



Efficient Resource Development – Think Deep!

CSUR Technical Luncheon Series

December 5, 2012



Presentation Outline

- The Duvernay
 - Introduction
 - Duvernay Overview
 - Activity Summary 2011/2012
 - Greater Kaybob Area Focus
- Wellbore Design Considerations
- Optimizing Treatment Design
- Operational Efficiencies
- Concluding Remarks
- Questions

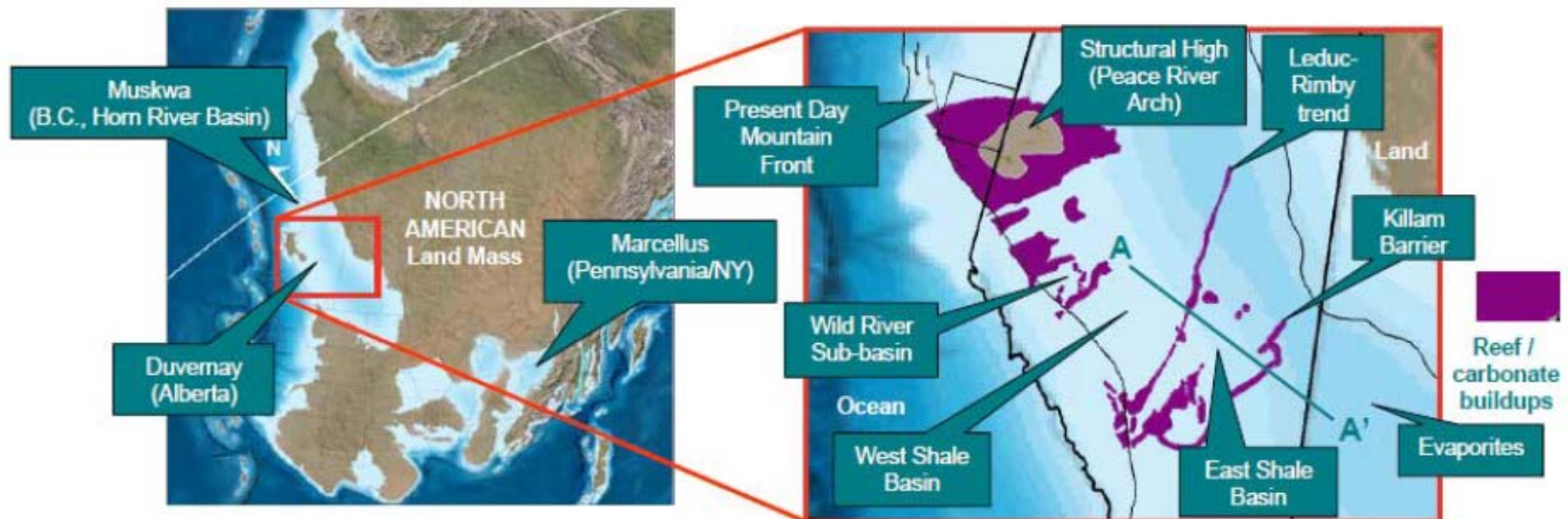
Efficient Resource Development

- One of Canada's most prolific resource plays
- Over \$4.5B spent on land sales in the last three years
- Associated high drilling and completion costs
- Economic viability of the play is front and center
- Drilling and completion efficiencies are proving to be instrumental at this stage
- Preliminary learnings will be critical to the long term development of the play

Duvernay Overview

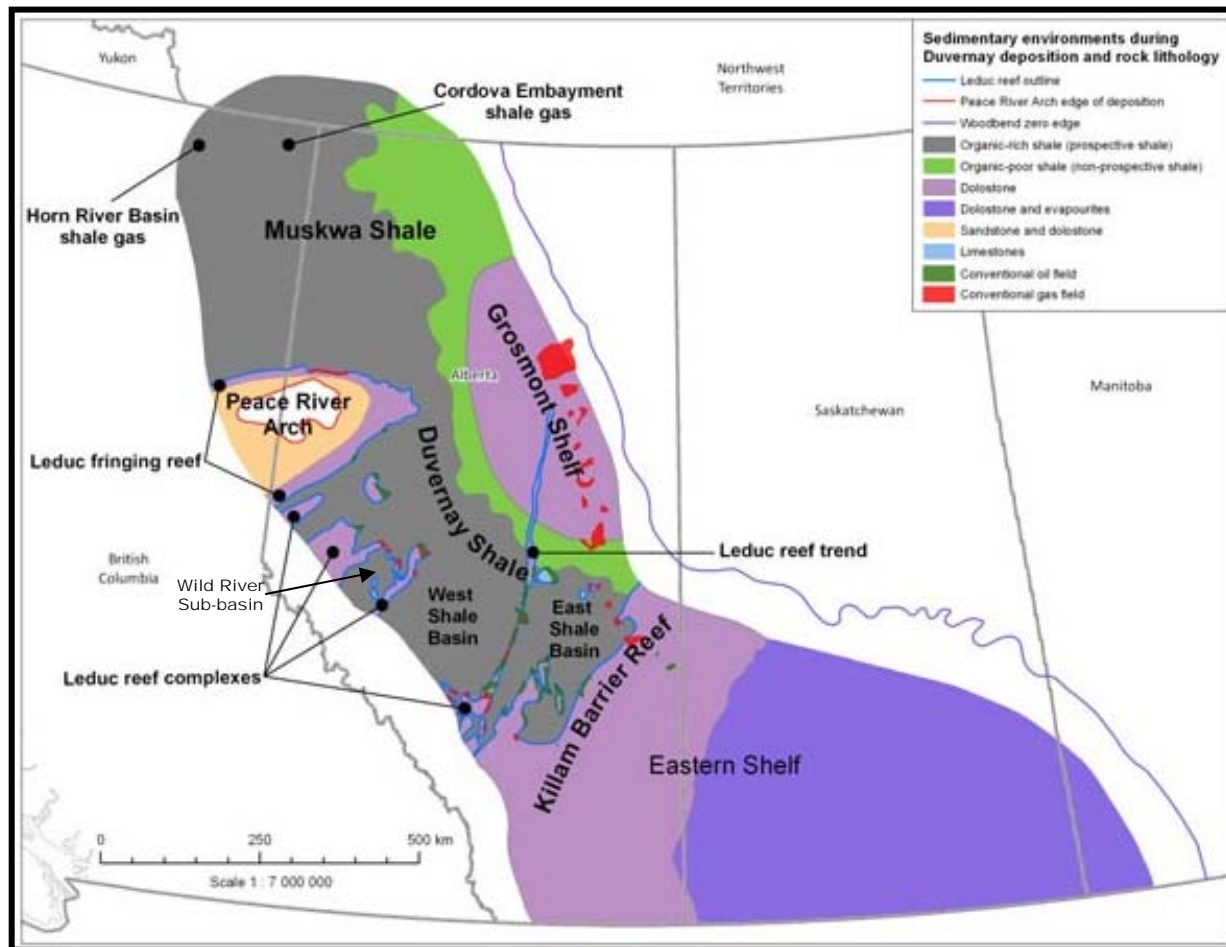


| Age | System | Series | Stage | Alberta | Texas | Appalachian |
|--------|---------------|--------------|--------------|---------------------|----------|-------------|
| 320 | Carboniferous | Late Miss. | Serpukhovian | | | |
| 340 | | Middle Miss. | Visean | | Barnett | |
| 360 | | Early Miss. | Tournaisian | Banff | Woodford | |
| 380 Ma | Devonian | Late | Famennian | Exshaw | | |
| | | | Frasnian | Duvernay/ Muskwa | | Rhinestreet |
| | | Middle | Givetian | Otter Park | | |
| | | | Eifelian | Evie | | Marcellus |
| | | Early | Emsian | | | |
| 400 | | Pragian | | | | |
| 410 | | Lochkovian | | | | |
| | | Lutetian | | | | |



Blakey <http://jan.ucc.nau.edu/~rcb7/namD385>, Dunn, L., Schmidt, G., Hammermaster, K., Brown, M., Bernard, R., Wen, E., Befus, R., and Gardiner, S.

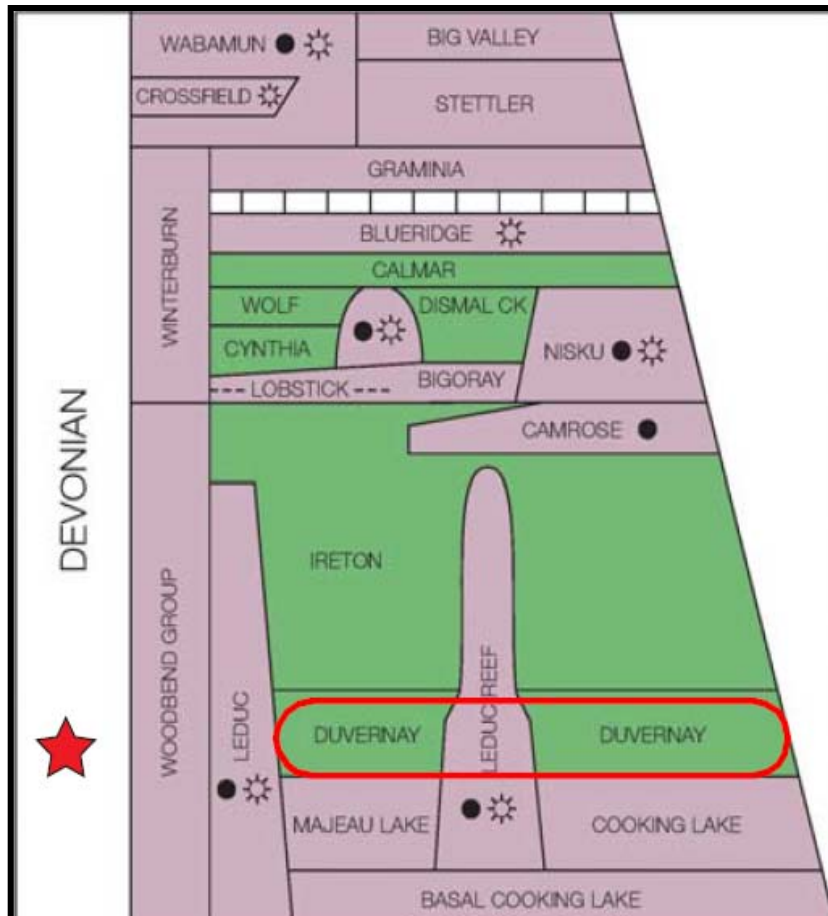
Depositional Play Extent



Source: modified from *Atlas of the Western Canada Sedimentary Basin*

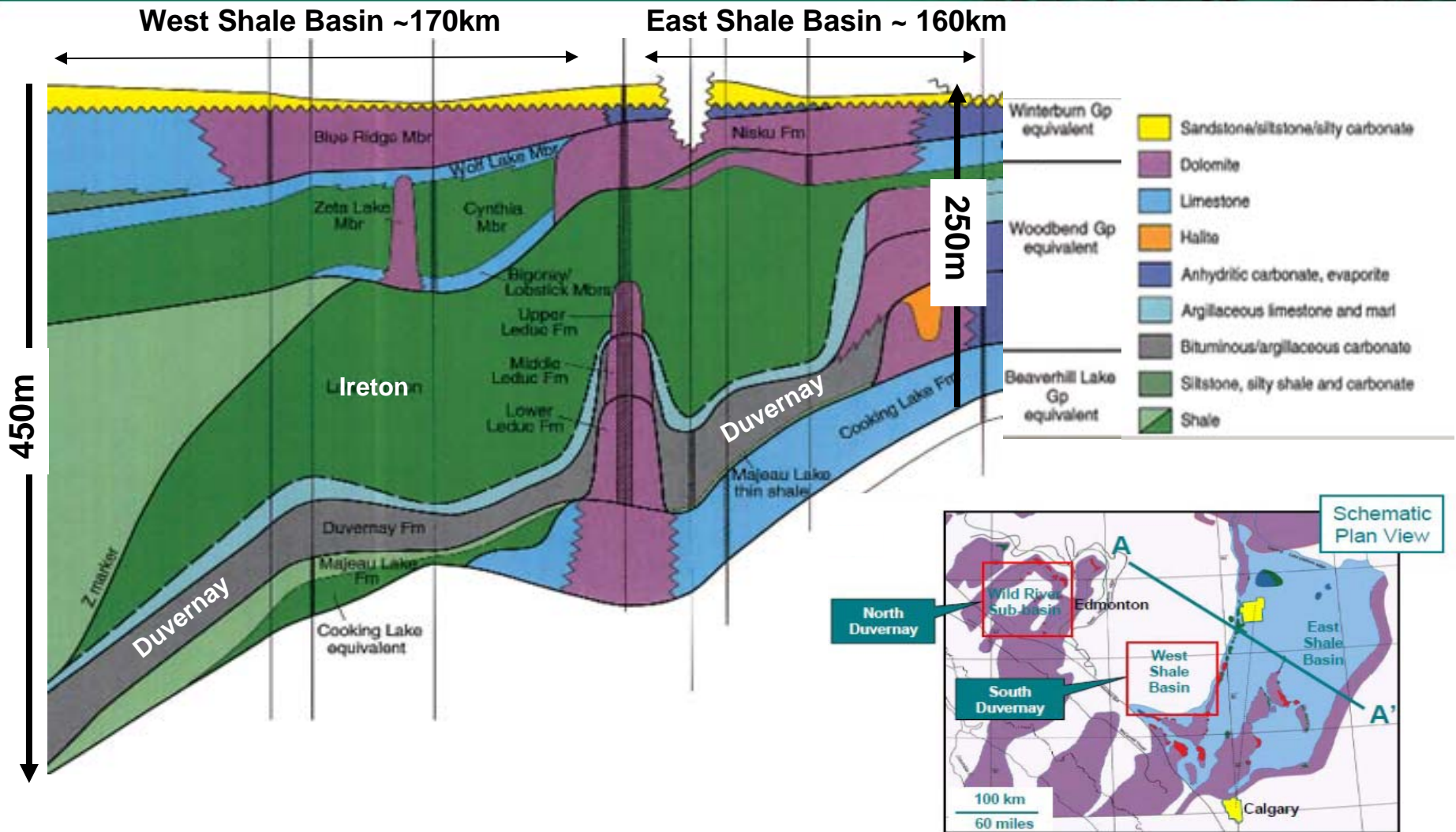
- Extent >100,000 km²
- VR₀% Equivalent Maturity ~ 24,000 km²
- Liquids-rich resource est. 2-5B bbls of liquid
- Liquids-rich window est. 7,500 km²
- ~750 Tcf of gas

Duvernay Key Attributes



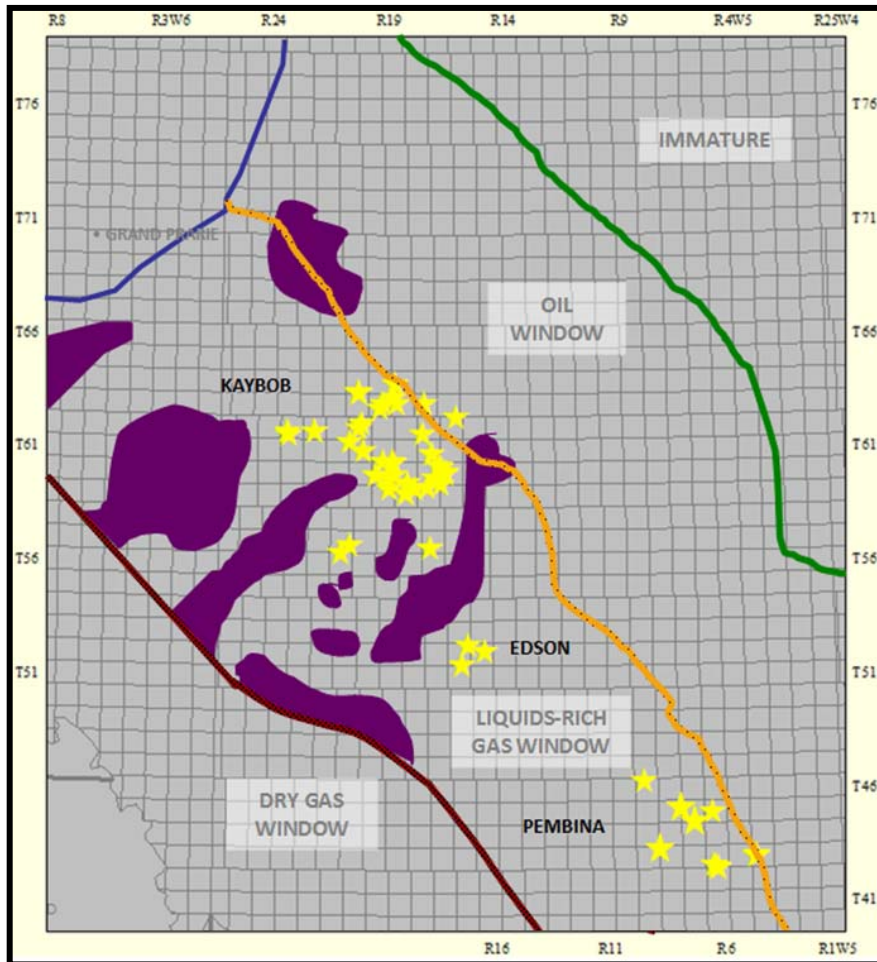
- Depth: 2400-4000m
- Thickness: 10-70m
- TOC: 1-20%
- Porosity: 3-15%
- Permeability: nD to μ D
- Complex Mineralogy
- Pressure: Normal to Overpressured

Duvernay Overview



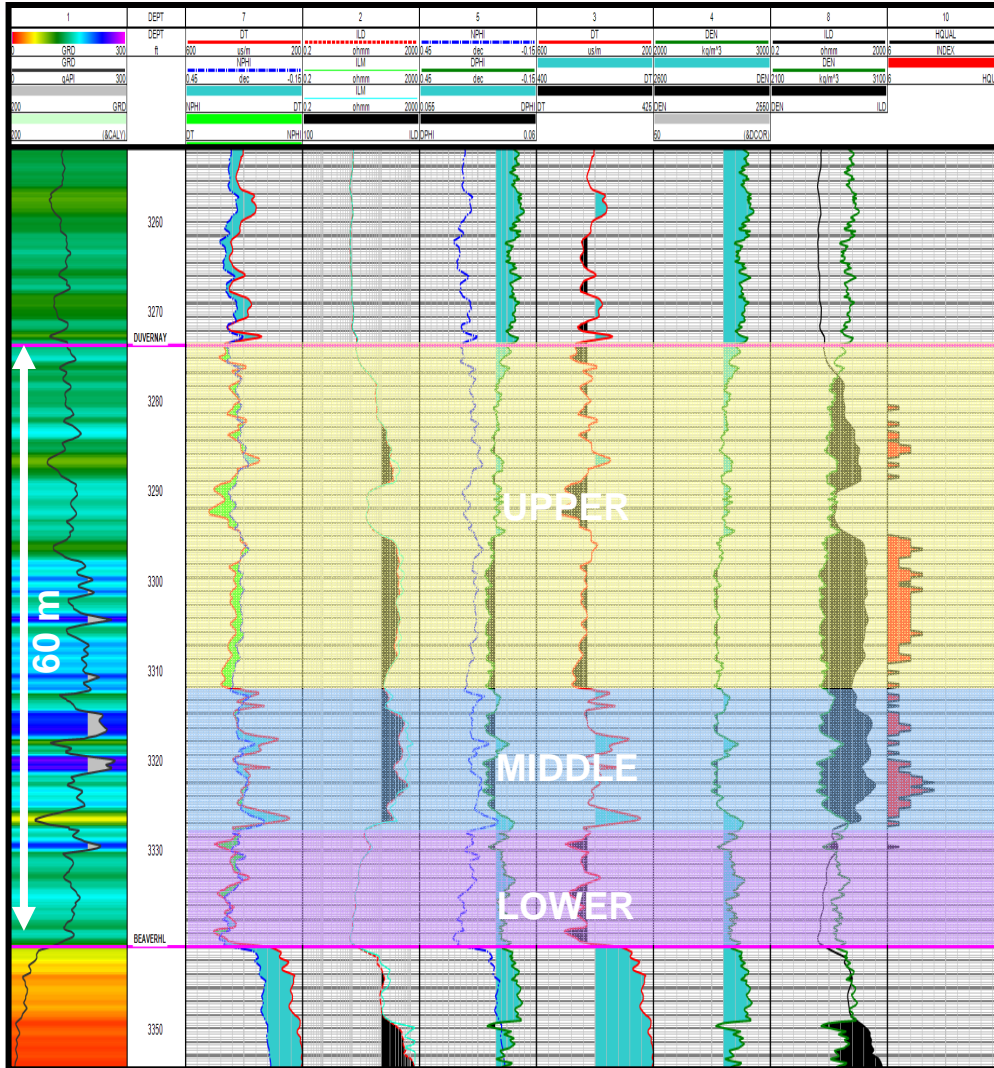
Switzer et al., Dunn, L., Schmidt, G., Hammermaster, K., Brown, M., Bernard, R., Wen, E., Befus, R., and Gardiner, S.

Duvernay Activity – 2011/12



- >50 Wells drilled to date
- ~ 17 Vertical Wells
- ~ 10 HZ Drilled and Completed 2011
- ~ 23 HZ Drilled and Completed in 2012

Kaybob Area – Key Attributes



- Depth 3200-3800m
- Thickness 35-60m
- Maturity 1.2-1.8%
- TOC - ~4.5%
- Mineralogy
 - Quartz content 1-47%
 - Carbonate content 10-90%
 - Clay content 3-37%
- Average Porosity ~6.5%
- Average Permeability ~400nD
- Pressure Gradient 15-20 kPa/m

Reservoir Impact....Think Deep!

- Heterogeneity
- Stress Environment
- Lateral Placement / Orientation
- Fracture Initiation
- Fracture Complexity
- Fracture Width
- Fracture Conductivity
- Deliverability



Applying What We Know.....



Activity Overview

Duvernay - Per-Well Estimated Characteristics by Operator

| | Drilling Costs [C\$mm] | Liquids Cut [Bbls/MM cf] | Gross EUR [Raw Bcf/Bcfe] | Wells/ Section |
|----------|------------------------------|--------------------------------|--------------------------------|-------------------|
| Celtic | \$10.5 | 100 to 125 | 6.6 to 7.2 Bcfe | 4 to 8 |
| Trilogy | \$12.0 | 80 to 100 | 5 Bcf | 6 to 8 |
| Yoho | \$10.0 | 100 to 150 | 4.3 Bcf | 6 to 8 |
| Enerplus | \$12.0 | 75 to 100 | 3.5 Bcf | 4 |
| Mako | \$12.0 | 100 | 5.8 Bcfe | - |
| Angle | \$12.0 | 50 to 200 | 2.5 to 6.8 Bcf | - |
| Encana | \$15.0 | 100+ | 3 to 6 Bcf | - |

Notes: Approximations based on company disclosure and public data.

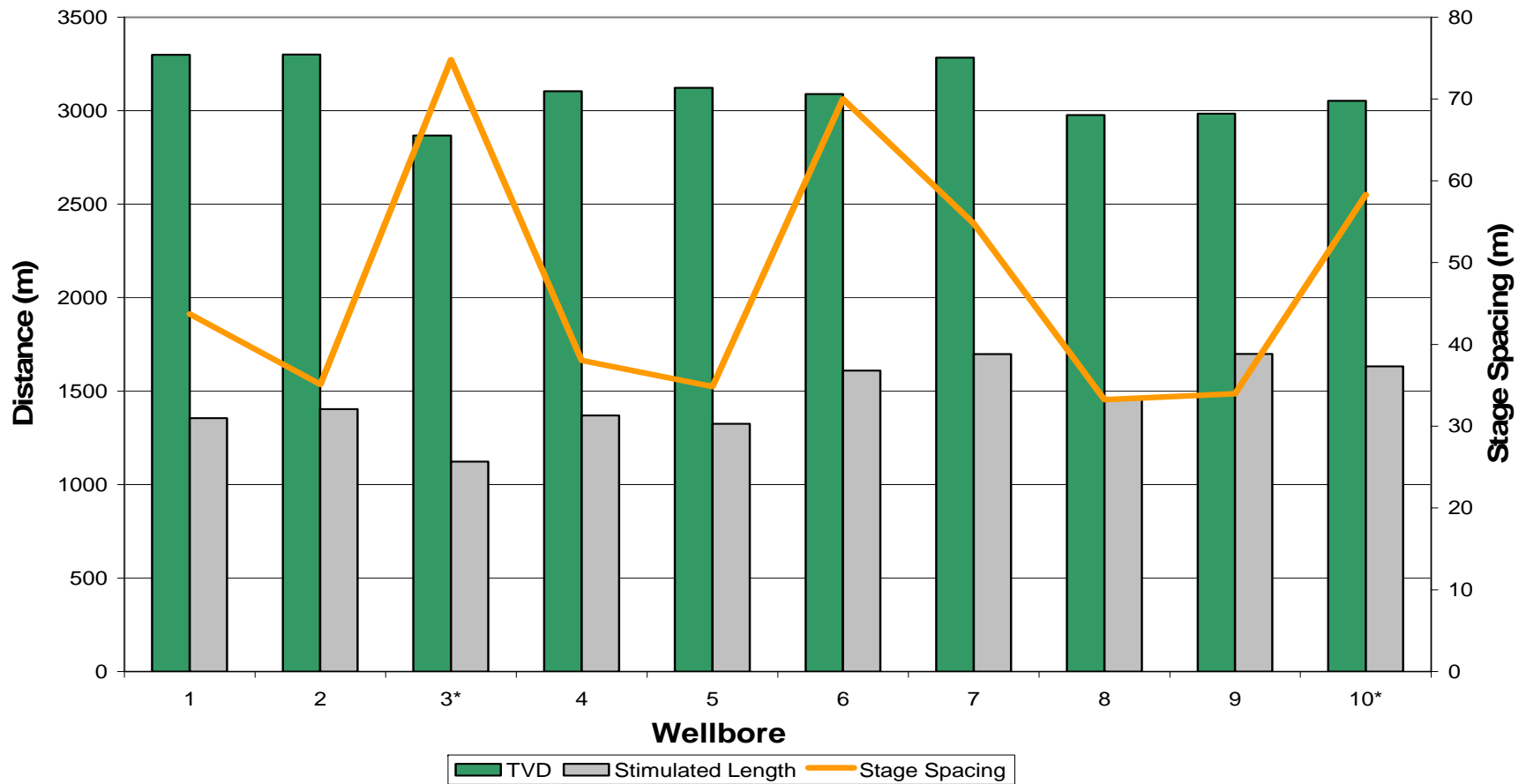
Source: Scotiabank GBM; Company reports

Activity Overview

- 10 wells in study area
 - 2 completions ongoing
- 6 Plug and Perf, 4 open Hole
- Single and Limited entry perforation strategies
- Various fluid systems
 - Slickwater, X-Linked and Hybrid
- Various Proppants
 - 50/140, 40/70 and 30/50
 - Mostly naturally occurring although some resin or ceramic tail-ins
- 2-20 m³ acid/stage

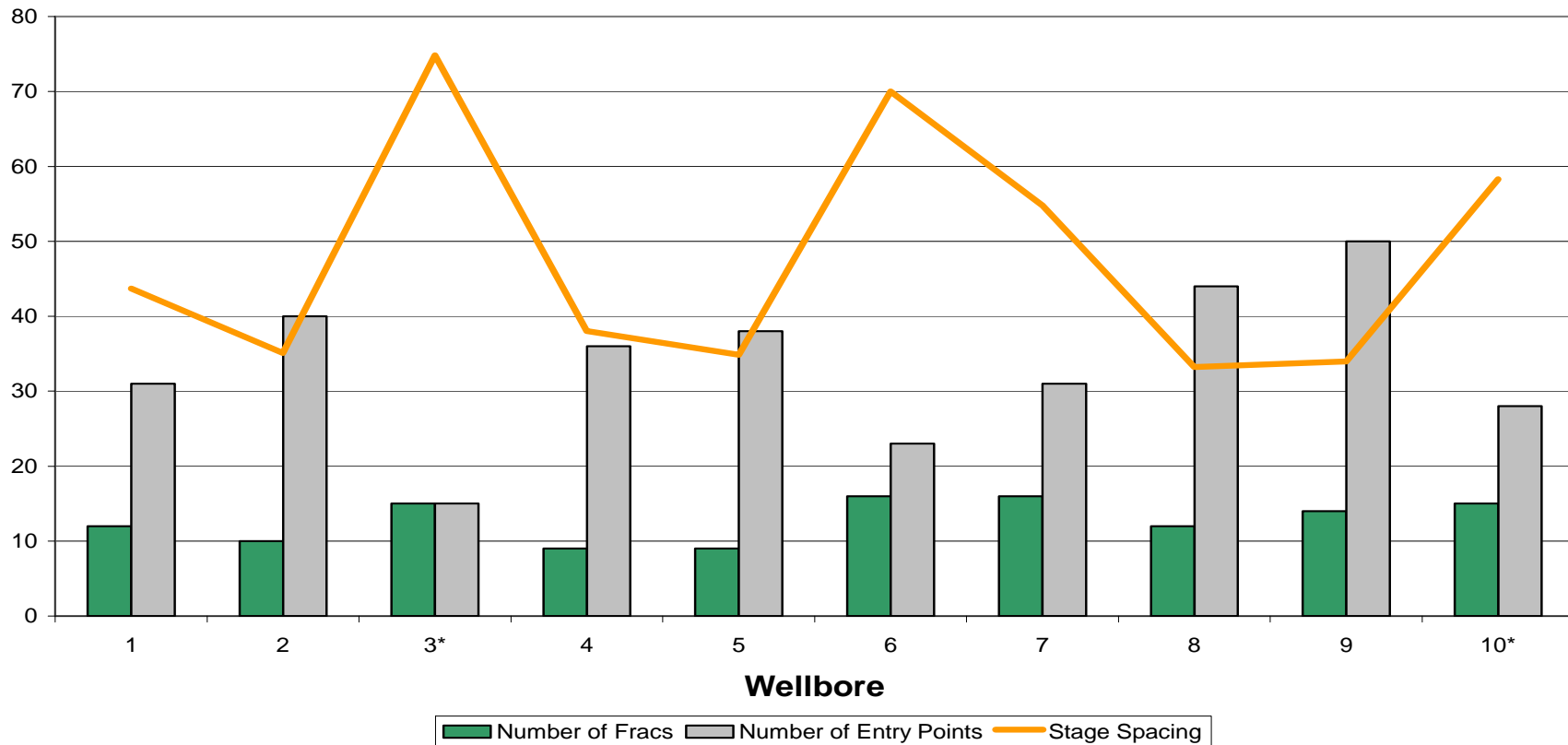
Activity Overview

TVD, Stimulated Length and Stage Spacing



Activity Overview

Number of Fracs, Number of Entry Points and Average Stage Spacing



Activity Overview

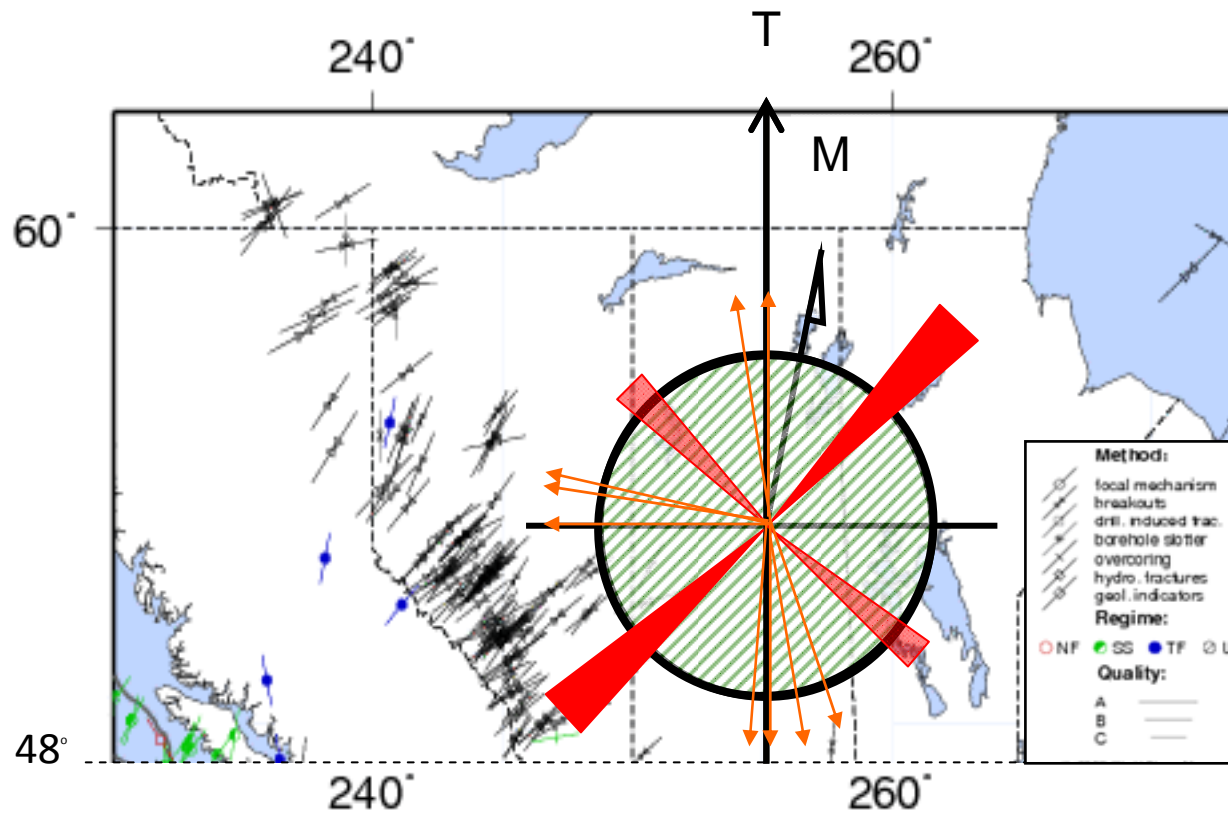
Wellbore Treatment Volumes



Wellbore Design Considerations

- Lateral Positioning
 - Azimuth
 - Lithofacies
- Wellbore Configuration
 - Cased vs. Open Hole
 - Perf Strategy
 - Tubular Specs

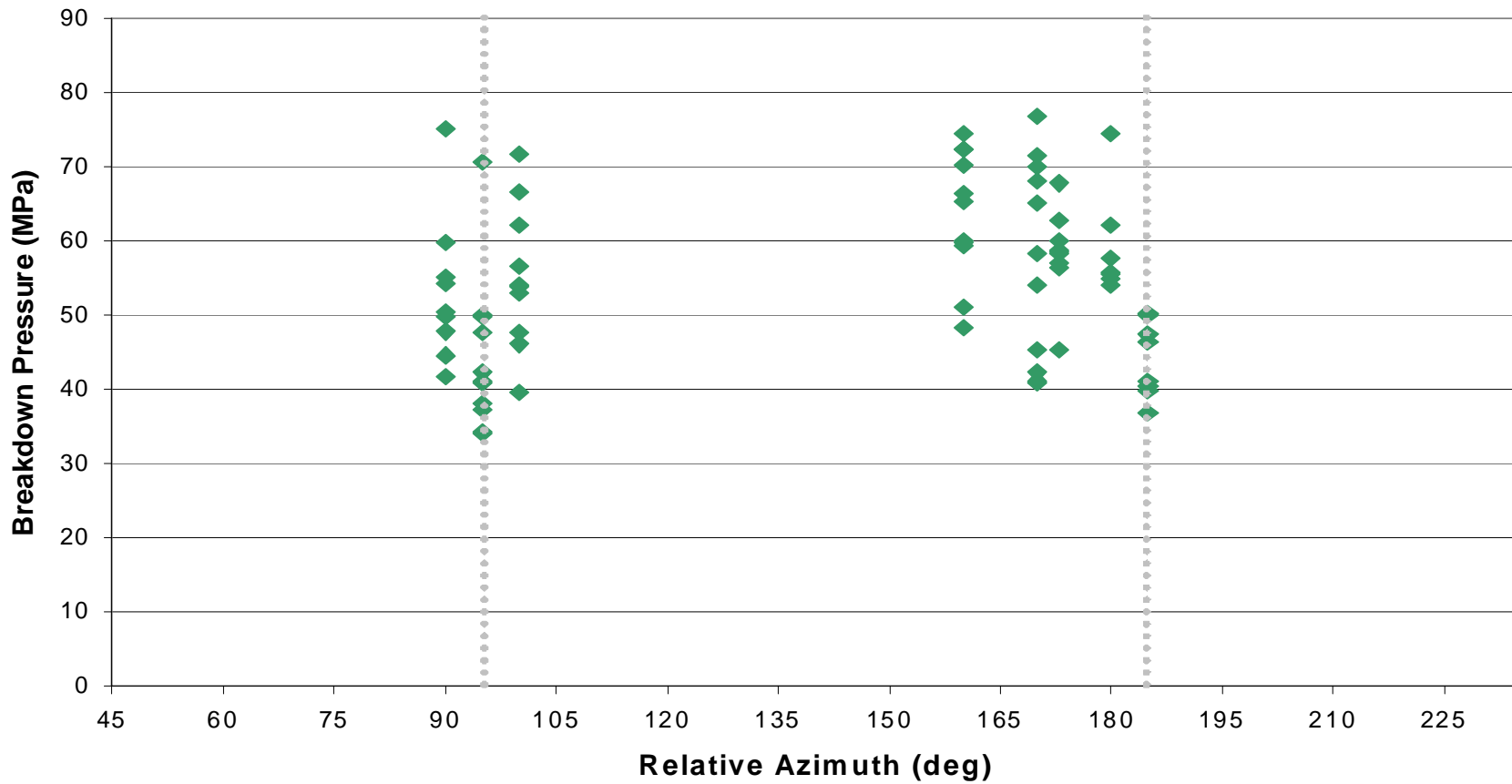
Lateral Orientation



World Stress Map Rel. 2008
 Heidelberg Academy of Sciences and Humanities
 Geophysical Institute, University of Karlsruhe

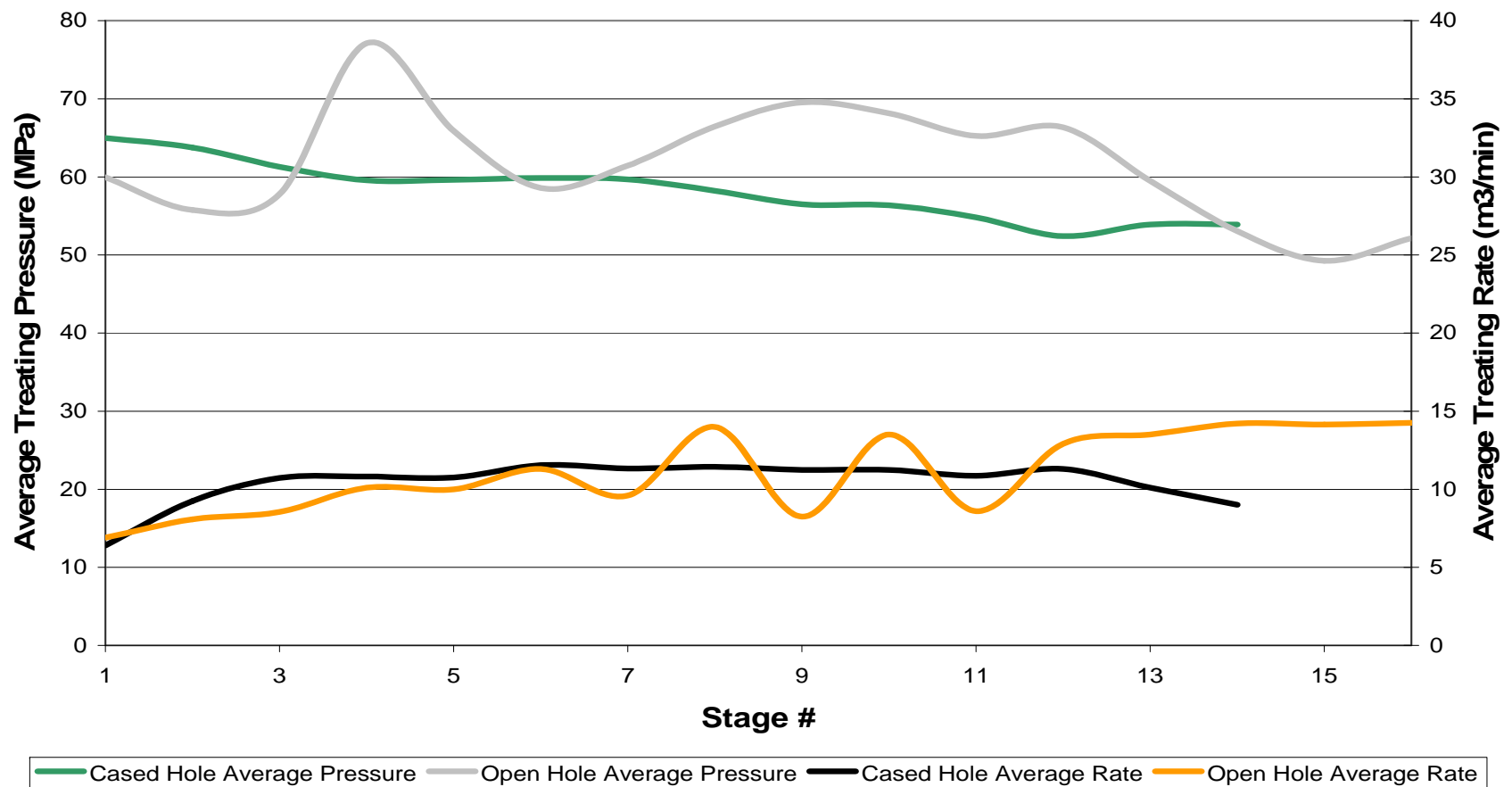
Lateral Orientation

Breakdown Pressure vs Relative Azimuth



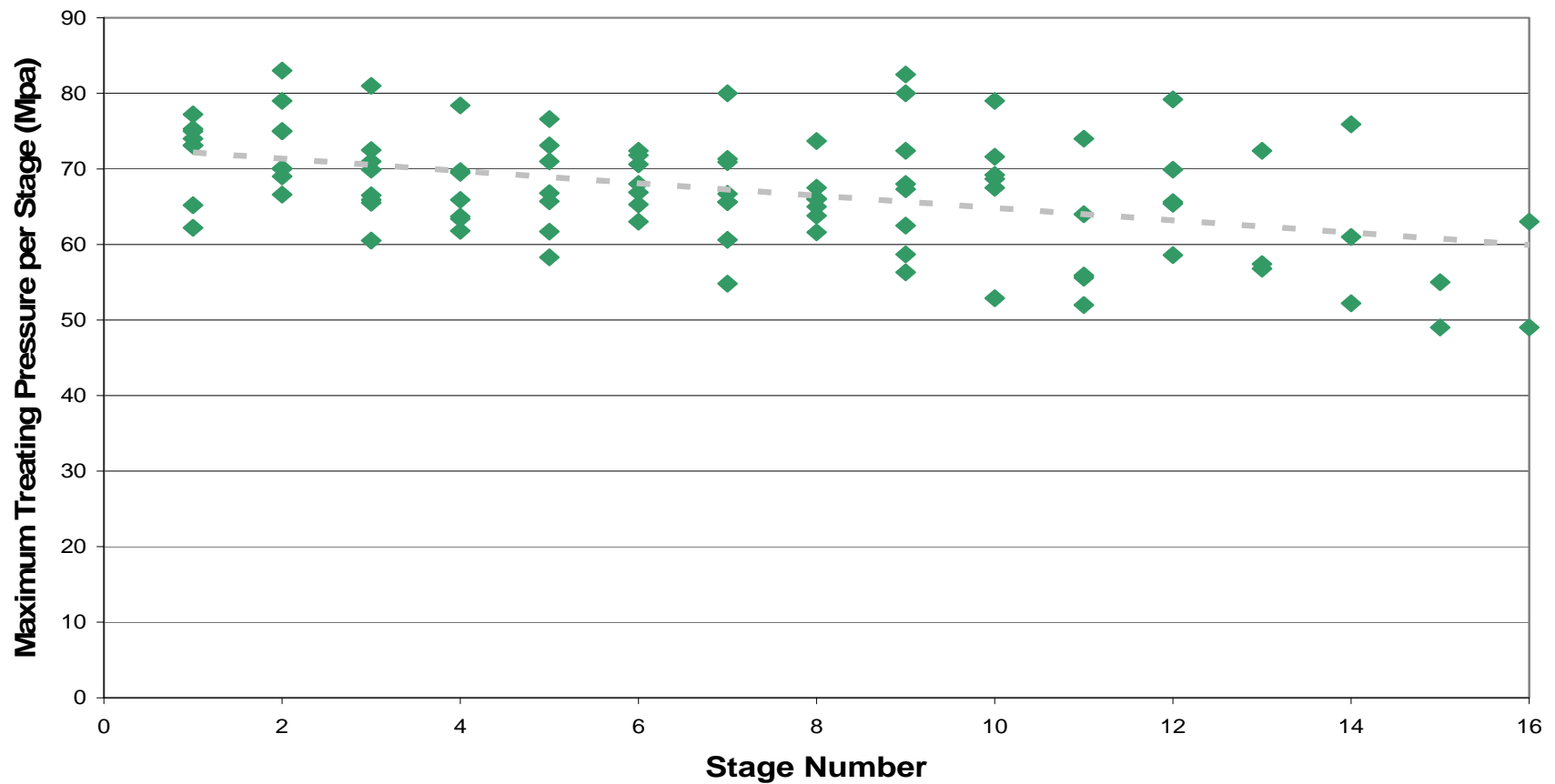
Wellbore Design Considerations

Cased Hole vs. Open Hole



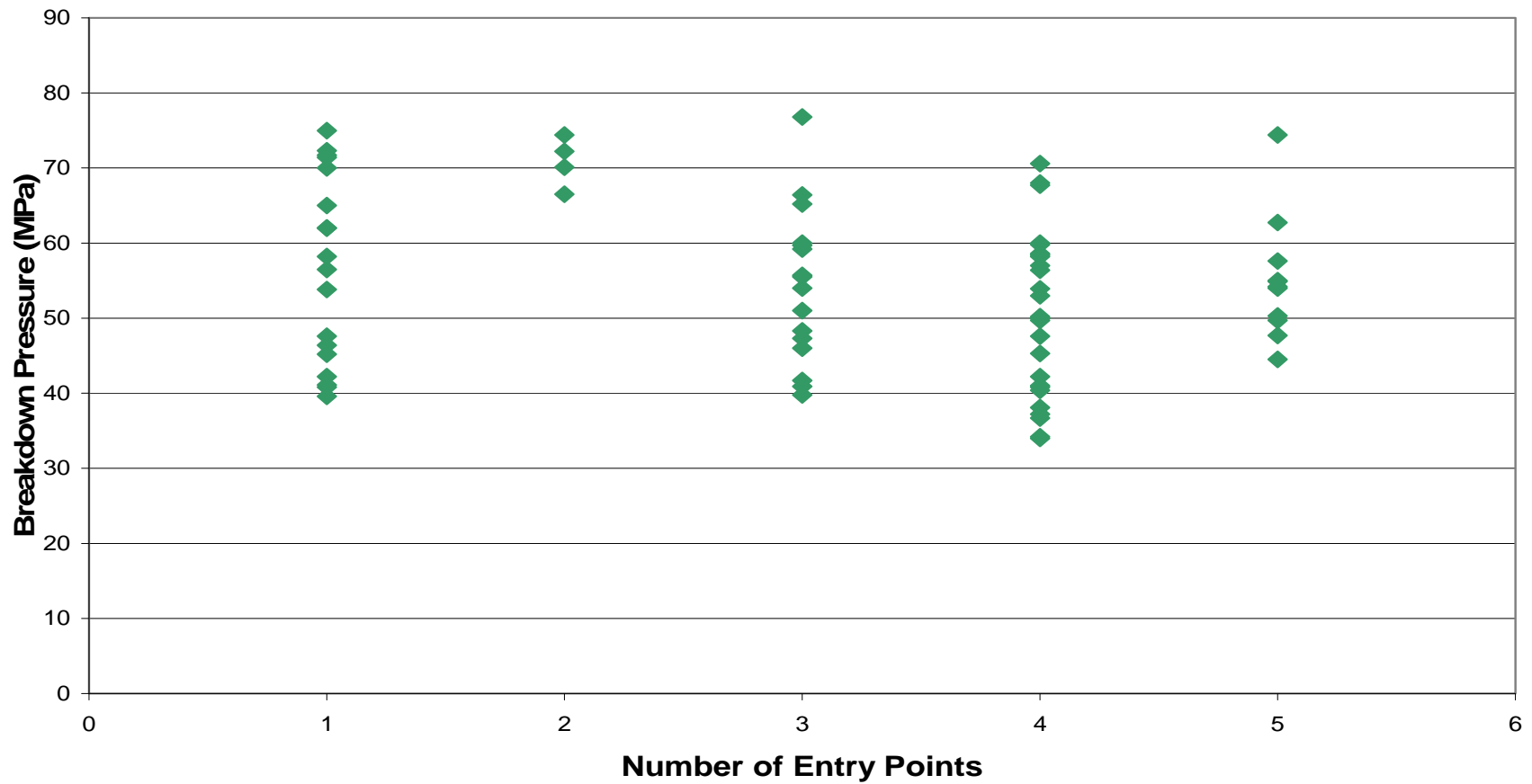
Wellbore Design Considerations

Maximum Treating Pressure vs Stage Number



Wellbore Design Considerations

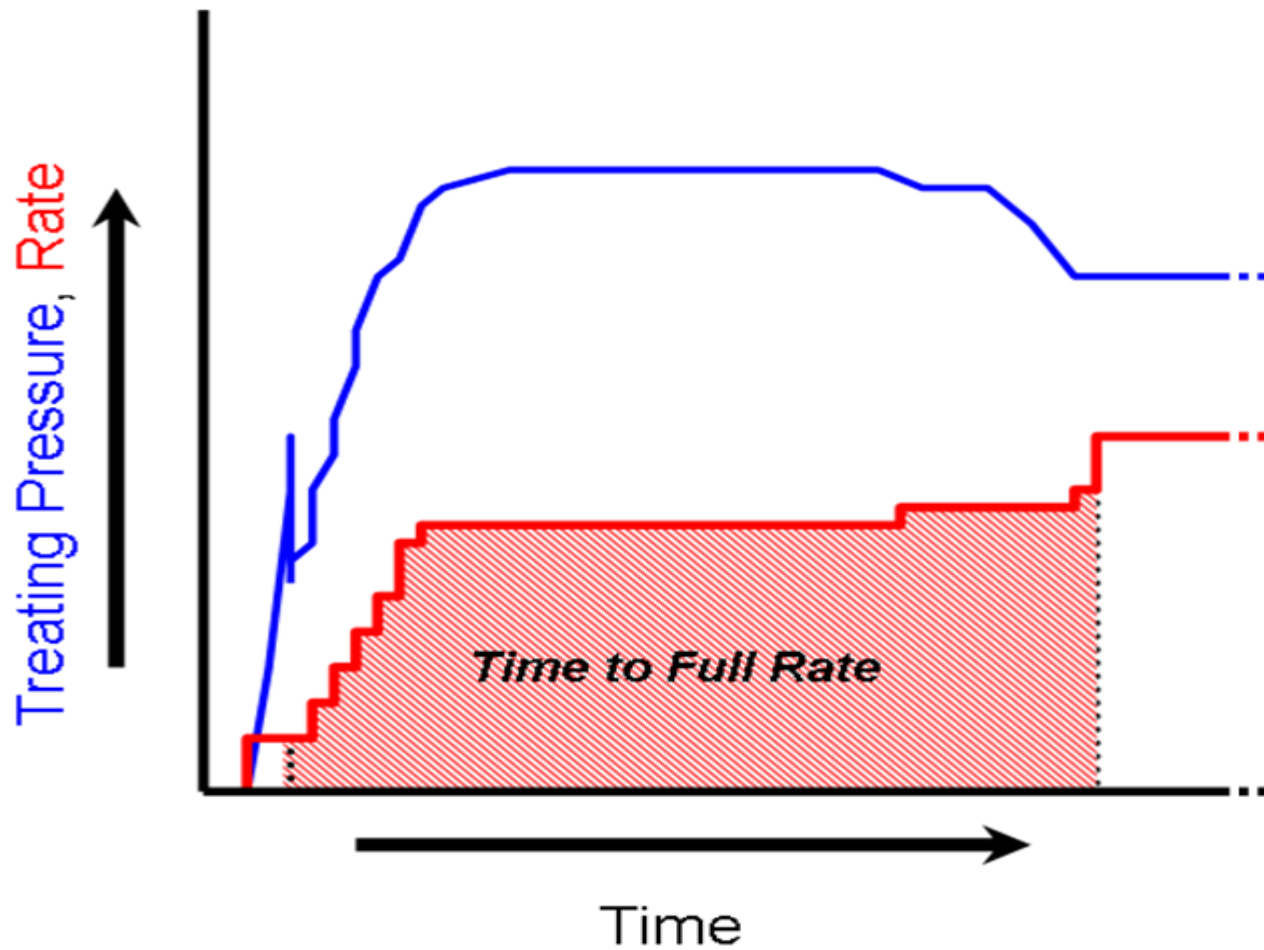
Number of Entry Points vs. Breakdown Pressure



Optimizing Treatment Design

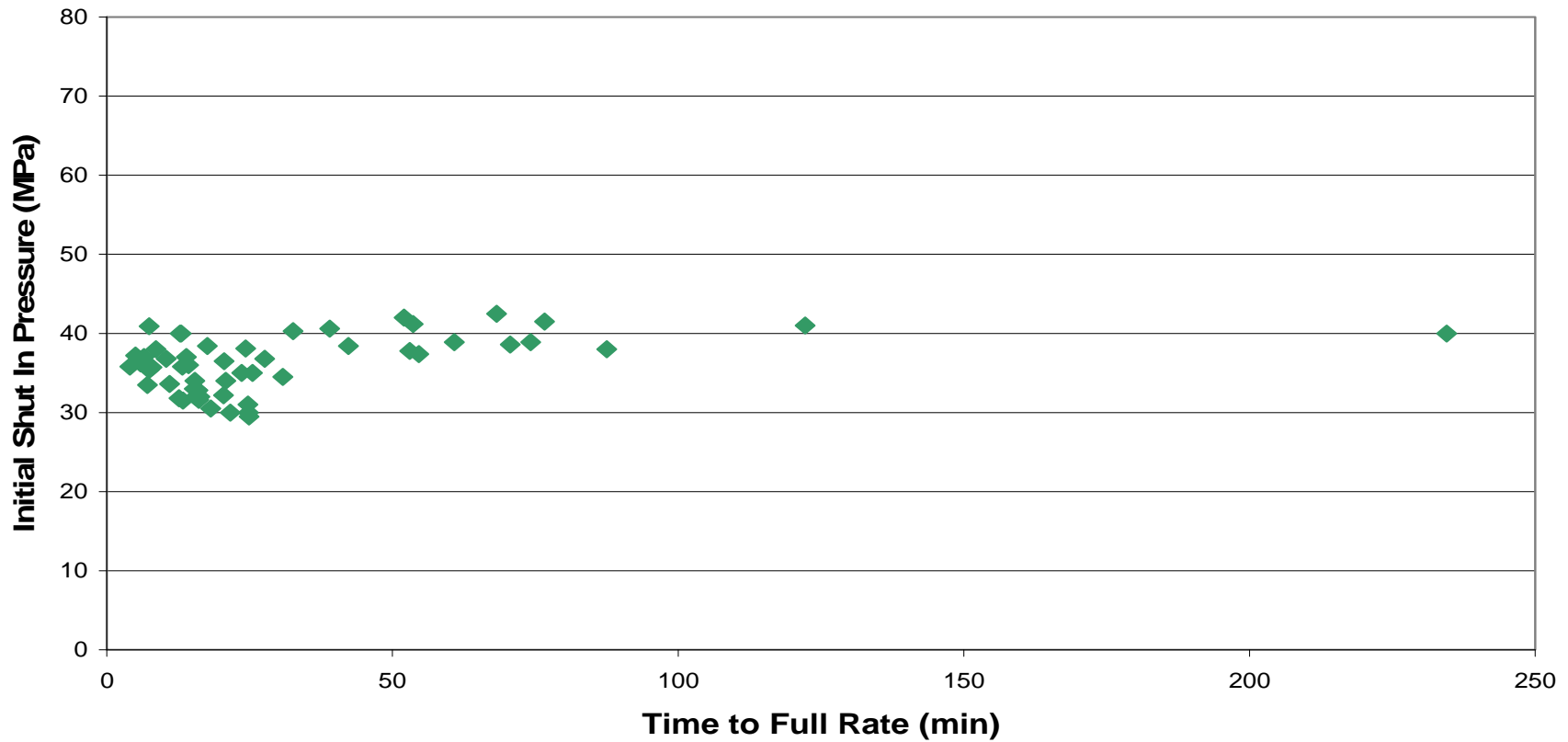
- Time to Rate
 - Initiation Variables
 - Acid Spearheads
- Proppant Selection
- Revisiting Toe Frac Design
- Operational Considerations

Time to Rate



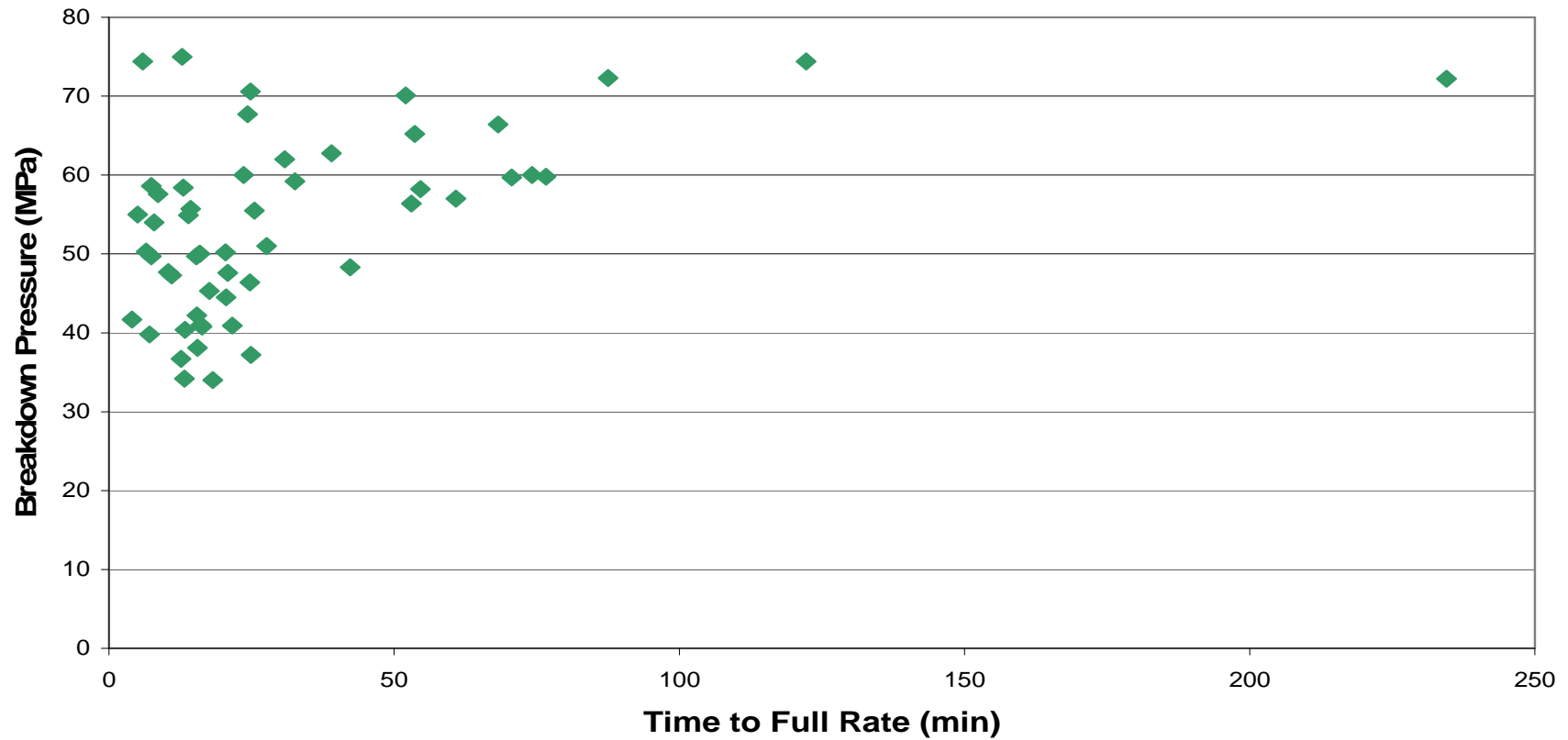
Initiation Variables

**Cased Hole
ISIP vs Time to Full Rate**



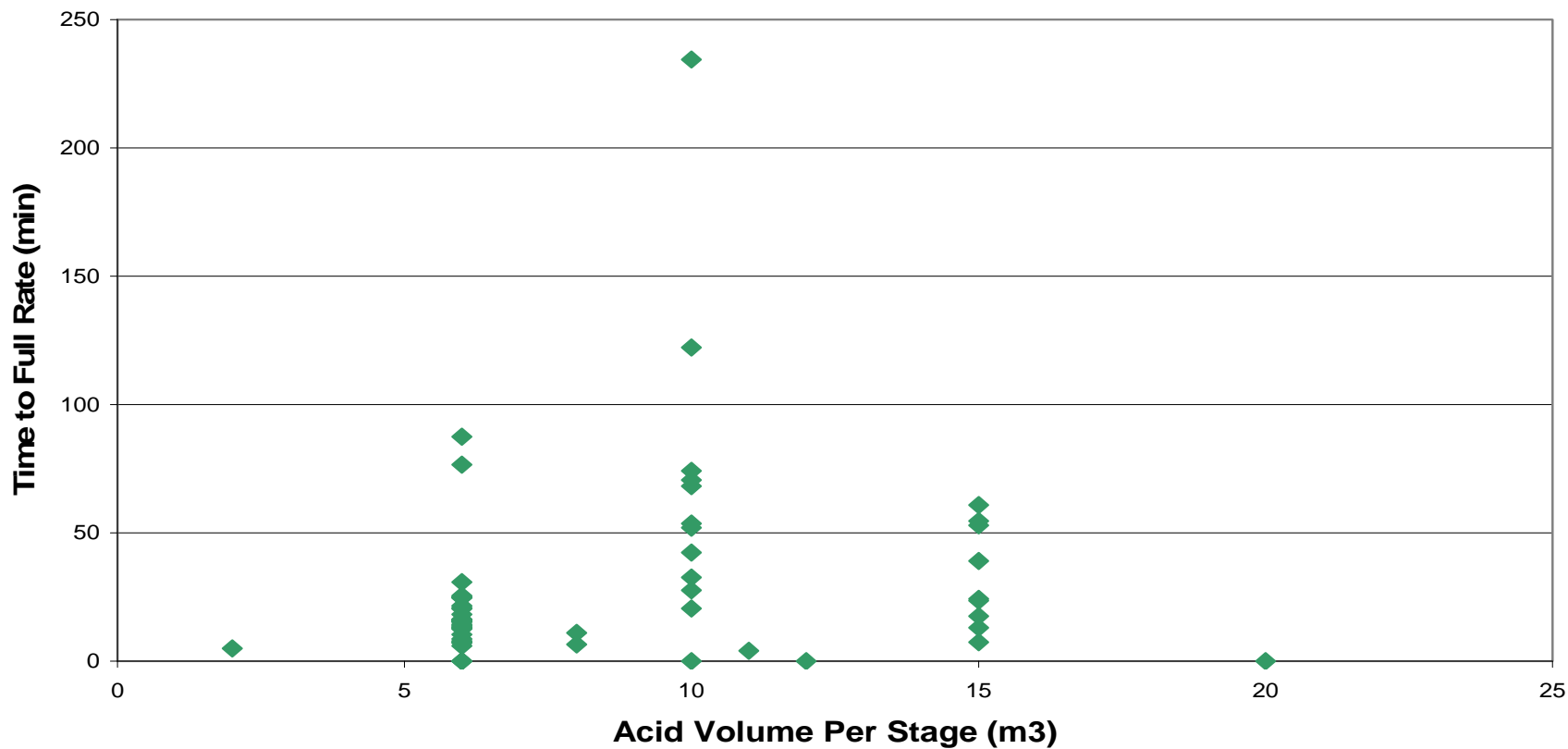
Initiation Variables

**Cased Hole
Breakdown Pressure vs Time to Full Rate**



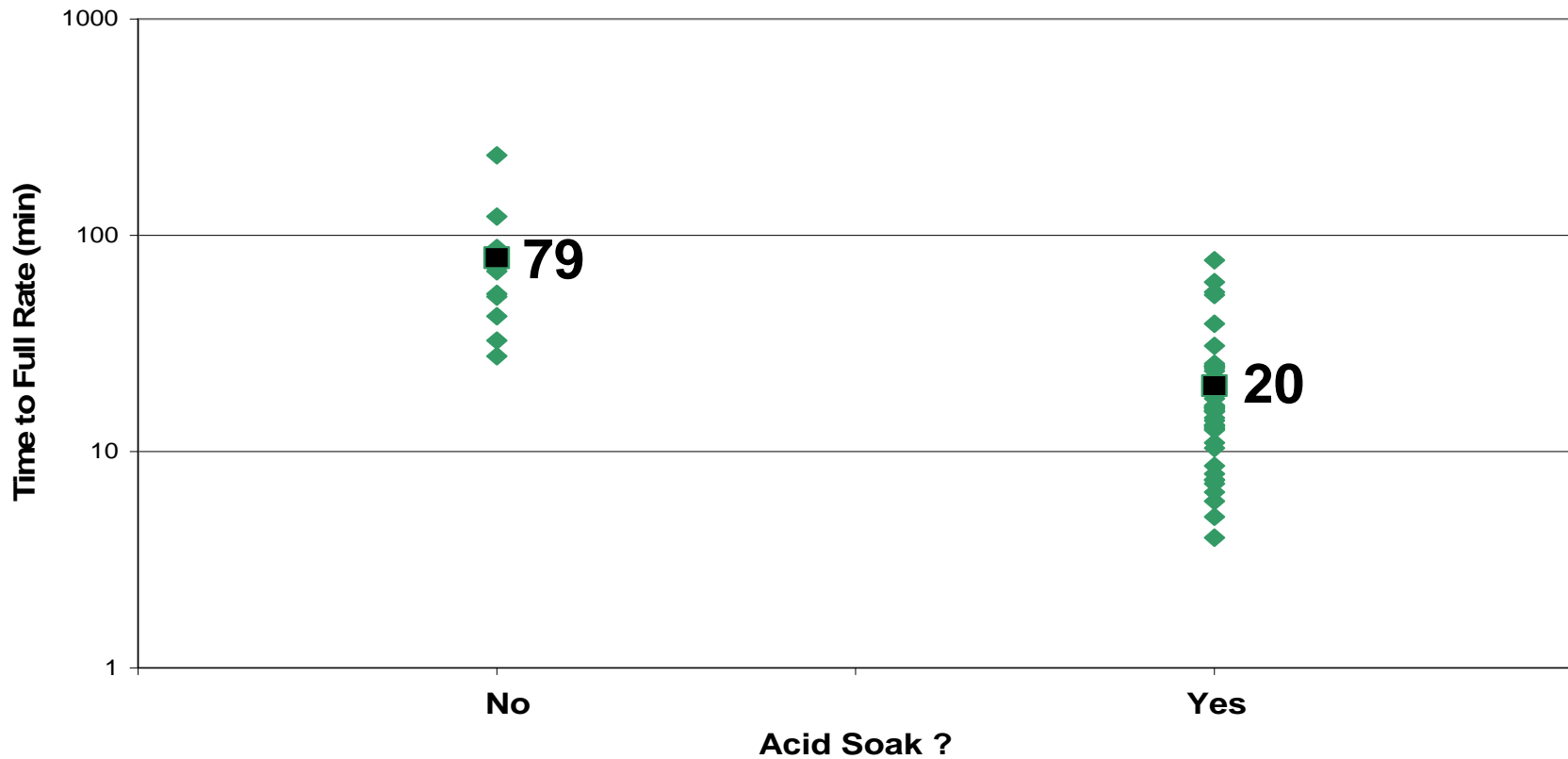
Acid Spearhead Design

**Cased Hole
Time to Full Rate vs Acid Volume**



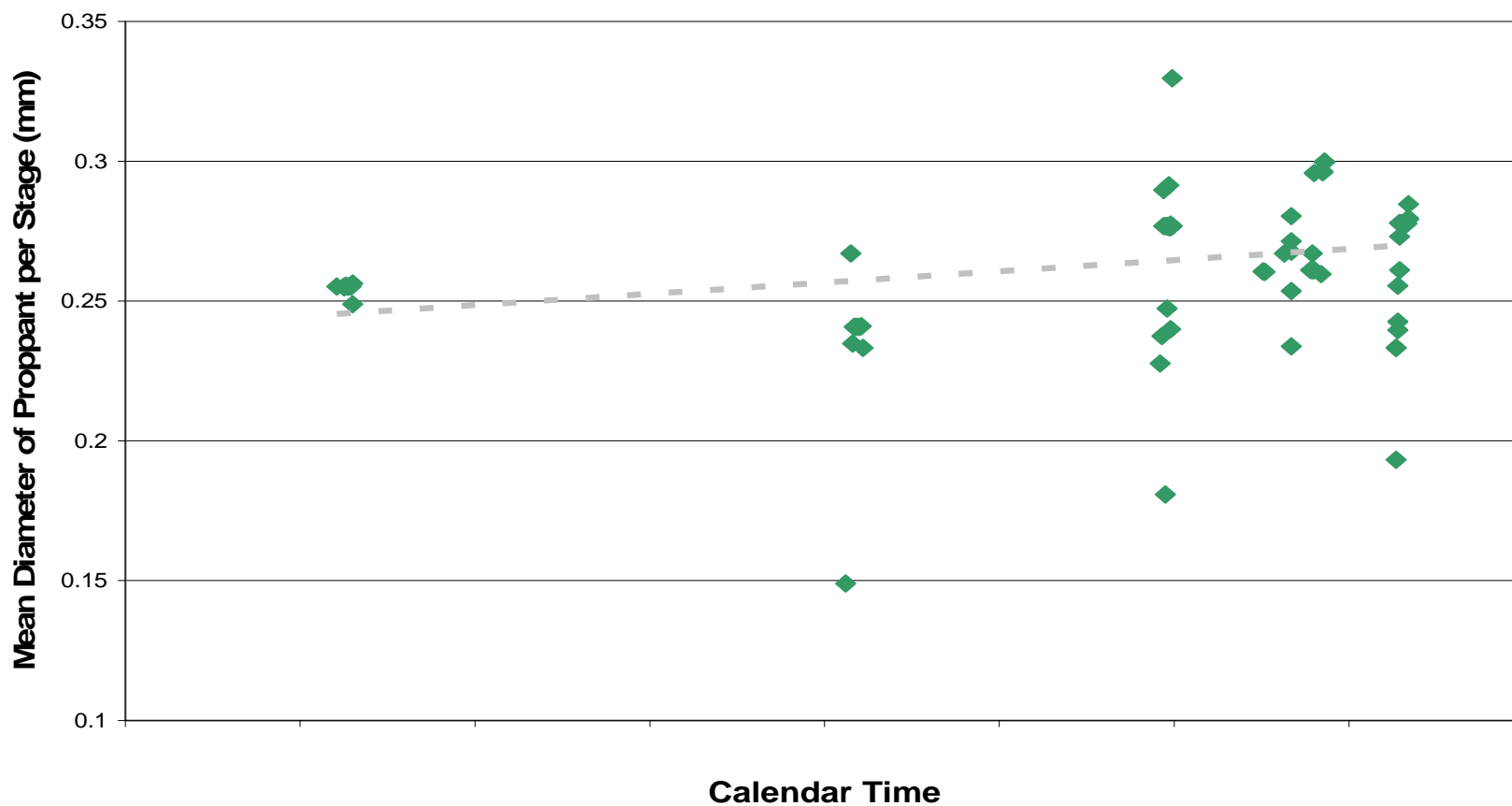
Acid Spearhead Design

**Cased Hole
Time to Full Rate vs Acid Soak**



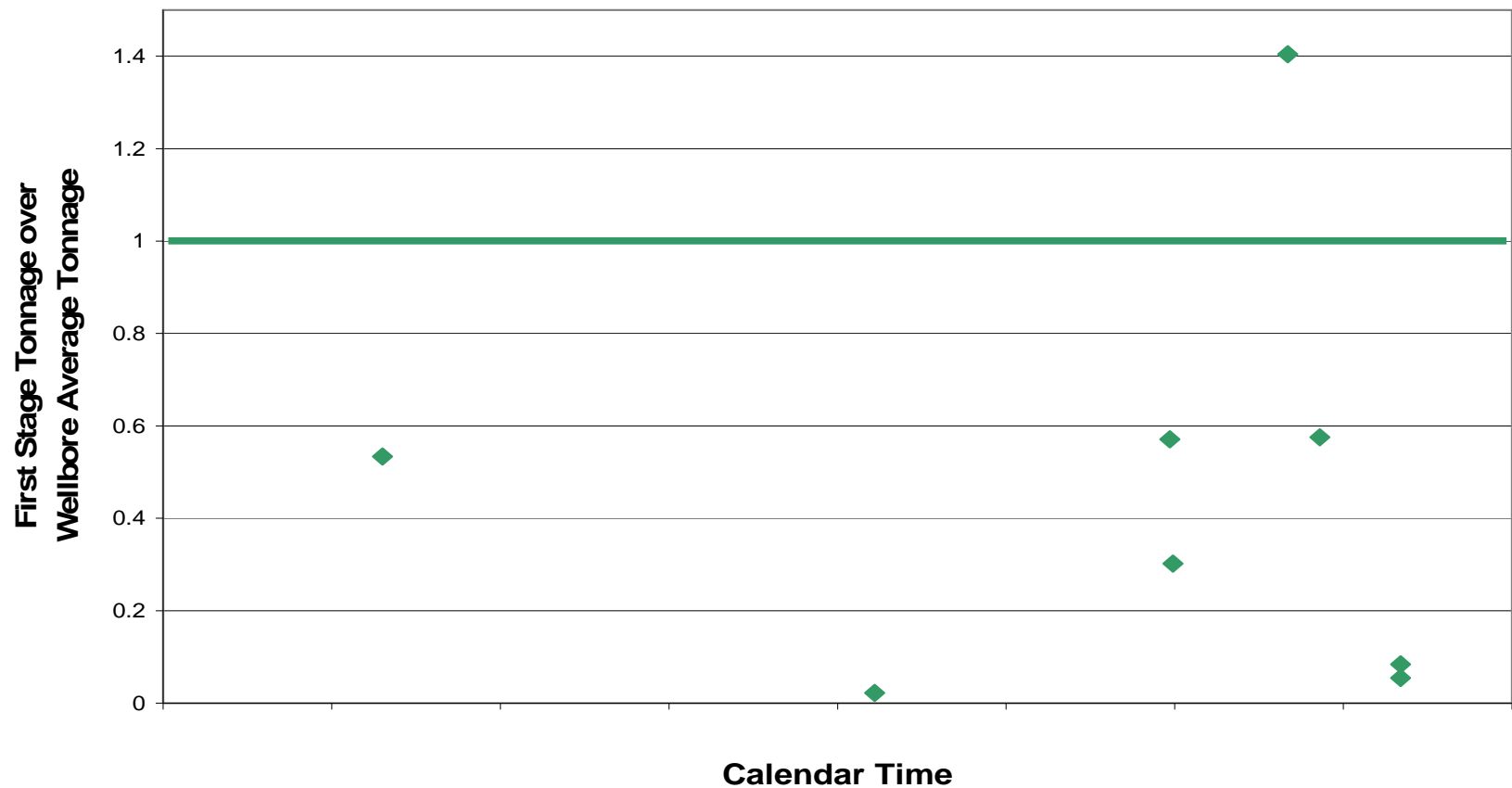
Proppant Selection

Proppant Mean Diameter Chronologically



Revisiting Toe Frac Design

First Stage Ratio of Proppant to Its Wellbore Average



Operational / Logistical Considerations

- Collaborative pre-planning is key
 - On site capacity for products
 - Lease sizing
 - Requirements for water, proppant, etc...
 - 24 hour operations
 - Concurrent operations
 - Pad drilling in the future

Efficiencies are lost when the job isn't designed properly.

Concluding Remarks

- Importance of reservoir characterization
- Tubular design for suspected treatment conditions
 - High rates and pressures
- Treatment design to consider:
 - Minimizing time to rate
 - Acid spearhead design
 - Maximizing production potential with proppant selection
 - Maximized toe frac design
- Efficient operations
 - Logistically challenging....be prepared!

Thank You....Questions?





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