

# **Cadomin Tight Gas Reservoirs along the Updip Margin of the WCSB Deep Basin\***

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Search and Discovery Article #10720 (2015)

Posted February 23, 2015

\*Adapted from extended abstract prepared in conjunction with a presentation given at CSPG/CSEG 2007 GeoConvention, Calgary, AB, Canada, May 14-17, 2007, CSPG/CSEG/Datapages © 2015

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## **Abstract**

The Cadomin is the best-defined and most widespread tight gas play in western Canada. Deep Basin sandstones and conglomerates blanket the western margin of the WCSB, and large gas fields are being developed in several areas. These projects are based upon occurrence of the best reservoir quality along the updip margin of the Deep Basin. This core display highlights variations upon this overall theme:

**Cutbank Ridge:** Pervasive fracturing develops economic reservoir quality in low-porosity, very poorly-sorted siliceous conglomerates.

**Wild River:** A large gas resource base in Cadomin conglomerates and sandstones is exploited through commingling with uphole zones, as Cadomin reservoir quality is not sufficient to support independent production.

**Hooker/High River:** Better sorting in finer-grained sandstones creates reservoir quality sufficient to support standalone development of the Cadomin reservoir. As in the areas to the north, its highly predictable mappability reduces development risk to acceptable levels.

## **Introduction**

The Cadomin is a widespread sandstone and conglomerate unit, representing an initial pulse of alluvial fan and fluvial orogenic sedimentation in Early Cretaceous time. It forms the initial fill of the northward-draining Spirit River Valley system, which is bounded sharply to the east by the Fox Creek Escarpment in the north, and the Taber Escarpment in the south.

## **Reservoir Description**

Poorly sorted medium- to coarse-grained sandstones and chert pebble conglomerates characterize the Cadomin. Alluvial fan to fluvial environments of deposition is indicated by large-scale, high-energy cross bedding, poor sorting, lack of marine indicators, and position atop the pre-Mannville unconformity. Very poorly sorted conglomerates are typical of proximal alluvial fan settings; sorting generally increases

eastward such that moderately sorted medium- to coarse-grained sandstones with minor pebbles are common in fluvial strata of the Spirit River Valley. There are no characteristic internal stratigraphic markers, and specific reservoir trends have not been mapped.

Conglomerates contain well-rounded chert pebbles, ranging from granules up to several centimetres in diameter. Sorting is typically poor, with sands filling interpebble pore spaces – only rarely is pebble-supported porosity observed. Finer sandstones feature more quartz and better sorting overall. Pervasive silica cement occludes most quartz sand-supported porosity, while pressure solution has produced sutured/stylolitic contacts, reducing porosity in more chert-rich sands and conglomerates. White (kaolinitic) clays fill much of the rare pebble-supported porosity.

Cadomin rocks are characteristically glassy and brittle, and have locally developed considerable permeability as the result of small- to moderate-scale fracturing. In places, fracturing has progressed to the point that core is rubble or has not been recovered. We have noted this style of fracturing in cores at Cutbank Ridge, in some cores in the Wild River area, and in near-Foothills areas.

In deeper Cadomin sections, core analyses show low porosities (commonly 5% or less) and permeabilities (<0.5 mD, with many values <0.1 mD). Where fractures are observed, porosities remain low, but permeabilities increase to the 0.5-10 mD range, with spikes to 100 mD+. Updip toward the Deep Basin edge, reservoir quality improves to 5-10% porosity and 1-10+ mD.

### **Hydrocarbon Occurrences**

The Cadomin produces gas from large pools in updip sections of the Deep Basin in northeastern B.C. and adjacent Alberta, at Wild River in west-central Alberta, and at Hooker/High River in southwestern Alberta. There is isolated production from high relief (Foothills) fractured reservoirs in northeastern B.C., Narraway, Findley, and Mountain, but at least some of this is commingled with the Nikanassin, so that the Cadomin contribution is difficult to differentiate. Published regional resource assessments do not address significant advances made within the last few years in producing gas from tight Cadomin reservoirs.

### **Cadomin Reservoir Examples**

#### Cutbank Ridge

Cutbank Ridge straddles the Alberta / B.C. border, encompassing the Cutbank Field in B.C. and the northern part of the Elmworth Field in Alberta. Drill depths range from 2,000 to 2,500 metres. Cadomin prospectivity was established with the initial development of the Elmworth Field in the early 1980's and Canadian Hunter's B.C. Deep Basin exploration program of the late 1980's. However, economic production rates could not be systematically achieved with the technology and gas prices of the day.

In 2003, based upon their "resource play" strategy, EnCana determined that the Cadomin could be exploited economically using current drilling and completion practices, and economies of scale associated with drilling and tying in hundreds of wells in a contiguous area. Burlington (now ConocoPhillips) has also been a major player at Cutbank Ridge.

### *CanHunter Elsworth 6-16-68-11W6*

Six metres of poorly sorted alluvial fan to braided stream conglomerates sit unconformably on Nikanassin fine-grained floodplain strata (Figure 1). Porosities through most of the section range from two to six percent, as large interpebble pores are filled by silicified sands and white clays. Up to 10% porosity occurs in a better-sorted section to the base. Permeabilities are much higher than would be expected (1 mD – 100+ mD) because of pervasive fracturing; note that some fractures shatter individual pebbles. Although many Cadomin producers drilled in this area are now commingled, Cadomin sections like this one are capable of economic production on their own.

A specific mechanism for Cadomin fracturing at Cutbank Ridge has not been identified. However, the highly siliceous, brittle Cadomin rocks fracture much more readily than other reservoir units in the area.

### Wild River

Large-scale, multizone drilling programs have been undertaken by several companies during each of the past several drilling seasons in the greater Wild River area. Cadomin strata, mappable throughout the area, form an “anchor zone” of production, with contributions from various less consistently developed reservoirs uphole. Production is commingled from almost every wellbore; only in particular areas will Cadomin reservoir quality be sufficient to support independent production. Initial productivities are generally modest (1-3 MMCF/D), drill depths are 3000 metres or greater, and multiple fracture completions are required – so economic development requires high gas-in-place, downspacing, and large, efficient drilling programs.

### *CanHunter Wild River 2-29-56-24W5*

Cadomin conglomerates are finer-grained and somewhat better sorted than at Cutbank Ridge, indicating a more braided fluvial setting, further from the sediment source area (Figure 2). However, there is still sufficient sandy matrix to occlude much interpebble porosity, so that porosities are generally in the 5-6% range. White clays and pyrobitumen also fill some pore spaces and throats. Permeabilities range from 0.1-1 mD, with little or no natural fracture enhancement. Extrapolating these characteristics across the entire Spirit River Valley fairway, one can see that the Cadomin provides a large, reliable gas resource base, but subeconomic deliverabilities on its own.

### Hooker/High River

Cadomin strata (locally termed the Basal Quartz) lie within a north-south trending valley system in the Hooker/High River area, part of a more regional valley mappable over 150 km. Drilling depths range from 2200 metres in the north to more than 3200 metres in the south.

Significant gas reserves were discovered in conventional stratigraphic traps in the Basal Quartz valley fill at Crossfield in the 1960's. Compton Petroleum extended the fairway south to the Hooker / High River area, and in 1999, participated in the High River discovery well, which demonstrated that gas was present and producible in the Deep Basin. Today, the Hooker / High River development covers about three

townships. The Cadomin/BQ are produced independently, with IP's in the 1-5 MMCF/D range. Downspacing has been undertaken selectively, guided by detailed seismic and geological mapping.

The Cadomin / Basal Quartz valley-fill section ranges in excess of 25 metres thick, but exhibits considerable variability, with net/gross ratios below 50% in some wells. Sandstones are finer-grained and less pebbly than the Cadomin to the north, and reservoir quality has experienced significant degradation through compaction and silica cementation. Porosities range from 5-14%, with permeabilities of 0.1-5mD, but isolated sweet spots with better sorting and/or coarser grain size may have 20-80 mD permeability. Downdip in 14-1W5, reservoir quality is significantly poorer, where core exhibits average porosity and permeability of 6.0% and 0.4 mD, respectively.

#### *Compton High River 11-4-17-29W4*

Stacked, metre-scale fining-upward successions form an overall fining-upward sandstone reservoir in the Cadomin / BQ (Figure 3). The basal 2.5 metres is coarse-grained to conglomeratic; above, fine- to medium-grained sandstone dominates. Sedimentary structures – large-scale cross bedding in coarser sands to more intricate current ripples in finer sands – indicate deposition in a current-dominated fluvial setting. A cm-thick mudstone bed at 2657.5 and other zones of mudstone intraclasts indicate intervals of low-energy deposition. Generally better sorting and less pervasive silica cementation supports better reservoir quality than in the conglomerates at Wild River and Cutbank Ridge.

### **Summary**

The Cadomin is the best-defined and most widespread tight gas play in western Canada. Deep Basin sandstones and conglomerates blanket the western margin of the WCSB, and large gas fields are being developed in several areas. These projects are based upon occurrence of the best reservoir quality along the updip margin of the Deep Basin. This core display highlights variations upon this overall theme:

- Cutbank Ridge: Pervasive fracturing develops economic reservoir quality in low-porosity, very poorly-sorted siliceous conglomerates
- Wild River: A large gas resource base in Cadomin conglomerates and sandstones is exploited through commingling with uphole zones, as Cadomin reservoir quality is not sufficient to support independent production
- Hooker / High River: Better sorting in finer-grained sandstones creates reservoir quality sufficient to support standalone development of the Cadomin reservoir. As in the areas to the north, its highly predictable mappability reduces development risk to acceptable levels.

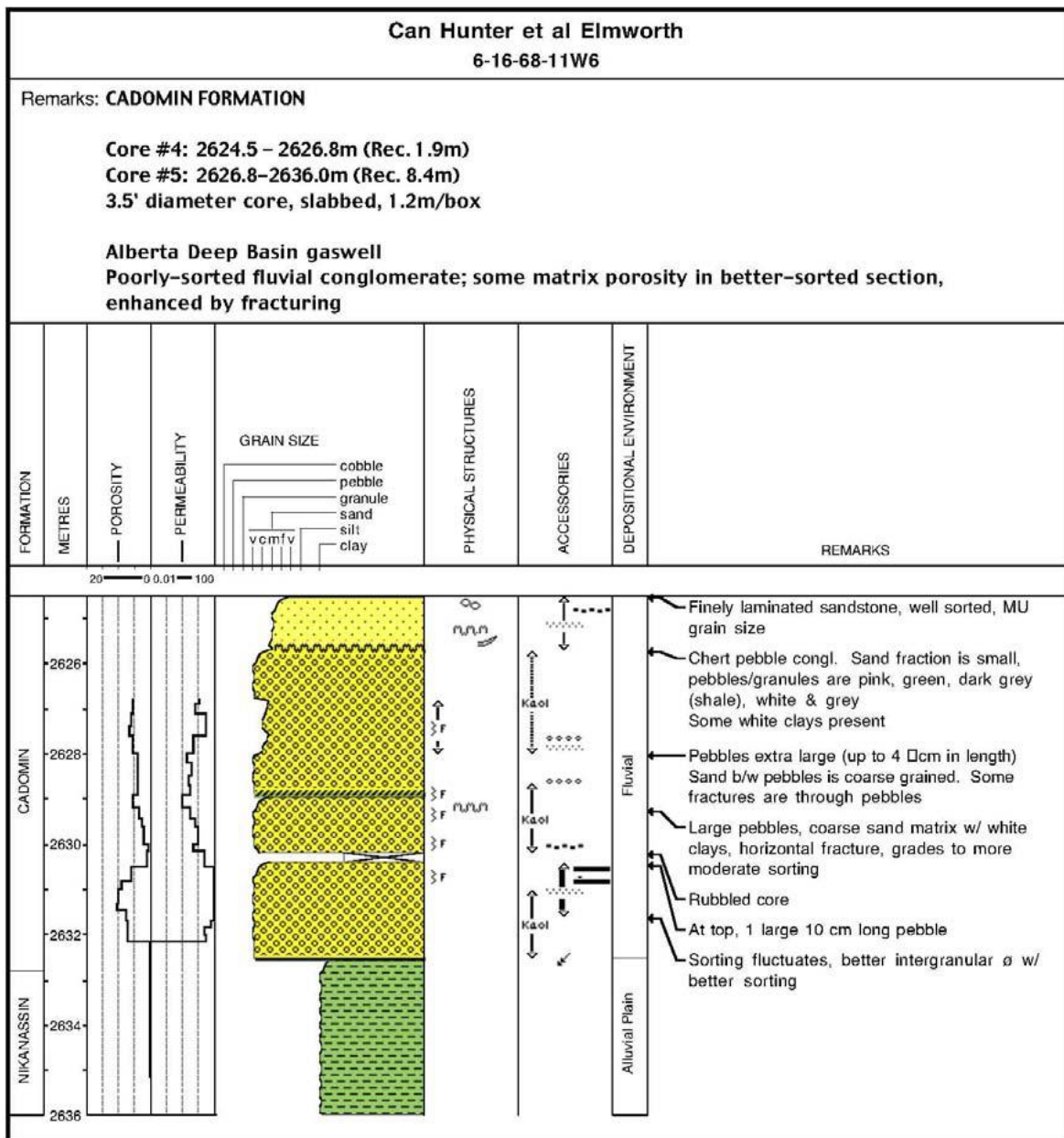


Figure 1. CanHunter et al Elmworth log, 6-16-68-11W6.

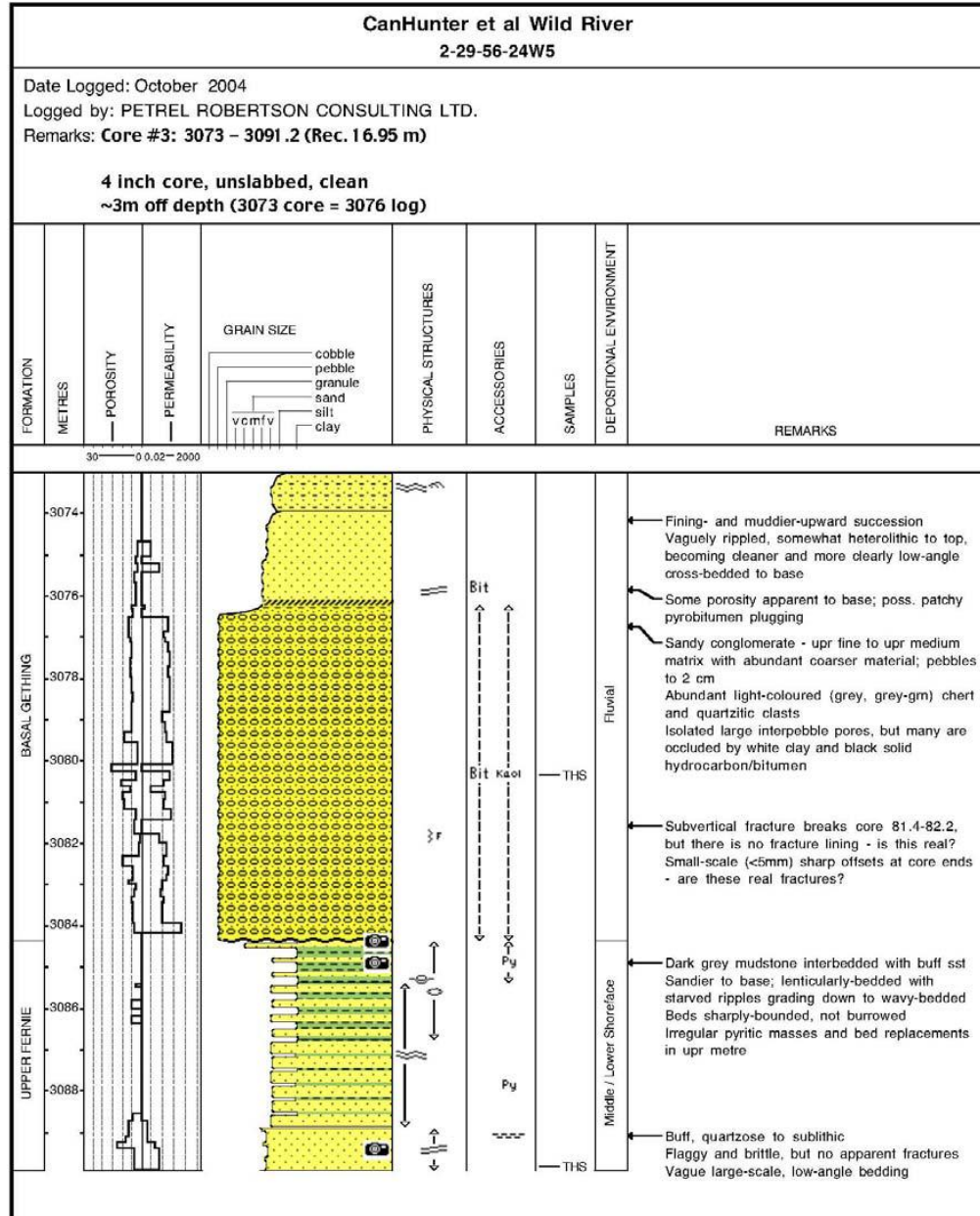


Figure 2. CanHunter et al Wild River log, 2-29-56-24W5.

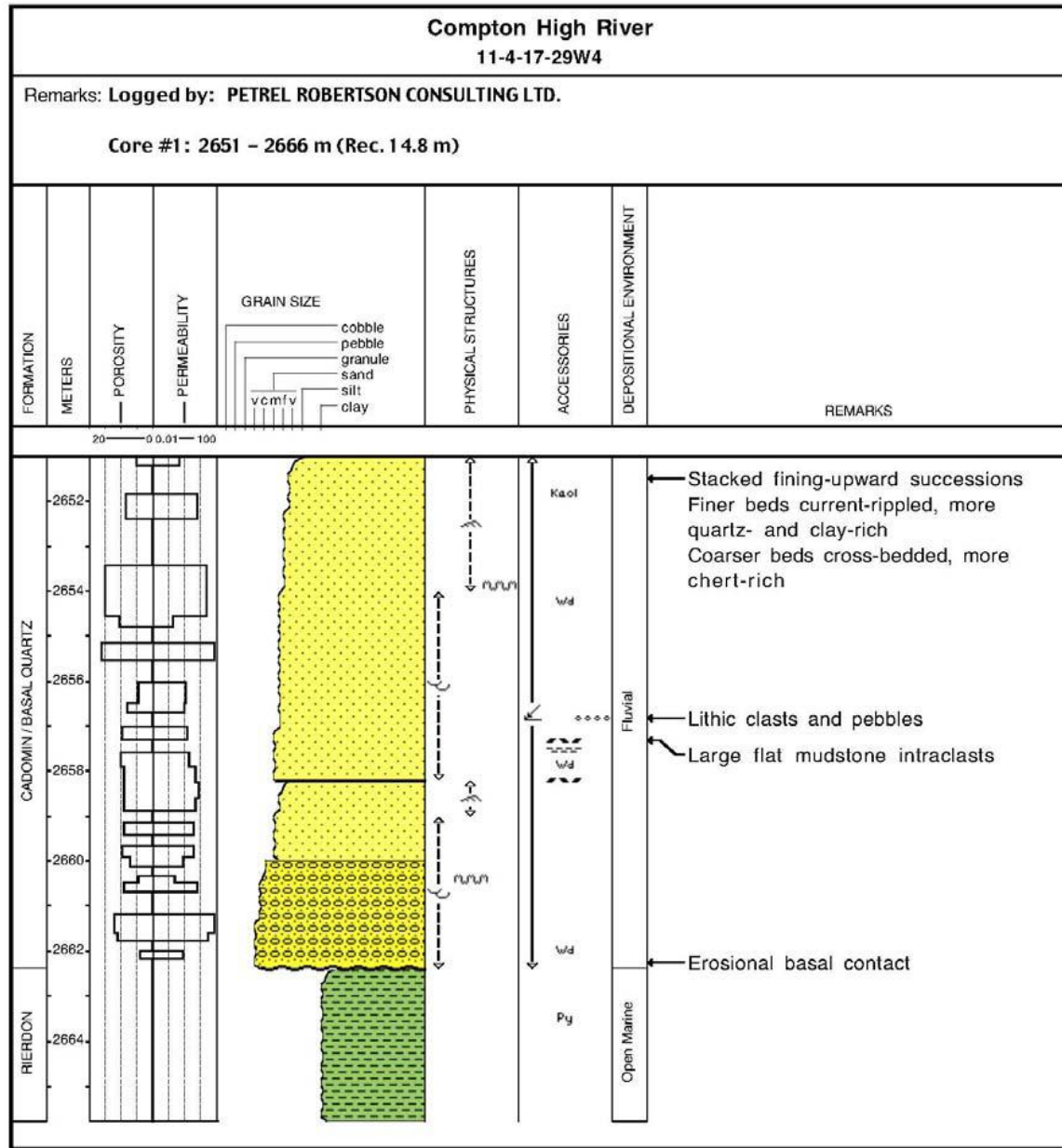


Figure 3. Compton High River log, 11-4-17-29W4.