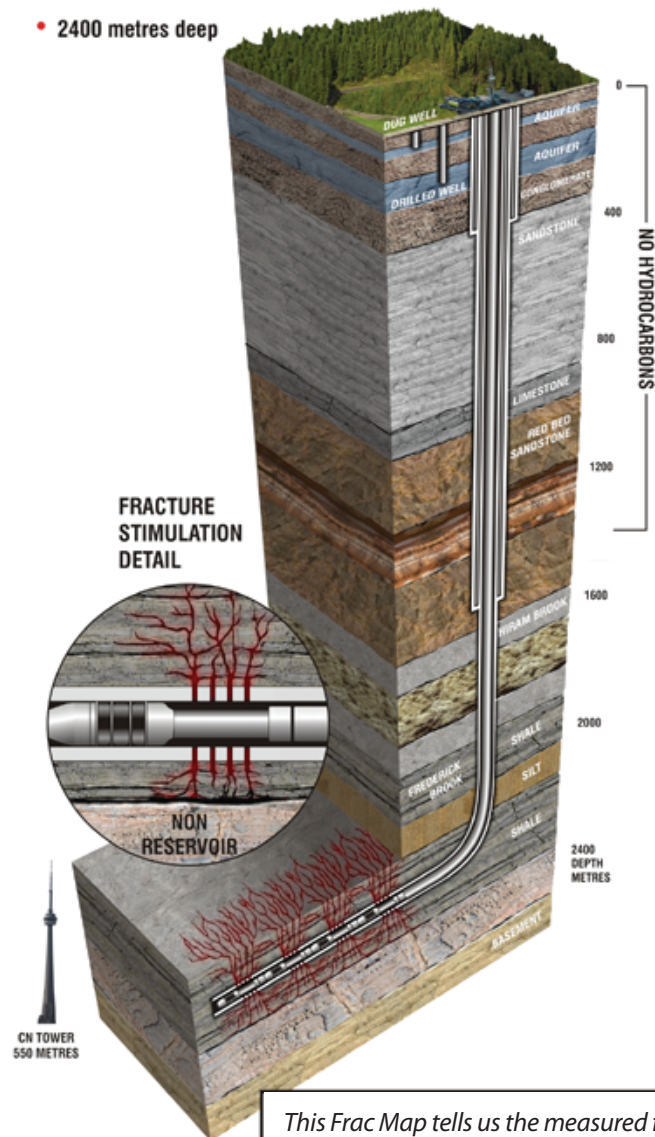
The production of shale gas relies heavily on the application of technology to effectively access the reservoirs containing natural gas. It is important for companies to have a clear understanding of how the reservoir has responded to the fracturing process as well as the ability to predict how much gas will be recovered from the fracture interval in the horizontal or vertical wellbore. This knowledge allows the natural gas field to be developed in a way that will optimize recovery of the resource.

Drilling and fracing is costly and requires large amounts of equipment and materials. The application of logistic processes that lower development costs while at the same time increasing well productivity and recoverable reserves are important for economic success. Companies often adopt a “manufacturing” style of development in order to achieve these cost savings. For shale gas development drilling multiple wells from a single pad is often used. Multi-well pads not only decrease the environmental footprint of the operations, but allow operational efficiencies to be achieved.

In addition to information about the composition and physical properties of the shale, companies often use a variety of techniques to better understand the effectiveness of the drilling and completion operations. Production logging, microseismic and frac tracers are some of the examples of the tools that are used. During the fracturing process, microseismic events are created that can be recorded from nearby monitoring wells or surface seismic recording devices. This process, called microseismic monitoring, allows the orientation, distance and complexity of the fracturing events to be observed and modeled. Importantly, the application of microseismic monitoring identifies both the lateral and vertical extent of induced fracturing. The location of the opened fractures, both vertically and horizontally allows companies to develop a plan for additional wells that will ensure that production from the reservoir effectively recovers as much natural gas as possible. Microseismic monitoring allows the volume of reservoir rock that has been stimulated to be determined and an estimate of total recoverable natural gas to be made.

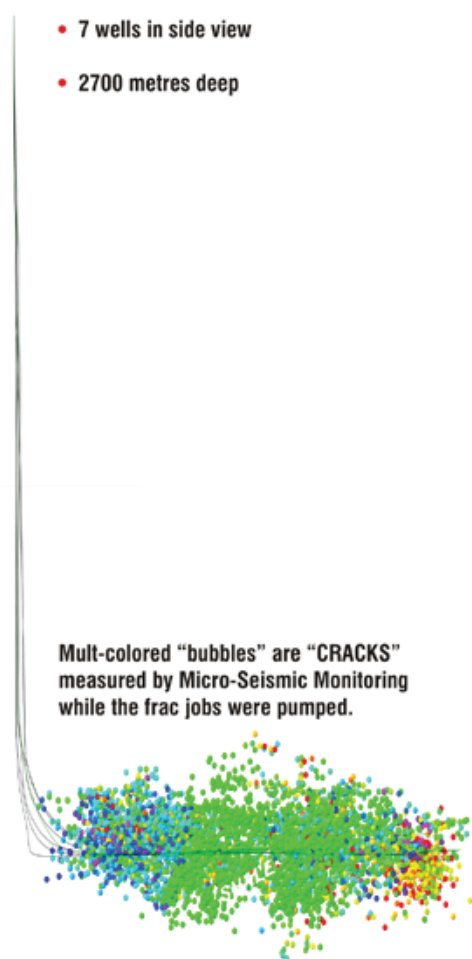
Model of a Frederick Brook Shale Gas Well

- 2400 metres deep



Real Example of Micro-Seismic Monitoring from an Apache Multi-Well Pad

- 7 wells in side view
- 2700 metres deep



This Frac Map tells us the measured frac height development is ~ 250 meters total and about 2 kilometers deeper than any groundwater aquifers.

Source: Apache Canada Ltd., copyright pending

Environmental Footprint of Shale Gas

Commercial production of shale gas requires numerous wells to intersect the gas bearing formation. The technologies of horizontal drilling and multi-stage fracture stimulation have enabled the surface footprint for shale gas wells to be minimized. Companies can still drill multiple wells from a single pad location and extract the natural gas from as much as 10 sq km. While the size of a multi-well pad is slightly bigger than a regular oil and gas lease the cumulative footprint for a shale gas field development is much smaller than it would be with conventional development using vertical wells. Fewer access roads and the concentration of facilities and pipelines within the pad footprint minimize the surface disturbance of shale gas development.

During the actual drilling and hydraulic stimulation procedures for shale gas development, there is a concentration of heavy equipment on site. The transport of materials such as frac sand and drilling supplies for the multiple wells is often handled by stockpiling at the wellsite. Water requirements for both drilling and fracturing can be large and commonly a lined reservoir pit or tanks are

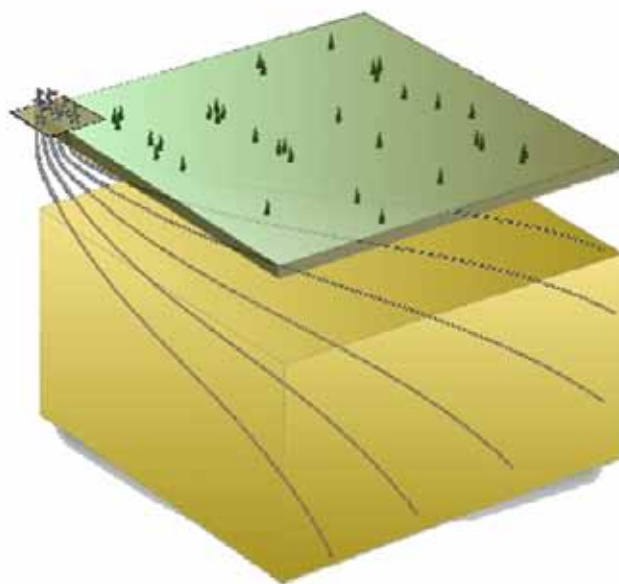
constructed for storage. In some cases, if the water sources are nearby, temporary pipelines are constructed to transport the water rather than using tanker trucks.

Upon completion of the drilling activities, all of the heavy equipment is removed and permanent surface facilities are constructed. In most cases, the final footprint of the wells and surface facilities is much smaller than the original drilling footprint.

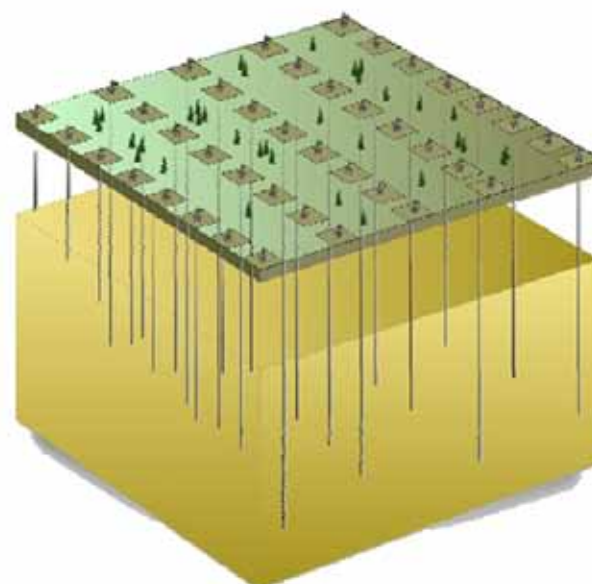


Courtesy of Apache Canada Ltd., 2010

The multi-well pad has significantly less disturbed area vs. the comparable vertical well scenario



6 Horizontal wells (8 fracs/well) = 48 total fracs per section



Same development would require 48 vertical wells each on a separate wellsite

Adapted from www.encana.com

Glossary & Terminology

Adsorption/Adsorbed: Refers to the molecular bonding of a gas to the surface of a solid. In the case of shale, natural gas is adsorbed or bonded to the organic material in the shale.

Aquifer: The sub-surface layer of rock or unconsolidated material that allows water to flow within it. Aquifers can act as sources for groundwater, both usable fresh water and unusable salty water.

Casing: Steel pipe placed in a well and cemented in place to isolate water, gas and oil from other formations and to maintain hole stability.

Disposal Well: A well which injects produced water into a regulated and approved deep underground formation for disposal.

Drilling Mud: A mixture of clay, water and other ingredients that are pumped downhole through the drill pipe and drill bit that enable the removal of the drill cuttings from the well bore and also stabilize the

penetrated rock formations before casing is installed in the borehole.

Fault: A fracture surface in rocks along which movement of rock on one side has occurred relative to rock on the other side.

Formation (geologic): A rock body distinguishable from other rock bodies and useful for mapping or description. Formations may be combined into Groups or subdivided into members.

Gas-in-Place (GIP): The hypothetical amount of gas contained in a formation or rock unit. Gas-in-Place always represents a value that is more than what is economically recoverable and refers to the total resources that are possible.

Horizontal Drilling: A drilling procedure in which the wellbore is drilled vertically to a kick-off depth above the target formation and then angled through a wide 90 degree arc such that the producing portion of the well extends horizontally through the target formation.

Hydraulic Fracturing (aka 'Fracing'): A method of improving the permeability of a reservoir by pumping fluids such as water, carbon dioxide, nitrogen or propane into the reservoir at sufficient pressure to crack or fracture the rock. The opening of natural fractures or the creating of artificial fractures to create pathways by which the natural gas can flow to the wellbore.

Microseismic: The process of using seismic recording devices to measure the location of fractures that are created during the hydraulic fracing process. Mapping of these microseismic events allows the extent of fracture development to be determined.

Permeability: A rock's capacity to transmit a fluid or gas; dependent upon the size and shape of pores and interconnecting pore throats. A rock may have significant porosity (many microscopic pores) but have low permeability if the pores are not interconnected. Permeability may also exist or be enhanced through fractures that connect the pores.

Porosity: The percentage of void space in a rock that may or may not contain oil or gas.

Produced Water: Water produced from oil and gas wells.

Propping Agents/Proppants: Silica sand or other particles pumped into a formation during a hydraulic fracturing operation to keep fractures open and retain the induced permeability.

Reserves: The estimated volume of gas economically recoverable from single or multiple reservoirs. Reserve estimates are based on strict site-specific engineering criteria.

Reservoir: A porous and possibly permeable rock formation containing oil or natural gas.

Shale Gas: Natural gas stored in low permeability shale formations.

Stimulation: Any of several processes used to enhance near reservoir permeability.

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