SETTING THE STAGE:
AN OVERVIEW OF THE DUVERNAY SUB-PLAYS
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INTRODUCTION

• Quick overview of Geography
• Geology
  – Regional deposition
  – Thermal maturity controls and mapping
  – Area comparisons
• Learnings from Kaybob and Willesden Green
• New lessons from the East Basin
• Quick Review
• Q&A
GLJ EXPERIENCE

- GLJ has evaluated significant portions of the Duvernay across all the development areas
- GLJ has also provided technical support on various A&D transactions:
  - Encana / PetroChina
  - Chevron / KUFPEC
  - Vesta / Riverstone
  - Artis / Warburg Pincus
DEPOSITION

- Basin filling sediment, 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 carbonate dominated
STRUCTURE AND THICKNESS

- Depth plunges from NE to SW (~2,200m to ~4,000m Drill depth)
- Thickest reservoir is in East Basin
THERMAL MATURITY MAPPING

- Thermal Maturity predicts hydrocarbon types, and can influence HCPV
- Mapping incorporates:
  - Burial depth
  - Source rock analysis
  - Condensate yields from producing wells
  - Other geologic controls...

- Maturity mapping is a key factor in economic viability based on commodities.
- Improvements in well design have increased the size of the economically viable area, but eventually the reservoir sets the limit.
THERMAL MATURITY IS NOT 1:1 WITH DEPTH

- Expected hydrocarbon type follows depth somewhat, but there are other controls which impact thermal maturity.
Where underlying structural highs exist, differences in thermal maturity can occur.

In Kaybob:
- over Swan Hills platform highs the Majeau Lake is thin
- Hypothesis is that Majeau Lake is behaving as an thermal insulator
- Therefore, higher thermal maturity (lower CGRs) in regions of thin Majeau Lake
UNDERLYING STRUCTURE

- Example of Majeau Lake thick and Swan Hills Embayment
  - CGRs of ~400 bbl/mmcf offset by ~200 bbl/mmcf
SNOWBIRD TECTONIC ZONE

- Willesden Green Maturity contours likely influenced by Snowbird Tectonic zone
- Influence is shown at Resourceful wells in T45-46, R03-04W5
  - NW Trajectory consistently lower CGR compared to SE
• Production reporting makes it difficult to quantify O+CGR ratios across the fairway
• GLJ has used the ‘high confidence production data’ to find other public data sources to contour thermal maturity
Available CGR data, in conjunction with gas analysis, data provides a (relatively) strong correlation.

Correlation helps corroborate thermal maturity interpretation in absence of ‘real’ production data.
MINERALOGICAL DIFFERENCES (WEST VS. EAST)

- Quartz dominated vs Carbonate dominated.
- Generally higher clay volumes associated with quartz.
• Continuous package of >2% TOC in West Basin

• Highly enriched organic horizons separated by organic-lean carbonate layers
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)*
CONSEQUENCE ON LOG ANALYSIS

- Organics have a strong impact on wireline log responses
- These impacts result in strong correlations
- West Basin Duvernay volumes-in-place are more readily determined utilizing regressions
KAYBOB WAS THE STARTING POINT

Kaybob is thick, has high HCPV, and was a look-alike to other shale developments at the time.
Kaybob has set the pace, but East Basin producing well counts surpassed Willesden Green early in 2018 behind development by Vesta and Artis.
Kaybob Activity to date has been weighted toward the condensate window (100-400 bbl/mmcf)
Primarily Shell and Encana/PetroChina
CIOOC, Hitic and Murphy/Athabasca are actively testing the oil window
Grouping wells by performance compared to “peer group” allows us to isolate influence of the Reservoir (Volumetrics) compared to influence of liquids.
Concentration of strong results likely related to higher pressure and gradients

Concentration of strong results likely related to HCPV
Note the comparison between Simonette North and South for similar condensate yields.

This disparity in results is reflected in the respective GLJ type curves and is influenced by:

- HCPV
- Absolute pressure and degree of overpressure
General Trend – MORE length, MORE stages, MORE sand, TIGHTER spacing
IMPACT OF COMPLETIONS ON OIL WINDOW (KAYBOB)

Sand and Rate are Correlated

Murphy 00/05-09-065-20W5 – completed with ~327 T/100m
Activity to date has been weighted toward the condensate window (100-400 bbl/mmcf)...

But recent activity by 1) Raging River (Baytex), 2) Crescent Point, and 3) the JV of Kiwetinohk and Journey will likely result in increased activity in the oil window.
WILLESDEN GREEN DISTRIBUTION OF RESULTS

EUR/RATE DISTRIBUTIONS BY MATURITY TIER - WILLESDEN GREEN AREA - SHRUNK GAS - EUR per 100T

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HOTSPOTS / DFIT PRESSURE GRADIENTS – WILLESDEN GREEN

Concentration of strong results in south portion of Willesden Green.
Including Paramount’s 13-05 well.
• West Basin is what we knew, and East Basin looked different…

• What indicates pay in the absence of TOC?
Jarvie (2011) refers to oil effect and why hybrid systems are beneficial for oil flow

Oil Effect is when S1/TOC > 1

Significant proportion of carbonate-rich reservoir showing oil effect.
2 early wells (00/05-18-034-24W4 and 00/08-20-033-24W4/0) completed with open hole technology.

The results were...less than spectacular compared to Cased well design.
Early development in Westerdale showed promise in adding entry point density

- Blue - ~12 m between perfs
- Green - ~6 m between perfs

But there appears to be a limit to these gains, as early results at tighter density (Red - ~4 m between perfs) are uncertain but have trended backwards

Do tighter perforations start to trend toward open-hole results and less fracture complexity?
Splitting results from the East Basin by Perforation intensity...
• Though not definitive binned results for Westerdale show improved results from NE to SW
• Mineralogy and interbedded hybrid system supporting improved results?
  – Or is it just Higher maturity with depth
  – Or just randomness and small sample size?
THERMAL MATURITY IS NOT (ALWAYS) 1:1 WITH DEPTH

- Early indications in the East Basin (via GOR and API measurements) suggest a strong correlation with depth
DIFFERENCES WITHIN THE EAST BASIN

Higher Clay and Quartz content with continuous TOC

Are interbedded TOC and carbonate rich lithology supporting results...or is it just ‘h’
Thickneses in the east trend significantly thicker than Kaybob, but HCPV is mitigated by the much lower average porosity (2-4% in the East compared to 4-6% in the West)
Note that despite the growth in sand intensity in the West Basin, to date the East Basin has remained relatively timid in its completions.
PACE SETTING OIL WELLS TO DATE
(*WITH COMPLETION DATA AVAILABLE)

Pace setting wells
00/05-09-065-20W5,
00/07-11-039-28W4,
02/14-06-032-24W4
compared to other Kaybob Results to date
SUMMARY

WEST BASIN
- Full spectrum of thermal maturity
- Quartz-dominated
- Continuous organic-rich sections
- Strong organic porosity component
- Proven commercial in the condensate window
- Oil Window results continue to improve with completions
- Development in the oil window comparable to East Basin in Kaybob, lagging in Willesden Green

EAST BASIN
- Primarily Oil Window
- Carbonate-dominated
- Interbedded organic horizons
- Much more mixed porosity system
- Proven to be commercially viable in some areas
QUESTIONS?

THANK YOU

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