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Learnings from the last 50 years of exploration and development in the foothills of the Canadian Rocky Mountains

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The foothills of the Canadian Rocky Mountains have been actively explored by the petroleum industry for nearly 100 years. Because the subsurface is densely sampled by seismic reflection data and boreholes, and is bounded by world-class exposures of thrusted Paleozoic carbonates that are the subsurface reservoirs, this belt may be the most thoroughly characterized fold-thrust system in the world. The last 50 years have seen numerous advances in the understanding of this trend, some generated by insightful investigations by field geologists and oil industry scientists, others by application of innovative technologies like 3D seismic data and borehole image logs.

The Canadian foothills, like many petroleum basins, has seen the focus shift to different parts of the hydrocarbon system as the trend matured through time. In the early and middle part of the last century, when the belt was relatively immature and the science of exploration geology was less advanced, exploration was focussed solely on finding traps that had surface expression. Analysis of surface geology was the basis for discoveries at Turner Valley (1924), Savannah Creek (1955), Moose Mountain (1960) and other fields. With the advent of CDP reflection technology, many subsurface traps without direct surface expression were found, including Waterton (1957), Wildcat Hills (1958), Jumping Pound West (1961), and Quirk Creek (1968). Three-dimensional seismic data has only been routinely used since the early 1990's in this belt, and it has had much greater impact on development of known gas accumulations than it has on generating new discoveries. The best example of how 3D seismic has impacted development success may be in Benjamin field, which was producing 10 mmcf/d in the early 1990's before 3D seismic was shot. Today that field is producing over 10 times that daily quantity of gas.

One of the byproducts of subsurface seismic reflection mapping and drilling in the last 50 years has been a tremendous advance in the understanding of the structural geology of compressional fault systems. Oil industry geologists (most notably from Shell Canada and Chevron), Geological Survey of Canada geologists, and academic scientists contributed a series of papers based on Canadian Rocky Mountain studies that would, in the absence of any other information, give students of structural geology a very advanced understanding of the systematics of thin-skinned thrust tectonics.

With one notable exception, the large foothills fields reservoired in the Devonian, Mississippian, and Triassic of western Canada contain almost exclusively natural gas. Therefore, the impact of source rock evaluations, hydrocarbon maturation/migration studies, and structural timing analyses have not been as profound as they probably are in hydrocarbon-bearing thrust belts elsewhere in the world. Maturity studies suggest liquid hydrocarbons migrated out of the foredeep before most traps in the foothills had formed. Decades of development in the foothills has demonstrated that very few, if any, traps are underfilled, indicating an excess of gas in the system at the end of the Laramide orogeny during the early Tertiary. Evidence from gas fields in central Alberta suggests that gas migrated in fill-and-spill fashion from pool to pool over a distance of at least 100km in the strike direction.

During the last decade, gas production from foothills fields has increased, but few new discoveries have been made. By far the most important challenge facing many companies during this decade of development drilling has been the prediction of fractured reservoir performance. The Paleozoic and Triassic dolomite reservoirs are generally low porosity (3-8%), low permeability (<1 md), and will not flow gas at commercial rates in the absence of natural fractures. Historically, the best reservoirs in the trend were developed first, and through time it became apparent that the best performance tended to be at the crests and on the forelimbs of structural culminations. More recently, as poorer-quality reservoirs began to be exploited, fracture prediction strategies including curvature mapping, and to a lesser extent kinematic structural modeling became important. But clearly the most important technology advance that has impacted foothills activities over the last decade has been not in geoscience but rather in the technology of directional drilling. Since about 1995, many of these poorer reservoirs like those in central Alberta, have been developed with widespread use of horizontal drilling. The horizontal well results are highly variable, with many wells experiencing only a few months of enhanced performance declining to rates comparable to nearby vertical wells. Some horizontal wells do experience sustained uplift in performance over the long-term, but it is not clear which of many variables - wellbore orientation, wellbore length, above-average natural fracturing, greater pore volume, absence of bedded anhydrites - is responsible.

Looking forward, it must be reiterated that the pace of new discoveries has slowed significantly in the last 20 years. Most new gas production is coming from accumulations that were discovered more than ten years ago and is only coming on stream as infrastructure expands and the economics of North American gas projects improves. Secondary reservoir objectives in the clastic Mesozoic succession will continue to be developed although accumulations discovered to date have proven to be of limited size and quality. The economics of ultra-sour gas development should also improve as the supply of traditional gas resources declines and prices increase. Hundreds of Bcf of this type of resource remain shut-in in the foothills due to economic and environmental concerns. Finally, one of the few remaining foothills plays that has yet to be proven successful but that could support large reserve sizes is in sub-thrust Devonian reefs. Barring significant new discoveries or changes in one of the above conditions, gas production from the foothills of western Canada is likely to begin declining steeply within the next ten years.