# Overcoming Complex Geosteering Challenges in the Cardium Reservoir of the Foothills of Canada to Increase Production Using an Instrumented Motor with Near Bit Azimuthal Gamma Ray and Inclination*

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## Abstract

The Cardium Formation is a conventional sandstone reservoir in the Western Canadian Sedimentary Basin. In the undeformed basin, the Cardium Formation is currently at a phase of exploitation requiring long horizontal penetrations and large scale, multi-stage, hydraulic fracture stimulation to ensure productivity. In the Canadian Foothill, the Cardium is complexly deformed and naturally fractured. Correctly placed wells take advantage of these natural fracture permeability pathways to support extremely prolific wells. To maximize production and effective reservoir drainage, horizontal wellbores need to be drilled to intersect multiple fracture networks within the deformed Cardium reservoir. Sub-seismic scale folds and faults result in rapid changes in reservoir bedding orientation and/or position and require very sensitive geosteering responsiveness in order to create an optimal reservoir penetration. The reservoir exhibits very good gamma character; and therefore gamma has been shown to be an effective tool for geosteering. An innovative instrumented motor that provides azimuthal gamma and continuous inclination 9 ft from the bit was used for geosteering several wells, and has proven to be a vital component in the drilling process. For example, in the case of a 5 deg change in apparent bedding orientation compared to the wellbore resulting in the wellbore exiting the reservoir, re-entry can occur as quickly as 100 ft when using the instrumented motor compared to 185 ft when using a conventional gamma positioned 50 ft from the bit. The 41 ft of "advance" notice allows you to get back in reservoir sooner resulting in an increase in reservoir penetration interval of 84 ft. In one case study, a horizontal leg was drilled using a conventional gamma, the well exited the reservoir due to an abrupt change in bedding orientation and 1138 ft of non-reservoir was drilled prior to re-entering the reservoir. With the near-bit information, this non-productive interval would have been avoided or significantly reduced.

This article will start out by introducing the complex reservoir of the Foothills. It will then present the unique challenges faced when attempting to geosteer and place the wellbore within the reservoir. We will review the near bit instrumented motor and discuss the workflow of how data

was used from the instrumented motor to help with geosteering the well. Finally, the results will be presented and a discussion of future work will be presented.

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**Asong Suh**
Scientific Drilling

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Houston, Texas

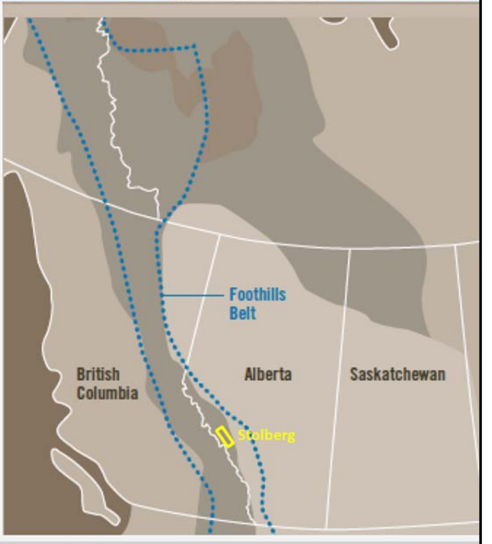
The **Ultimate Partner** In Wellbore Placement

# PRESENTATION OUTLINE

- Introduction
- Geosteering  Challenge
- Use of Near bit Azimuthal Gamma Ray and Inclination
- Operations and Results
- Discussions/Questions

# CARDIUM FORMATION

- Conventional sandstone reservoir
- Western Canadian Sedimentary basin
- Underformed basin
  - Requires long horizontal
  - Multistage fracture stimulation






Presenter’s notes:

- This sandstone is the lower member of the Cardium Formation: a clastic wedge of shales, siltstones, sandstones to pebble conglomerates.
- Drilling is in the Stolberg area of the Alberta Foothills.

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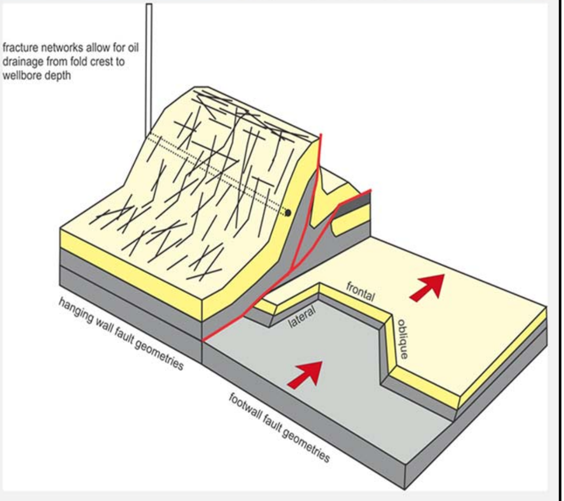
# CARDIUM FORMATION IN CANADIAN FOOTHILLS

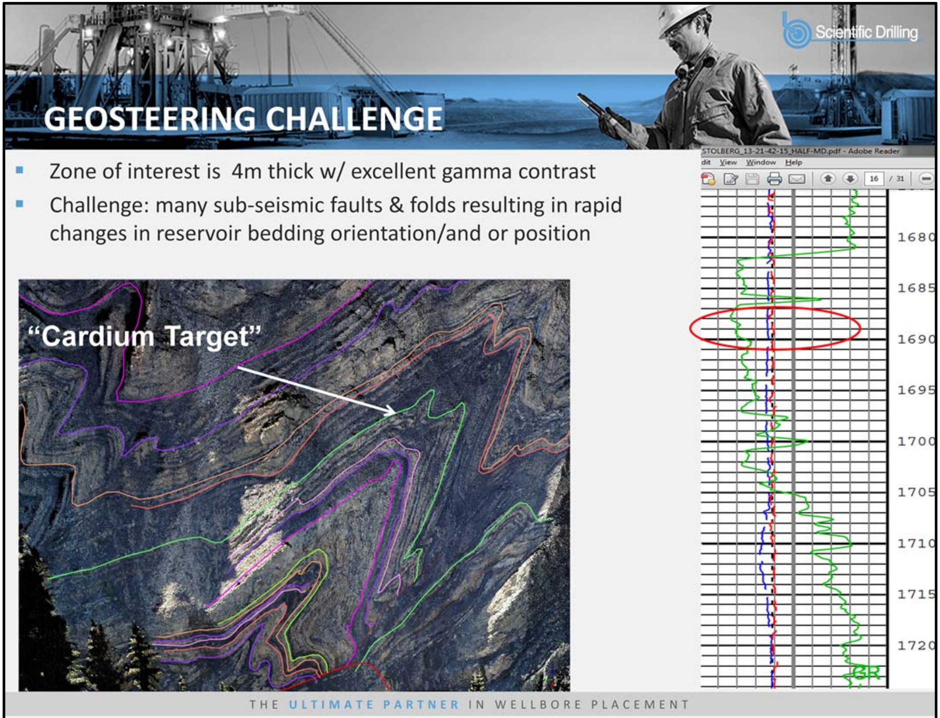
- In Foothills Cardium is:
  - Complexly deformed
  - Naturally fractured
- Well placement takes advantage of natural fracture permeability
- Wells are drilled to intersect fracture network…no need to frac




THE ULTIMATE PARTNER IN WELLBORE PLACEMENT

Presenter's notes:

- Natural fracturing occurs in the foothills as a direct result of bedding planes being folded and faulted under compressional stresses.
- The natural fracture system created by these stresses is aligned perpendicular to bedding and as such, horizontal wellbores are required to intersect the fracture network and continuous geosteering coverage is required to remain in the reservoir section.




Presenter's notes:

- Zone is characterized by 4-5 m of clean sandstone, a hot gamma marker followed by 4 m of clean sandstone followed by an increase in silt composition into finer grained, tighter rocks at the base. The main horizontal target while geosteering are the 4 m of clean sandstone at the base of the hot gamma marker (1686-1690 m MD).
- Picture shows an outcrop on the side of a mountain around with structure very similar to what is being drilled. The horizontal well is drilled out of the computer along the green line.

# GEOSTEERING w/ GAMMA RAY

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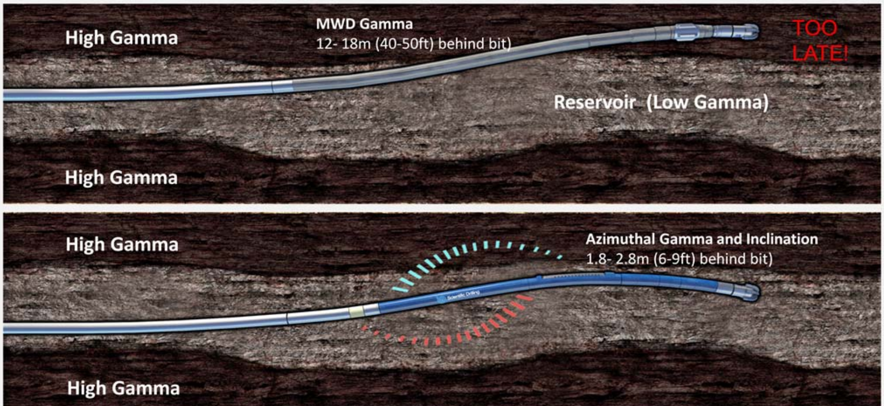
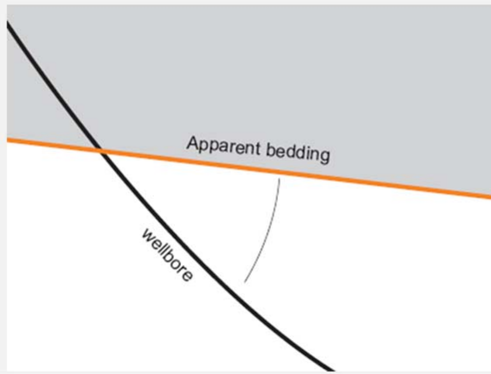
- Challenges w/ MWD Azimuthal Gamma
  - Can't react quickly
  - Takes too long to determine direction of exit
  - Loss production when out of reservoir



# GEOSTEERING w/ GAMMA RAY

- Example: If zone is exited @ 5° apparent bedding dip
  - w/ Near bit GR (2.7m from bit), have to drill 30.7m to get back in zone
  - w/ MWD GR (15m from bit), have to drill 56.4m to get back in zone
  - Achieve 25.7m (84 ft) of additional reservoir penetration because of near bit sensor






Presenter’s notes:

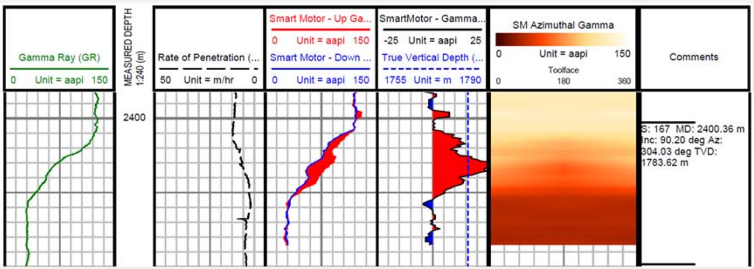
- Assme 8 deg DLS to re-enter the zone.

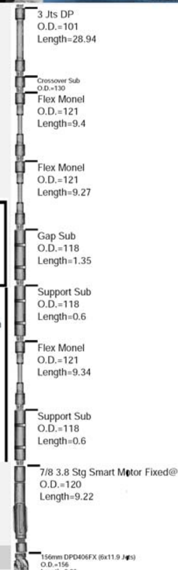
# NEAR BIT SENSOR

- Instrumented Motor
  - Standard mud motor with electronic payload
  - Measures azimuthal gamma ray and continuous inclination  2.7m from bit
  - Data transmitted to surface real-time via short hop and MP or EM MWD
  - Available in 3.75”, 4.75” and 6.5”

# OPERATIONS

- Azimuthal GR & Continuous Inc 2.7m from bit
- Data sent real-time to Manitok
- Collaboration between DD, Geologist and MWD key to success
- Example: Drilling down section




THE ULTIMATE PARTNER IN WELLBORE PLACEMENT

Presenter’s notes:

- Each big square is 5 m.


- Total of 19 wells drilled in Stolberg area

- 7 Wells drilled using radial gamma positioned about 12-18m from bit
  - Average Horizontal Length: 562.6m (1846 ft)
  - MD drilled in gross sand 397.1m (71% )
  - MD drilled in net reservoir: 56.4m (10% "sweet spot")

- 12 Wells drilled with near bit Azimuthal GR/Inc Instrumented Motor (2.7m sensor to bit)
  - Average Horizontal Length: 525.5m (1724 ft)
  - MD drilled in gross sand 413m (79%)
  - MD drilled in net reservoir: 209m (40% "sweet spot")



Presenter's notes:

- Gross Sand is generally a 10-15 m body of Cardium sand with streak of 4 m of reservoir quality sand.
- The "sweet spot" is the 4 m net reservoir strip.
- Gross sand is anything with an API gamma cleaner than ~45 API. Net reservoir sand is cleaner than ~25 API, with an accompanying geologist description better than 6% porosity.