PUSHING THE LIMITS OF THE DUVERNAY:
LOOKING AT POTENTIAL IN NEW AND UNTESTED AREAS
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INTRODUCTION

• Quick Overview of Basin Geology
• Thermal Maturity
• Step Though Opportunities in the Basin
  – East Basin
    • Differences within the East Basin
    • Where is the productive limit?
  – Willesden Green Oil Window
  – Pembina
  – Edson to Wildwood
  – Kaybob Oil Window
• Conclusions
• The study area includes all areas GLJ has evaluated for clients from 2011 to 2019.

• Yellow polygons represent lands GLJ has completed detailed evaluations in the Duvernay comprised of:
  – Yearly reserve and resource reporting
  – Bank financing reports
  – Acquisition, and divestiture evaluation reports and support
  – Local studies, including HF Modeling
The Duvernay is the basin filling sediments, offsetting Leduc carbonate buildups.
West Basin was a more typical shale resource:
- High organic content
- Quartz dominated; highly brittle
- Sourced from north
Rimbey-Leduc trend may have acted as barrier
East Basin is carbonate dominated
QUICK COMPARISON OF WEST VS. EAST BASIN

WEST BASIN

- Full spectrum of thermal maturity
- Quartz-dominated
- Continuous organic-rich sections
- Strong organic porosity component
- Oil Window results continue to improve with completions

EAST BASIN

- Primarily Oil Window
- Carbonate-dominated
- Interbedded organic horizons
- Mixed porosity system
- Oil Window is proven to be commercially viable
• Depth plunges from NE to SW (~2,200m to ~4,000m Drill depth)
• Thickest reservoir is in East Basin
POROSITY DEVELOPMENT

- Organic-matter hosted porosity important component of storage system...particularly in the **West Basin**
- The proportion of “organoporosity” increases with increasing thermal maturity.

*Modified from L. Dunn (2011)*
KAYBOB WAS THE STARTING POINT

- Kaybob is thick, has high HCPV
- Was a look-alike to other shale developments at the time
• Expected hydrocarbon type follows depth somewhat, but there are other controls which impact thermal maturity
THERMAL MATURITY

• GLJ Relies on a number of data sources outside of production data to guide maturity contours in the Duvernay.

• Mapping incorporates:
  – True vertical depth
  – Source rock analysis
  – Geothermal Gradient
  – Magnetic Surveys
  – Other geologic controls
  – Condensate yields from producing wells

• Maturity mapping is a key factor in economic viability based on commodities.

Geological Data + Production Data = Thermal Maturity Mapping
• One of the most active areas in the Basin (~125 producing wells)
• Predominantly Oil Window
The East Basin is comprised of interbedded organic rich layers and fractured carbonates.

Unlike the West basin which is predominantly has “organoporosity”, the East basin has a mixed porosity system of organoporosity, matrix porosity and fractures.

Oil may need to be mature enough (higher API) to migrate into the carbonate fracture porosity.
Early indications in the East Basin (via GOR and API measurements) suggest a strong correlation with depth.
CAN API PREDICT WATER?

CAVEAT ALERT - SMALL SAMPLE SIZE

- Measured API’s in the East Basin appear to show a strong correlation with steady state water-oil ratios.
DENVER BASIN – NIOBRARA ANALOGY

• As with the East Basin, the Niobrara shows interbedded organic source rock with carbonate beds
• As with the WCSB, development to Northeast is up dip
• Up dip development shows higher water production
• There appears to be a tipping point with Water cuts at which oil production is significantly inhibited.
Peak oil generation occurs at and ~ Tmax of 435°C. This roughly correlates to depths as shown in RED.

Strictly generating oil may not be sufficient, maturity may need to be far enough into the oil generation to expel sufficient water to attain commercial thresholds.

The location of this threshold can fluctuate with technology, capital and prices.
• Originally developed in the gas window.
• Paramount had first step out into oil window in the south
• 2018 allowed for Oil window development in the north.
- Paramount has pacesetting wells in 39-04W5
- The recent Northern wells have inferred a large oil fairway.

The North Wells may have lower IP, but since they shallower, drill costs are cheaper.
• Quartz and TOC rich reservoir.
• Interbedded carbonate stringers.
• In the northwest of the Willesden green area, there is potential of additional HCPV within the Ireton downlapping onto the Duvernay.

• Where the Ireton carbonates directly overly the Duvernay, there is evidence of hydrocarbon charge
  – Relatively low porosity, ~2%.
  – Unknown porosity type, but NMR response has shown it to be dominantly free fluid

• Between clinforms, clay-rich Ireton shales are sandwiched between the Duvernay and clean Ireton carbonates.
• Limited well control, but clinoform carbonates can be correlated relatively well.
• Results in the Ireton map at left showing “pods” of clinoform carbonate that falls within defined standoff height of the top of the Duvernay.
PEMBINA OIL WINDOW

- First Tested by Sinopec in 2012.
- Teine (2018) has drilled 3 wells delineating the play.
• Teine’s initial production shows rates of up to 200 BOPD.
• The 02-05-047-09 Sinopec wells may not be representative of what the reservoir can deliver as it was D&C in 2012.
• Carbonate thickness increases from West to East.
• Effective TOC rich reservoir near Teine wells is only ~15meters.
• Frist Wells Drilled by Vermilion and CNRL (2011-2014) – Dry Gas
• Crescent Point shows the Volatile oil window is productive.
• The Crescent Points well is the first well in this part of the basin.
• Resulted in peak production of ~150 BOPD.
• Lots of running room in Cond, and Oil windows.
• Moving from West to East, Carbonate thickness increases dramatically.
• Due to the carbonate thickness increasing, organic rich zones decrease to about 10 meters.
• Kaybob – Origin of the Duvernay Play
• Operators are moving from the condensate window to the oil window
There has been lots of recent activity in Kaybob, particularly the Oil Window.

Reservoir Gross thickness and HCPV thin to the North East. (45m to ~25m)

Dozens of wells have been licensed or D&C in the Oil window, even in further step out areas around the Sturgeon Reef.

With large completions, initial results look promising.
• The Duvernay is a complex system, not just a blanket shale.

• Once a productive edge has been characterized, the East Basin has potential for blanket development.

• In the Willesden Green/Pembina/Edson areas, technological advancements have shown a productive (and potentially economic) oil window exists.

• Kaybob is not a one trick pony. Operators are moving from the liquids rich gas areas into the full oil window, by utilizing larger completions.
THANKS

Thank You to all of the clients we have worked with on the Duvernay. We truly appreciate your support.

+ many other operators and financial institutions
QUESTIONS?

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