Shale- and Siltstone-Hosted Hydrocarbon Resources of Alberta: Methods and Assessments*

Steven Lyster¹, Dean Rokosh¹, Andrew Beaton¹, and Fran Hein²

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¹Alberta Energy Regulator / Alberta Geological Survey, Edmonton, Alberta, Canada (steven.lyster@aer.ca, dean.rokosh@aer.ca, andrew.beaton@aer.ca)
²Alberta Energy Regulator, Calgary, Alberta, Canada (fran.hein@aer.ca)

Abstract

Alberta has historically been the home to much of Canada's hydrocarbon production. New technologies are unlocking resources from shale and siltstone formations that have the potential to dramatically increase Alberta’s resource base beyond conventional pool-based reservoirs. The Energy Resource Appraisal group of the Alberta Energy Regulator has developed a methodology for quantifying the resources in shale, siltstone or tight sandstone reservoirs that are characterized by continuous hydrocarbon saturation rather than discrete pools. This methodology is data driven and incorporates the quantification of uncertainty at every step. A wide variety of data sources are used for resource quantification, including geological picks, log analysis, adsorption isotherm analysis, XRD mineralogy, organic petrography, Rock Eval, reservoir tests and Dean Stark testing. The geological variables that have sufficiently dense sampling are mapped using geostatistical simulation. Secondary variables that are correlated to the mapped variables can be determined by modelling the bivariate relationships. Other variables that are sparsely sampled or have large uncertainty are assigned values based on univariate distributions. The uncertain distributions for all variables are simulated 1,000 times and the results used to calculate potential resource endowment. The results of the 1,000 iterations represent the range of uncertainty in the resources. Recent work has produced hydrocarbon resource estimates for previously unassessed units, including the lower Doig siltstone and the middle portion of the Colorado Group. The application of porosity and net thickness cutoffs has been used to estimate technically recoverable resources in the Duvernay Formation. Other assessments are in progress to better understand the quantity of gas, NGL and oil resources in Alberta.
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Resource Evaluation of Shale and Siltstone

Calgary, AB

Introduction
The Alberta oil, gas, and liquids resource evaluation project has expanded from organic-rich shale to include tight sandstones and carbonates. Our goal is to determine the extent of each play area and estimate total recoverable resources in-place. Our method of estimating the resource envelope incorporates the concept of “competency” at every step in order to quantify the total range of petroleum resources. The method is geared towards early appraisal of unconventional resources.

We are currently focusing on oil-rich tight sandstones and carbonates, especially shale reservoirs sand, wet oil, and gas fields. Formations such as the Cretaceous sandstone-rich Cardium, Viking, and Glauconite, and the Devonian Slave Point and Swan Hills carbonates have become the most highly drilled areas in Alberta. Drilling for oil or natural gas liquids in organic-rich tight sandstone reservoirs is conducted in the Devonian Formation, Devonian to Mississippian Dauphin and Bakken formations, and the shallower- and siltstone-dominated Triassic Monterey Formation.

The next phase of the project is to determine technically recoverable resources for oil shale. The first project includes the liquid-rich Devonian and Monterey formations.

Resource Evaluation of Tight Sandstone and Carbonate

Cardium Formation Sandstone Halo

Viking Formation Halo (Sandstone, Silt, Shale)

A Sampling of Prospective Unconventional Hydrocarbon-Rich Areas

Montney Siltstone

Estimates of Initial Resources in Place for Select Alberta Shale and Siltstone Strata

All formations will be evaluated for technically recoverable resources in the next phase of the project.

<table>
<thead>
<tr>
<th>Formation</th>
<th>Natural Gas (Tcf)</th>
<th>Barrel Oils (MMbbl)</th>
<th>Total (MMboe)</th>
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<tbody>
<tr>
<td>Cardium</td>
<td>3.9</td>
<td>0.9</td>
<td>4.8</td>
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<tr>
<td>Swan Hills</td>
<td>3.9</td>
<td>0.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Devonian</td>
<td>3.9</td>
<td>0.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Boreal</td>
<td>3.9</td>
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<tr>
<td>Total</td>
<td>15.6</td>
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</table>

<table>
<thead>
<tr>
<th>Resource Area</th>
<th>Total Recovery (MMboe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembina Field</td>
<td>4.6</td>
</tr>
<tr>
<td>Tight Carbonate</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Conclusion
The Alberta Geological Survey is continuing to work to quantify resources in unconventional plays. Future work will include determining technically recoverable resources and dividing large units into more refined plays based on common fluids, reservoir properties, production characteristics, and other geological and engineering criteria. All resource estimates, data, maps, and shifting as can be found on the website of the Alberta Geological Survey, www.ags.gov.ab.ca.

Acknowledgements
This resource determination work has been a team effort consisting of members of the Petroleum Systems and Earth Resources team including, Daryll Anderson, David Rechert, Mike Bethune, Chris Chevron, Greg Kwan, Dan Fleischer, Luke McFarlane, Glen Price, and John Paulucci.
Introduction

The Alberta Energy Regulator / Alberta Geological Survey is continuing work to quantify the hydrocarbon resources in shale and siltstone units. This work includes many formatives, reservoirs, and units. The initial assessments look at all hydrocarbon initially in place but will eventually include cut-offs to quantify technically-recognizable resources.

Recent but as-yet-unnamed assessments include:
- the middle Colorado shale from the top of the Second White Specks Formation in the town of the Fish River (Zones 1 and 2);
- the lower Doig Shale, which is equivalent to the upper Montney Formation in British Columbia.

Assessments of these units take into account uncertainty at every step and produce estimates of gas, oil, and natural gas liquids in place.

**Why Consider Uncertainty**

To illustrate why uncertainty is important, consider the following:

- the prospective area (Rohr 8%) of the Doig Shale Formation is about 60,000 km².
- The average shale thickness (100–125 m) in the Doig Shale is about 18 m.
- Shale thickness × prospective area of the Doig = 900 km³.
- The average bulk density of the Doig Shale is about 2.26 g/cm³.

- The mean of shale in the Doig Shale is about 2.2 ± 0.7 g/cm³.
- The AGS shale assessment project team collected about 10 kg of core samples from the Doig Shale.
- Therefore, 300 kg (2.2 ± 0.7 g/cm³) × 0.000300003003455 of the entire Doig Shale.

**Acknowledgements**

Thank you to the members of the AER/AGS shale report team: Steve Anderson, Mike Barbara, Troy Bozzone, Dongming Chen, Yong-Cheng T. Mi, Madhu, Cristina Pena, and John Peterson.

**Related Publications**

Grain Density and Mineralogy of Hydrocarbon-Bearing Shales and Siltstones in Alberta

Grain Density from Mineralogy

There are several different analyses that can be used to find the grain density of a reservoir unit. The preferred method used in this assessment at the Alberta Geological Survey is to use XRD-derived mineralogy to calculate the weighted average, grain density of core samples. The procedure for this is as follows:

1. Convert total organic carbon (TOC) content to kerogen. The factor for this is typically between 1.0 and 1.4.
2. Calculate the volume-weighted average grain density.
3. Convert the total porosity to shale, siltstone, or tight sand, the same change of 0.05 g/cc (or t/m³) in the grain density also affects the calculated porosity by about 2–3%.
4. Calculate the weight-volume average density: \[ \frac{\sum W_i V_i \rho_i}{\sum W_i V_i} \]

Comparison to Other Methods

To ensure that the XRD-mineralogy-derived grain densities are unbiased, the results were compared to other available data. Two other lab tests provided porosity and grain density information: helium pycnometry and a Dean Stark test. Both tests use bulk density from geophysical logs (\(\rho_b\)), grain density (\(\rho_i\)), and fluid density (\(\rho_f\)) for calculation of porosity:

\[ \phi = \frac{\rho_f - \rho_b}{\rho_f - \rho_i} \]

Porosity in shale, siltstone, and other unconventional reservoirs is a major factor in estimating hydrocarbon resources in place. Accurately quantifying the pore volume is important because the real states of continuous unconventional plays mean that even a relatively small volume of gas greatly affects resource estimation.

Introduction

Porosity in shale, siltstone, and other unconventional reservoirs is a major factor in estimating hydrocarbon resources in place. Accurately quantifying the pore space is important because the real states of continuous unconventional plays mean that even a relatively small volume of gas greatly affects resource estimation.

A common way to calculate porosity is to use density logs. The process uses a specified grain and fluid density. The grain density is often not at a constant measured value based on the broad lithologies of the reservoir, such as sandstone or limestone.

Density Porosity

The density porosity of an interval, \(\phi\), can be calculated by using the equation:

\[ \phi = \frac{\rho_f - \rho_b}{\rho_f - \rho_i} \]

This uses bulk density from geophysical logs (\(\rho_b\)), grain density (\(\rho_i\)), and fluid density (\(\rho_f\)).

Importance of Grain Density

Varying the assumed grain density changes the calculated porosity. The higher the grain density, the more it is concentrated in less volume, which leaves a more empty volume as pore space for the same bulk density. This effect is shown here, with porosity as a function of bulk density:

The lines of different grain densities are not quite parallel, but they closely follow one another. At a low bulk density, corresponding to high-porosity reservoir rock, a change of 0.05 g/cc (or t/m³) has a relatively large effect. Above 1 g/cc, the effect becomes less pronounced, and a change of 0.05 g/cc (or t/m³) has a relatively small effect.

Variation Across Lithographic Units

Variation in density and porosity are also present. The makeup and grain densities can be quite different.