Big Data and Predictive Visual Analytics in Tight Oil Resource Assessment: Cardium Focus

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Industry Trends – Big Data & Visual Analytics

• **Presentation Emphasis**
  – Focus on tools and methodologies used by reservoir engineers to conduct high level, unconventional resource play analysis

• **Toolkit**
  – Trend analysis (VISAGE, Excel, @Risk, Reserves Evaluation Software, Genetic algorithms)
  – Mapping software (GeoScout/Accumap/Surfer)
  – Raw hub access (IHS,GDC, HPDI-U.S., State Oil and Gas Commissions in the U.S.), Frac databases

• **Methodology**
  – Determining key correlations and “driving metrics” that aid in resource assignment and future development modeling

• **Oil industry’s evolving Business Intelligence in the realm of “Big Data”**
  – “Big Data”, or the analysis of large data sets, will continue to become a key basis of competition and development for individual firms in the energy sector (which has historically lagged finance and healthcare in this domain)
  – Major area of focus in recent news (McKinsey, Forbes, World Economic Forum)
  – Visual analytics are a way to cut through big data sets graphically – identifies trends and outliers
Industry Trends – Big Data In Oil & Gas

• Sheer volume of data needs to be analyzed more efficiently
  – 750K wells in Western Canada alone, 3.3 million producing entities in the United States. Global market still catching up on energy database digitization
  – Analysts (Financial, Reservoir, Production, etc.) have to use best tools to optimize decision-making

• Oil & Gas companies benefiting by:
  – Reducing time to discovery
  – Advancing business intelligence and embedded analytics
  – Trade off between volume of data vs. speed of analysis

• All the Big Techs want a piece of O&G industry
  – HP, IBM, IHS, Oracle, etc.

• Opportunity for new innovative companies to gain O&G market share
  – Companies like VISAGE equip people in the energy industry to make better decisions (identifying trends in production, operations, and capital expenditures), opening opportunities to analyze thousands of wells or data points in seconds
• Conventional decline analysis has limited value when analyzing multi-stage horizontal fracture wells with 4 months of post-frac production in early play analysis

• Focus shifts to greater integration with volumetric analysis, increased used of probabilistic methods, type curve generation, reservoir modeling & simulation leading to the use of more advanced data normalization software

• Think of datasets in terms of distributions
Resource Methodology Outline: Iterative Process

**Estimated OIIP**
- Assumed petro-physics cut-offs
- Key pitfalls and limitations
- Areal extrapolation

**Undeveloped Reserve/Resource Assignments**
- Assign reserves and resources offsetting performance using volumetrics and analogy
- Use Geostatistics for step-out distances
- Reserves vs. Contingent vs. Prospective

**Performance Data**
- Initial rate and profile assumptions
- Geographic sub grouping to find trends
- Type curves (Aarps eqn.)
- Sensitivity to Stimulations
- Driving or indicating metrics

**Recovery Factors**
- Check performance / decline analysis versus OIIP estimates
- Do these make sense based on produced fluid encountered?
North American Oil Resource Plays: **Cardium Focus**

- Major Development in Tight Oil Plays in N.A.
  - Viking
  - **Cardium**
  - Bakken
  - Ante Creek Montney
  - Doig
  - Lower Amaranth
  - Three Forks-Sanish
  - Pekisko
  - Lower Shaunavon
  - Barnett Combo
  - Niobrara
  - (many more, Slave Point, Beaverhill Lake, Glauconite)

Source: Company data, Macquarie Research, April 2010
Cardium is also useful because of the scope of the dataset (over 1900 multi-stage fractured horizontals) – +60,000 bopd HZ alone

Large number of interest holders, well distributed production across operators (compared to other plays, ie: Bakken; effectively a two company play)
Cardium example used due to HZ maturity and well count

Whether it’s actually unconventional or not is another discussion

- Some variance in interpretation between ERCB, COGEH
  - COGEH focuses on large, continuous accumulations
  - ERCB focuses on permeability (basically tight oil/gas = unconventional)

Cardium poses unique challenges because while it is somewhat continuous in the greater trend, it has localized geological boundaries that can have conventional HCPV restraints

Zero edge typically well defined (NE-SW orientation)
Regardless of whether deemed unconventional or not, we can agree that areas being explored now primarily fall under “tight oil resource development”

- **Tight oil plays tend to have common characteristics:**
  - Large, untapped OIIP
  - Low permeability
  - Legacy vertical production

- **Canadian vs. U.S. tight oil plays**
  - U.S. plays such as Niobrara tend to be pure shale oil; **Canadian** plays tend to be tight sands with siltstone/shale intervals
Due to the local field considerations and the significant amount of vertical well control, most Cardium development falls into the Reserves or Contingent Resource classification.

- Remember:
  - Discovered → Reserves or Contingent Resources
  - Undiscovered → Prospective Resources
Methodology: Cardium Geology

Cardium Type Log

Wapiabi Shale

Conglomerate

Sandstone

Transition

Blackstone Shale

100/13-36-048-08W5/00
Reference (KB) Elev.: +619.3 m
TVD: 1884.9 m
Mud Resistivity: 1.8
Cur Operator Name: Bonterra Enng Corp
Date Drilg Completed: 1997/12/15
Methodology: Cardium Geology Limitations

- For horizontal wells accessing traditionally tight sections, the variability in porosity cutoffs applied by analysts can cause potential swings in OOIP calculations – difficulty in determining contributing intervals (requires calibration vs. production)
- Porosity cut-offs most controversial in transitional zone (which can vary greatly in shale content)
- GLJ uses modified shale baseline approach to capture incremental reservoir contribution in the 0-6% porosity wedge
  - Observed shale baseline porosity from 9% at extreme updip to 2% downdip – 3% shale porosity is a common value

Conglomerate and Upper Sand rich zone

Transitional – 50% sand, 50% shale

Transition - Bioturbated zone – 20% sand, 80% shale
Using consistent procedure, can map entire play for OIIP

Once mapped and gridded as shown, can be used as a base diagnostic by which to identify optimal areas of development
**Methodology: Cardium (Areas to Exploit)**

- Remaining recoverable oil (MSTB) per section based on difference between theoretical RF (12%) and HZ EUR to 2011 + cumulative vertical production
- Can use varying theoretical RF’s (10, 12, 14, 16%) based on different HZ spacing - the key is that this grid shows relative differences
Methodology: Predicted Area vs. 2012/2013 drills

- Remaining recoverable oil (MSTB) with white dots representing new 2012/2013 HZ Cardium on-stream wells
- Reasonable correlation – wells being drilled where predicted
- Can use this to predict 2014, 2015 drills and put together development plans

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• Question becomes, what can be booked (reserves vs. contingent vs. prospective resources)
  – How to define “discovered” = must be “known accumulation” i.e. individual body of petroleum in a reservoir, penetrated by a well and demonstrated the existence of hydrocarbons by testing.

• Reserves are generally better understood – hinges on production, well control and geological interpretation

• Where it gets trickier is on Contingent and Prospective resources
  – Conventional Reservoirs
    • Single well - entire accumulation commonly “Discovered”
    • Undrilled structures or iso-fault blocks “Undiscovered”
  – Unconventional “Continuous Deposits”
    • When is the accumulation discovered?
    • How far from confirmed productivity is discovered?

• 2 primary considerations
  – How far to step-out (geostatistics allows us to quantify)
  – What to consider when assigning recoverable resources
Methodology: Resource Boundaries (Geostatistics)

- Geostatistics used to determine geographic correlation or variance
  - Strong method to determine distances by which reasonable extrapolations can be made about a dataset – generated algorithmically
  - Check vs. multiple metrics (IR, IR/frac, 6 month prod/100 m length)
- In other words – rules generated for a population are valid “this distance from population”
- For our Cardium HZ dataset – (every HZ drilled post 2007 in all fields in AB), there seems to be an inflection at approximately 1.5 km (~1 mile)
Methodology: Resource Boundaries (Geostats mapped)

- Geostatistics results can allocate distance markers which can frame your step-out boundaries
- Here are 1 mile bubbles around all HZ Cardium production
Methodology: Boundaries (Geostats mapped by Year)

- Same map as before (1 mile bubbles) – but with on-stream year shown. Again, depicts where the drilling is going.
- In Cardium, primarily edge step-outs (more than infills).
Methodology: Type of Resource? (Reserves / CR / PR)

- Geostatistics become the guide to define “discovered boundary”

- For the Cardium, the distance (~ 1 mile) is less than for more geologically continuous and homogenous plays (e.g.: Montney gas, or ND Bakken oil) where you might expect 3 miles or more

- Localized geology is the driving force (amount of sand, presence of conglomerate, reservoir quality of transition zone) and it varies greatly across the play

- Reserves typically assigned adjacent to production, Contingent Resources filling up the halo within the discovered boundaries and Prospective Resources layering into the areas outside discovered boundaries but where geological mapping or seismic suggests some possibility of reservoir extension

- Next question becomes how to determine EUR
  – Type curve generation and develop correlations
Methodology: Type Curves

- Type curves useful when applied correctly, but...lots of decisions need to be made in how they are generated
  - Tend to smooth and flatten early time data, peaks don’t always occur in month 1 or 2 or 3
  - Be aware of membership considerations and survivorship bias
  - Average of 1 and 49 is 25, but does that tell you anything?

- Creating percentile curves shows scatter range

- For the Cardium, important to generate by region/field, then subdivide into drilling vintage year and cardinality (to capture stimulation differences) – single type curves don’t represent the data variability

- Consider various normalization methods: to peak, to frac, to date, to geology (phi-h, HCPV)
For the Cardium, important to generate by region/field, then subdivide into drilling vintage year and cardinality (to capture stimulation differences) – single type curves don’t represent the data variability.

Shouldn’t group cardinality 7 wells with cardinality 2 wells - different drainage considerations.

Infill EUR Assignment (HZ’s 1-4 vs. 5,6,7,8)
- Determined based on existing drainage and reservoir quality
- Clear early evidence of diminishing returns and likely depletion but small dataset
Quickest way to determine groupings that demonstrate trends or outliers

- In the Cardium, slick water frac’s perform better than other stimulations across all memberships (field, vintage, etc.)

When frac databases (Canadian Discovery) are tied into analytics software (VISAGE) and raw production data (IHS) the diagnostic plots can be generated very quickly.
Methodology: Stimulation Trends

- Normalization tools provide quick commentary on frac trends
  - Cardium frac stage counts have increased progressively over the years

- Evaluate per stage metrics to determine relative differences
  - EUR/stage
  - Rate/stage
  - 6,9,12 month cumulative/stage
Methodology: Using Contour Visualization

- Once you get into per-frac metrics using contouring software (Surfer), one can quickly identify hot spots and properly scale up or down future locations based on completion plans.
Methodology: Cardium EUR in a distribution

- EUR’s (Estimated ultimate recoverable) generated algorithmically (well-by-well) and fine tuned with engineering judgement

- Important to iteratively compare to geology and revise
  - Geology revision where performance demands it
  - EUR revision where sufficient performance uncertainty forces greater emphasis on geology

- This applies to “declinable” wells - here defined as greater than 18 months prod. What happens with newer wells? Or development?
  - Rely on correlations to generate estimates
  - Determine which “driving metrics” have predictive value
Methodology: Driving Metrics (what matters?)

- **Cardium EUR Correlations**
  - Peak oil rate shows decent correlation
  - Even better EUR predictor is 12-month cumulative oil prod
  - Correlations become stronger when sensitized for region (field, TWP blocks)
  - Geology (net pay, phi-h) actually shows poor correlation to EUR (even worse in initial rate prediction)
  - Emphasizes geological complexity – conglomerate, sandstone, transitional and relative contributions of each
Methodology: Driving Metrics (or not?)

• Important to recognize that certain relationships just aren’t useful
  – Limited correlation between initial/peak rates and HZ well length
    - no matter how its sliced or diced

• Binning datasets can lead to better conclusions
  – Shorter HZ’s perform worse than longer HZ’s
For advanced analysis in determining key driving metrics, you can use genetic algorithms:

- Replaces more simplistic linear correlations (or logarithmic, or polynomial)
- Uses a search or optimization method that mimics biological evolution
- Example software for this is Discipulus (www.rmltech.com)
• GLJ’s Cardium reserves and resource booking strategy is largely *area dependent* relying on extensive geological support to calibrate HZ performance results and generate type curves to book halo style development where justified.

• Data correlations tend to be superior the further out in time you go (IE: 6 month cumulative oil production better predicts EUR than peak rate) – *largely intuitive*.

• Need to look very closely at membership when building type curves. Populating based on region, fracture, vintage yields better results - but, have to maintain large enough data sets to be statistically significant.
Conclusions: Using Big Data & Visual Analytics

- In large, unconventional and continuous resource play assessment the quick manipulation of expansive data sets is paramount, and, the need to do so will only increase
  - More and more data is being placed online (frac databases, electronic well data, provincial and state O&G bodies digitizing efforts)

- Regional productivity benchmarks can be used to compare and contrast resource plays, drilling results, future development programs and perhaps most importantly for investors – companies
Thank You

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