

The Foothills of Western Canada, a Fold and Thrust Belt Natural Gas Play.

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The Foothills of the Western Canadian Sedimentary Basin (WCSB) has a long history of natural gas production for the Canadian and American markets. As a supplier to the North American gas market, the Foothills will continue to play an important role over the next 10 years due to the steady upward pressure on natural gas prices resulting from increased demand and decreased supply. This firming in price, coupled with the existence of an established infrastructure in the Foothills, will allow the economical development of many of the remaining natural gas prospects.

The current reserves of natural gas for all of North America that are tied into the natural gas market is 250 TCF. Based on the 2000 figures from the National Petroleum Council, the consumption of this product is currently 25 TCF per year for Canada and the United States. This figure is expected to increase to 30 TCF per year by the year 2010. However, the discovery rate for new gas to replace the continual consumption is decreasing each year. Using numbers published annually by the Alberta Energy and Utilities Board (AEUB), the British Columbia Ministry of Economic Development (BCMED) and the Federal National Energy Board (NEB), it appears that there is annual shortfall in Canada of 7% between produced marketable reserves and booked marketable reserves of natural gas. Taking the North American market as a whole, this figure could be as high as 10%. The steady increase in natural gas prices is providing an incentive to explore for new natural gas reserves and efficiently deplete already proven reserves in the Foothills of the WCSB.

The Foothills is part of the WCSB that lies within the fold and thrust belt of the Canadian Rocky Mountains. (Fig.1) The area is situated on the eastern side and directly adjacent to the Canadian Rocky Mountains. It covers 40,000 square miles of land that runs from the northwest to southeast through four of Canada's territories and provinces. The topmost northwestern point lies just north of the Northwest Territories border at the town of Fort Liard. The Foothills is also in part of the adjacent Yukon Territory and then runs southeast through the provinces of British Columbia and Alberta. It terminates at the American/Canadian border at the town of Waterton. The Foothills has already provided 40 TCF of in place natural gas reserves and has the potential to provide more. It is tied in via pipeline to the North American gas gathering system that feeds natural gas to eastern Canada, the eastern seaboard, midwest and northwest of the United States and California.

The northwestern and southeastern limits of the Canadian Foothills are controlled by political boundaries and the extent of the natural gas gathering system. The width of the belt is defined more on geological grounds. (Fig. 2) An area called the Triangle Zone defines the eastern side of the Foothills. This is a descriptive term for the subsurface shape of the rocks in cross-section that form the effective edge of the fold and thrust belt. Beyond this lie the conventional exploration and development plays of the WCSB. The western edge of the Foothills belt is defined generally by the topographic high that is formed by the front ranges of the Rocky Mountains. This topographic high provides limitations of access due to its extreme relief. It is also frequently the eastern edge of national or provincial parks, which provides another restriction to access.

One of the reasons for the unique nature of the Foothills belt is the type of geological structures that are found in the surface and subsurface. The Foothills is part of the larger fold and thrust belt of the Rocky Mountains, a geological structural domain where the sedimentary rock of the WCSB has been deformed by horizontal compression. The rocks have been effectively shortened by one of two mechanisms. In some cases, the structural complexes have reservoir rocks faulted and stacked on top of each other to form structures in which the reservoir rock may be fault repeated two or three times. In other cases, the rocks have been folded by the horizontal compression into tight folds where the reservoir rock may be broken or fractured. In areas where the reservoir rock has been fault repeated, the fields in the Foothills may have multiple individual pools of hydrocarbon stacked on top of each other. Where the reservoir rock

has been tightly folded, the resultant fractures can greatly enhance the productive capacity of a reservoir that would not produce had it not been folded.

Many of the Foothills fields have reservoir rock that has been fractured naturally. This fracturing leaves a degree of uncertainty in the calculation of marketable gas reserves. This is reflected by the unusually large difference between the marketable and gas in place reserve figures seen in certain Foothills pools. A good example of the under evaluation of a fractured Foothills reservoir is seen in the production profile for the Moose Mountain Field, a Foothills natural gas field that has a naturally fractured reservoir (Fig.4). Between 1985 and 2000 the field produced steadily from two pools. No additional wells were tied in, nor was there any work on the existing wells to access more reserves. The original marketable reserves were given as 130 BCF with the gas in place reserves of 250 BCF (AEUB). Over the subsequent years, as the cumulative production increased, the gas in place reserves has correspondingly been revised upwards. In 1999 the total production exceeded the original marketable reserves and the field is still producing at 40 MMCF per day.

One of the major additions to marketable reserves in the Foothills may well come from an increase in understanding of naturally fractured reservoirs. If this is true, it may not be unreasonable to add an extra 10 TCF of gas to the marketable reserves of the Foothills belt purely through the more effective development of current in place reservoirs.

The rock formations that produce hydrocarbons in the Foothills are spread throughout the stratigraphic column. (Fig. 3) The youngest producing formation is the sandstone of the Cardium formation. The oldest producing formation is the carbonates of the Beaverhill Lake group. The bulk of the gas produced to date is from the Mississippian aged rocks, which have produced 26 TCF of the total reserves. The next most prolific producers are the Triassic and Devonian aged rocks which have produced 6 TCF each. The Cretaceous has added 2 TCF to the reserves.

The Foothills has been divided up into five categories based on structural style, stratigraphic framework and history of exploration: First Generation, Second Generation, Third Generation, Triangle Zone and Reef/Stratigraphic play types. (Fig. 4)

The First Generation plays of the Mississippian aged reservoir formation dominated the early Foothills exploration effort from 1914 to 1960. These plays have contributed 37% of the in place gas reserves to the Foothills. They are found in structures formed by single thrust sheets and generally follow a fault bend fold structural style. Formed along the outer edge of the Foothills belt, these plays lie in the part of the Turner Valley formation where the environment of deposition was dominantly high energy, as is reflected in the grainstones that form most of the Turner Valley formation. The outer Foothills area has less rugged topography with softer Cretaceous rocks at the surface that allow for better seismic imagery of the structures.

The Second Generation play type dominated exploration efforts from 1960 to 1980. These plays have contributed 27% to the gas in place reserves of the Foothills. They contain both Mississippian and Devonian aged reservoir rocks and are formed in structures composed of multiple thrust sheets with a dominant fault bend fold structural style. Second Generation plays lie in the inner Foothills belt in the part of the Turner Valley formation that was formed in a lower energy environment of deposition that resulted in the rock matrix being dominated by wackstones and packstones. These reservoir rocks are generally inferior to the grainstones of the outer Foothills and need fractures to enhance the productivity. The inner Foothills area has rugged topography, often with high velocity Paleozoic Carbonates at the surface. These factors contribute to the poor quality of the seismic data recorded. However, because some parts of the structure may be exposed at surface, geological surface mapping becomes an effective exploration tool.

Third Generation play types have become increasingly important in Foothills exploration since 1970. To date, these plays have contributed about 20% to the gas in place reserve base. Third Generation plays form structures that are dominated by the detachment fold structural style. This deformation has the ability to fracture the reservoir rock intensively. As a result, rocks with moderate to poor matrix reservoir can become good producers. However, this fracturing may negatively effect fields that have good matrix reservoir rock if they have a very active water drive. The structures in this play type

have steep dips and disharmonic folding. This leads to problems with seismic imaging, although these plays can often be effectively mapped using surface mapping techniques because of the amplitude of the folds.

The next play type to be described is the Reef/Stratigraphic type. It has played a relatively minor role in Foothills exploration strategy from 1970 – 2000 and has contributed only 5% of the gas in place reserves to the Foothills to date. This play type is dominantly a stratigraphic play that extends from the conventional part of the WCSB and can occur either in the regional or on thrust sheets in the Foothills. In both cases the seismic imaging of the play is hampered by the complex geology of the shallower strata, large variations in topography and steep dips on the reservoir rock itself or in the overlying strata. On the positive side, the reef plays to date have been prolific producers from good matrix reservoirs in the Devonian. It is a play that relies heavily on advances in seismic technology to provide the direct imaging necessary to provide successful drilling locations.

The Triangle Zone is a complex interaction of the two structural styles—it has multiple thrust sheets as well as a detachment folding component to enhance tight reservoir rock. There has been a resurgence in exploration of this play type since 1995. It has contributed 10% of the gas in place reserves to the Foothills. This play type involves primarily Cretaceous aged sandstone reservoir rocks. Because of its position in the outer Foothills and the velocity contrast between the rocks, it is well imaged on seismic data.

Production from the various play types has changed over time. (Fig. 5) Early production was dominated by the Reef/Stratigraphic, First and Second generation plays. Since the mid 1980's the Third generation and Triangle zone plays have contributed an increasing amount to the annual production.

In summary, the Foothills has a long history and has proved itself capable of producing large amounts of gas at high rates. Current published data gives the gas in place reserves for the Foothills as 40 TCF, of which 19 TCF is considered marketable gas and 13 TCF have already been produced. It currently produces nearly a TCF of raw gas a year. Based on the latest work by the Canadian Gas Potential Committee using a discovery history process model it has 27 TCF yet to be discovered in existing plays. The three largest fields left to be discovered in the WCSB will be in the Foothills and each will be greater than 1 TCF in size.

All gas reserve figures are in place numbers, unless otherwise stated.

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Andrew Newson started his career in Canada with United Geophysical working as a junior geophysicist in the High Arctic. After a spell in Houston processing for United Geophysical he came back to Calgary. Then he worked as a field geologist mapping in the Alberta and BC Foothills for Shell and BP. This was followed by three years in New Zealand where he was responsible for several successful oil wells in the Taranaki Overthrust Belt. On returning to Canada he joined Canterra, Husky and then Sceptre before starting consulting in 1992.

In the last 10 years he has consulted through Moose Oils Ltd on a variety of domestic and international projects. The primary focus has been the close integration of geological and geophysical data in structurally complex areas. Today Moose Oils Ltd is one of the few APEGGA registered consulting companies operating in Calgary that provides this specialized service.

During this time Andrew has been a successful explorer for hydrocarbons for his clients and has contributed to their success in a variety of play types in the Foothills of Alberta, BC, Yukon and the NWT.

He has also been the recipient of numerous awards. Among them was the CSPG's Link Award in 2000 for his talk "Foothills, The Future for Exploration". His company Moose Oils Ltd has also received an award from NSERC and the Conference Board of Canada for its contribution to the Fold-Fault Research Project. He is a regular speaker at

conferences both domestically and internationally and has undertaken numerous roles as technical editor and chairperson for the CSPG structural geology group. Andrew regularly leads field trips to the mountains and spends time field mapping for his clients.

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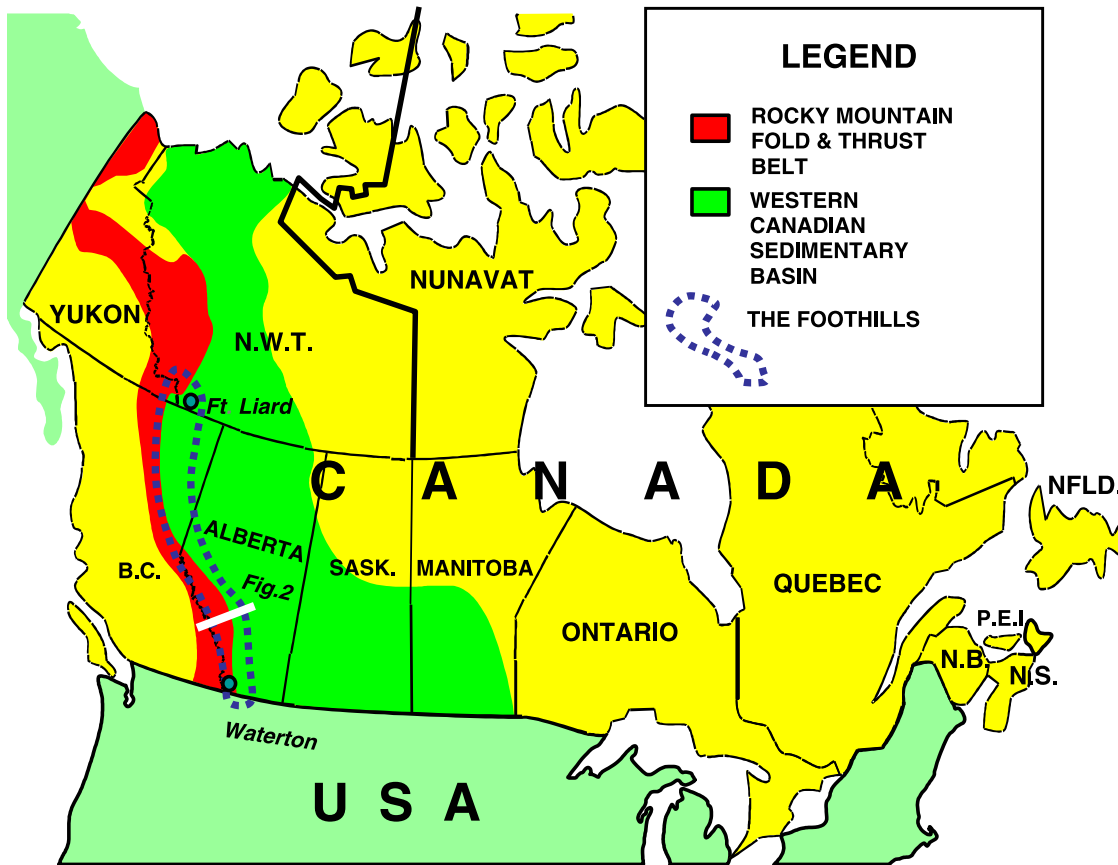


Fig. 1

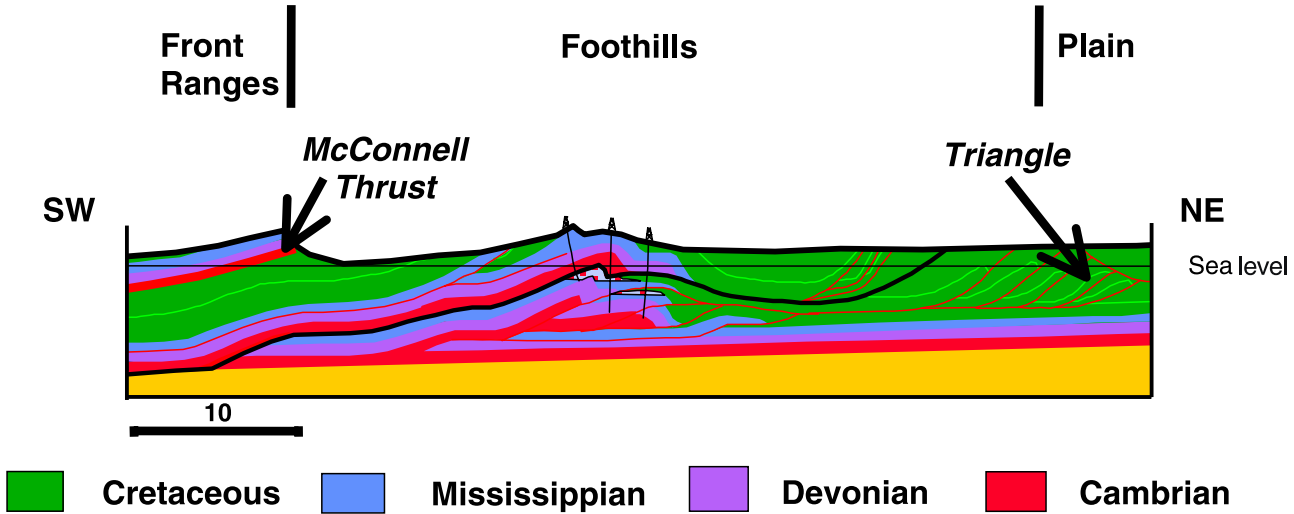


Fig.2

Age	m.	Lithology	
Tertiary	700 / 1200	Sands with minor shales	
Upper Cretaceous	700 / 1500	Sands with minor shales	
	800	Shales with minor sands & conglomerates	✱ Cardium
Lower Cretaceous	400	Sands shales & coals	✱ Viking
Triassic	250 / 500	Limestone sands & shales	✱ Pardonet / Baldonnel
Permian to Pennsylvanian	0/120	Sand & shale	✱ Taylor Flats
Mississippian	400	Dolomitised limestone	✱ Turner Valley / Debolt
Devonian	600		✱ Palliser
Cambrian	500		✱ Beaverhill Lake
Pre-Cambrian		Igneous & metamorphic	

Fig. 3

Foothills Play Types

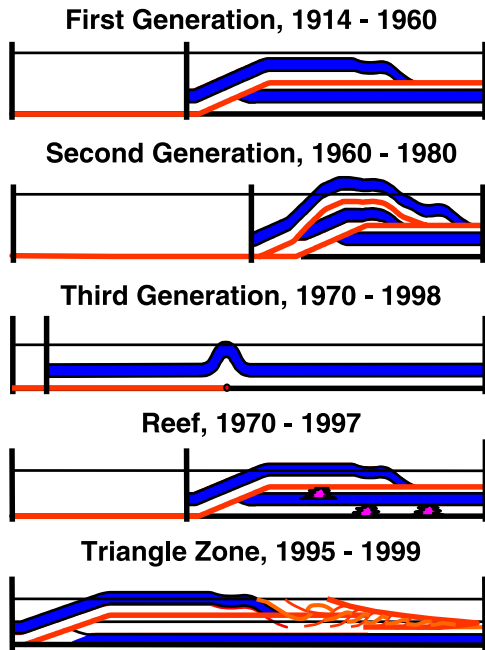


Fig. 4

Annual Production in mmcf of marketable gas

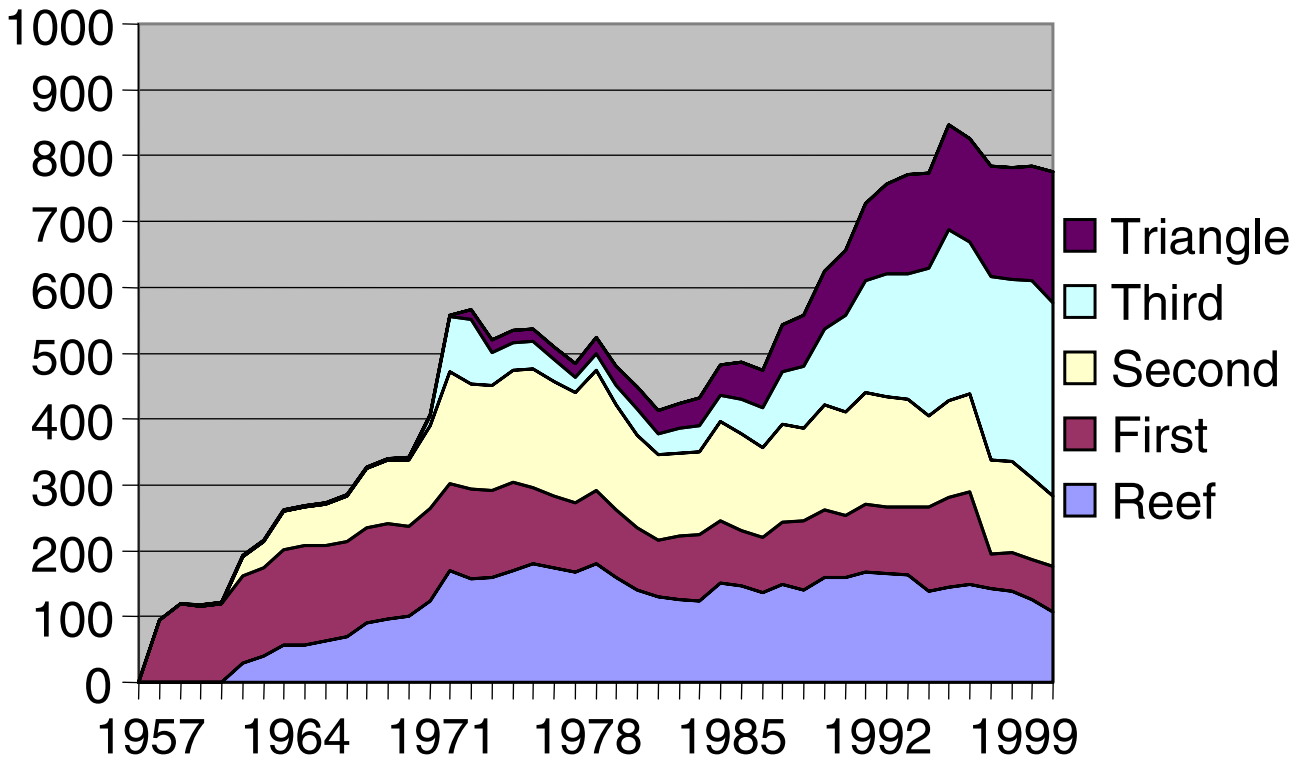


Fig. 5