53rd General Meeting
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Virtual Conference

Wellbore Positioning Technical Section

The Industry Steering Committee on
Wellbore Survey Accuracy (ISCWSA)

Quantitative Analysis of Geological Data Uncertainty to Increase Positional Confidence

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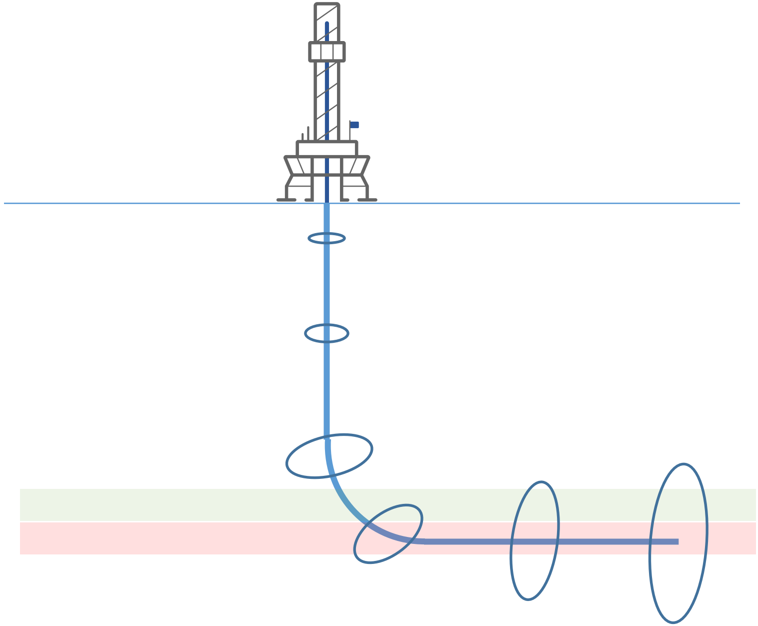
Helmerich & Payne

Depth and Vertical Errors

- Pipe stretch
- Thermal expansion
- Pipe tally
- Surface surveying

- BHA sag
- Accelerometer errors
- Survey aliasing

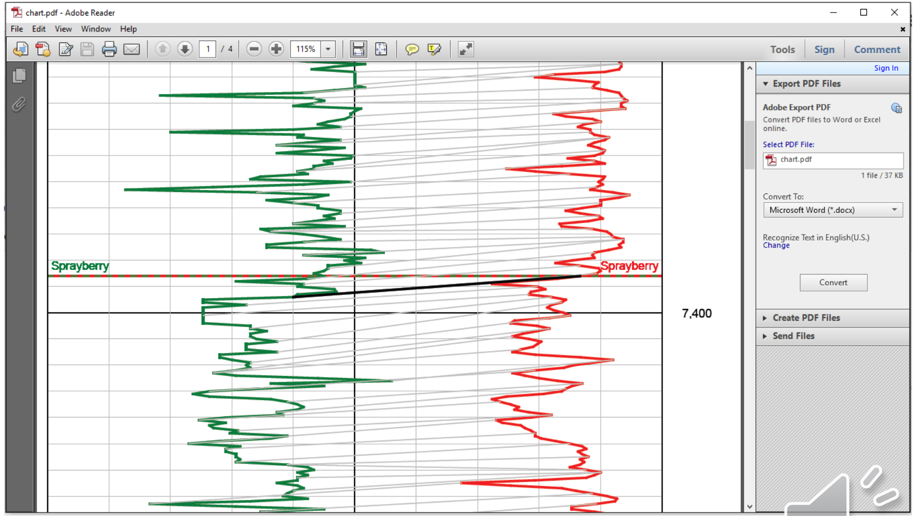


Previous Work

- Geological data has been used to aid in positioning
- Usually qualitative
- **Quantitative** data could be implemented in the error model!
- Several applications could be considered (target sizing, SAGD, CA…)

Formation Top Detection

- Algorithmic approach to pattern recognition
- Option for human interpretation
- Traditionally used for
    - Earlier target changes
    - Reduce the need for corrective doglegs



Formation Top Detection

- Use of a “forward model” using empirical data to TVD correct a reference log
- Gamma is automatically correlated
- Notifications when a marker is crossed
- Is this accurate and repeatable?

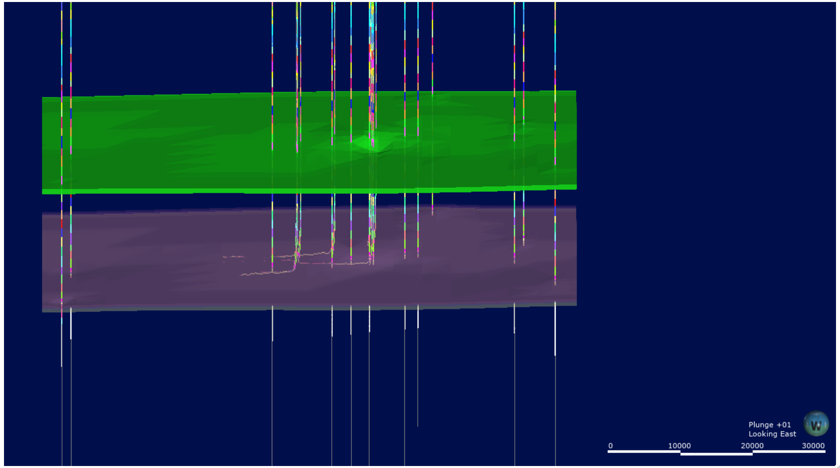
Driving to Grand Junction Office

- If I leave from the office, how far?
- If I leave from my house, how far?
- If I leave from Glasgow, how far?

- Once I reach this marker…
  - 11.1 miles

In Practice

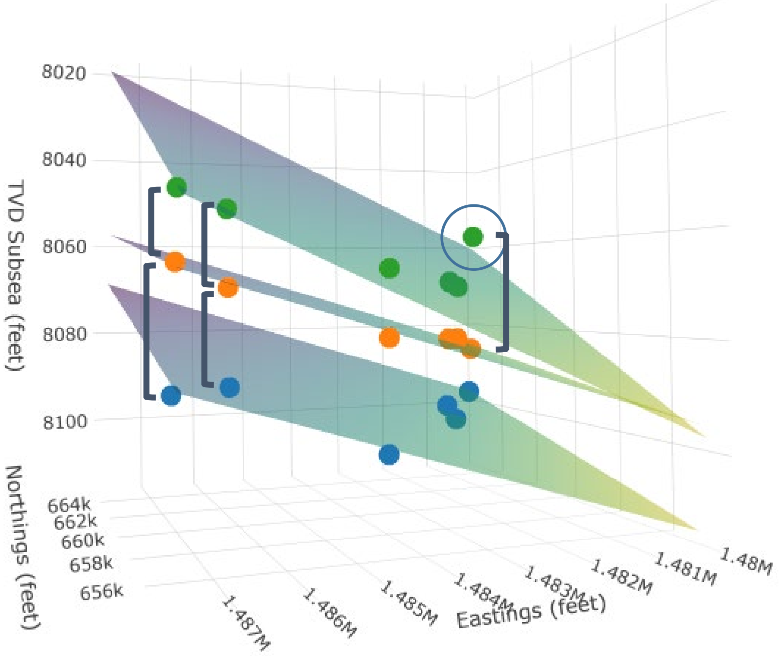
- Data from 4 pads in North Dakota, USA
- 8 wells crossing same formations
- Compared to independent model
- Consistency in measurements
  - *Relative* error is crucial



Outliers

- Gross error detection
- Land surveying
- RKB measurements
- Pipe tally
- …

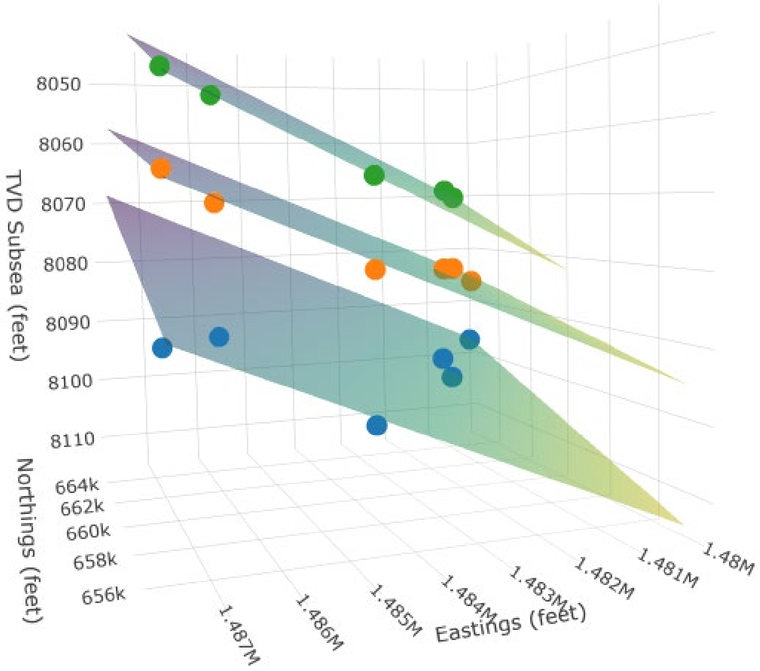
Formation Tops and Layer Models



Repeatability

- Consistent slopes between layers
- Agreement with linear models
  - $\sigma\_1 = 1.016$ ft
  - $\sigma\_2 = 1.467$ ft
  - $\sigma\_3 = 0.212$ ft

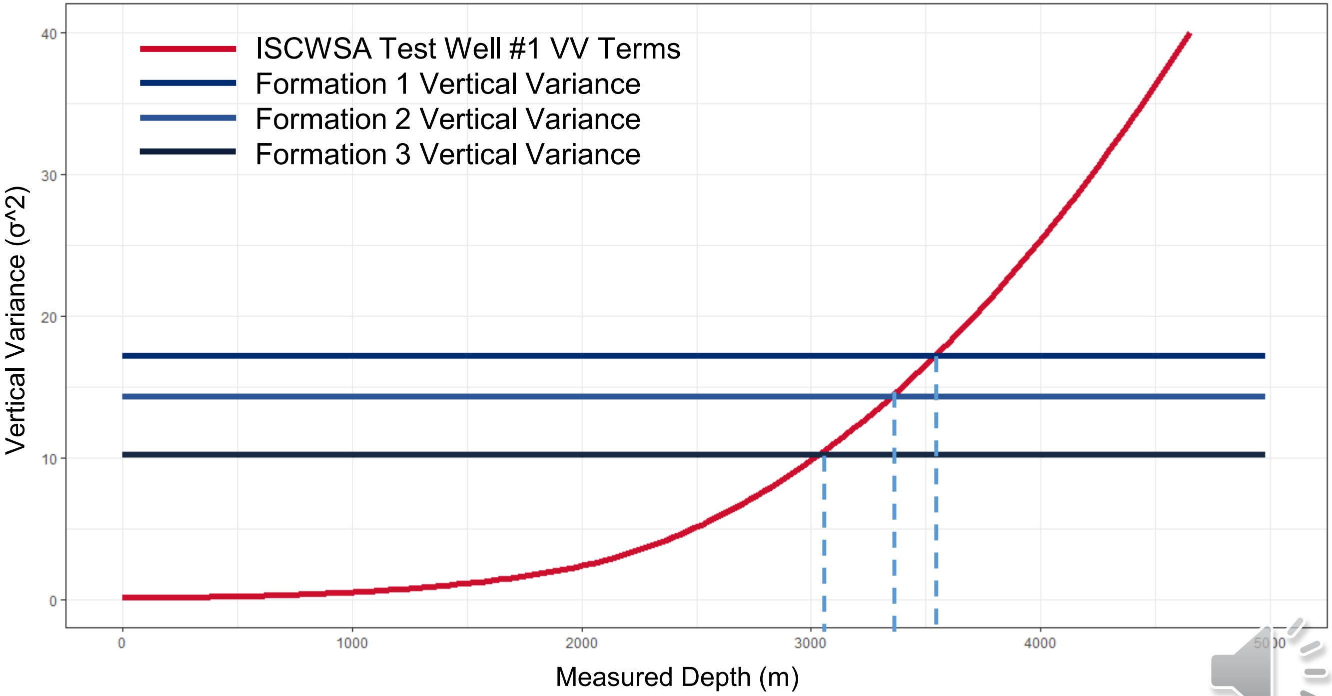
Formation Tops and Layer Models



Top Detection

- Using a single well
- Suggests depths to consider switching error terms
- Assumed to be depth-independent

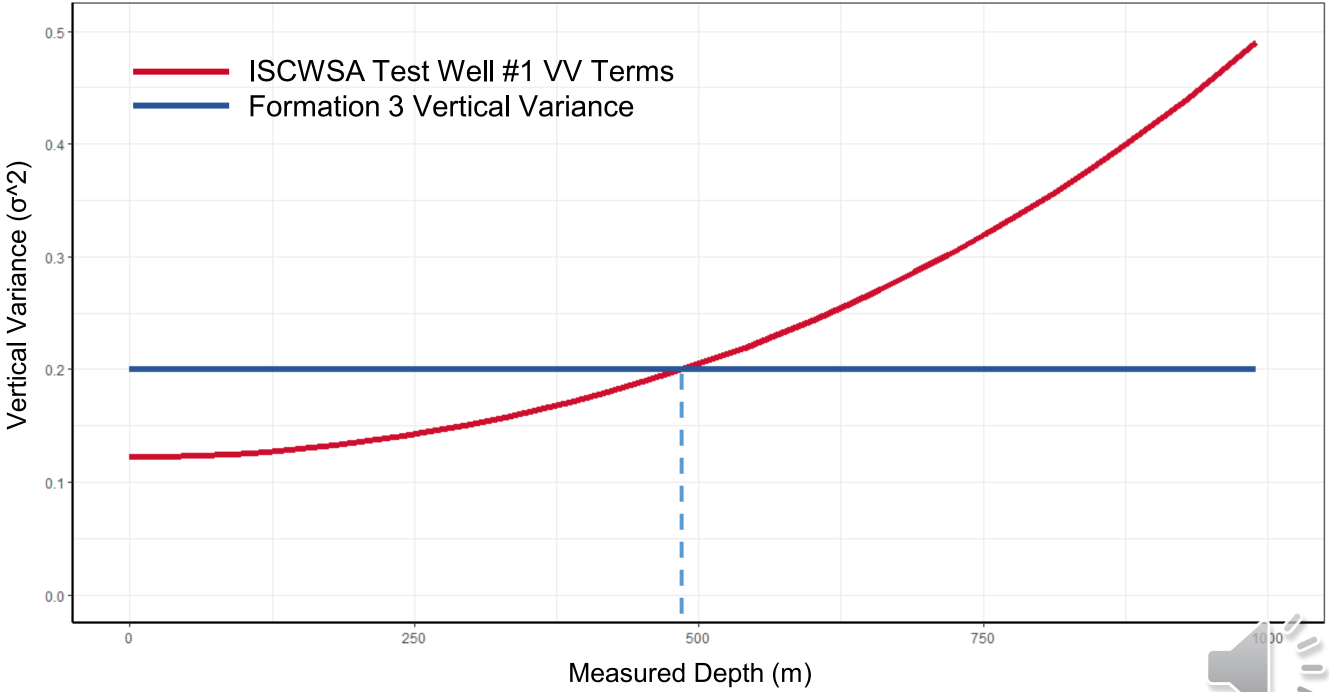
Comparison of Variances from Surveys and Geologic Models Using a "Flat" Model



Top Detection

- With higher resolution data
- Suggests very low error
- Almost immediate error reduction

Comparison of Variances from Surveys and Geologic Models From 4 Pads



Potential Ways to Fit Into the Error Model

- Option 1: Combined Uncertainty
  - Geologic variance considered to be constant
  - Survey variance for ISCWSA test well 1 is known
  - Combination of independent measurements

- Option 2: Use vertical uncertainty from the geologic tie-on
  - Collapse vertical dimension

- Uncertainty remains relative and not absolute

Error Comparison

ISCWSA Test #1 Survey Vertical Axis Standard Deviations

MD (m)	Survey σ (m)
450	0.4343
1020	0.7186
2010	1.6741
3000	4.3375
4020	7.4460

*MWD+HRGM

Geologic Formation Vertical Axis Standard Deviations:

Average Formation Depth (m)	Geologic Vertical Survey σ (m)
2458	0.0648
2462	0.3097
2467	0.4471

Error Reduction – Combined Surveys

- Precedent in application (SPE-178826, Ledroz, et al., 2016)

- Reduction in error using a weighted average method

- Implementation into the error model
  - Has been done previously
  - This would be depth-dependent

Error Reduction – Geologic Tie-On

- Once the marker is reached, vertical uncertainty can be “reset”
  - Like resetting error propagation
- “Collapsing” the vertical error terms
- “No-Error” with surface uncertainty?

Recap

- Algorithmic, repeatable approach to geologic marker recognition
- Significant error reduction at depth
- Potential applications
  - Target sizing, relative distance drilling (e.g. SAGD), collision avoidance, etc…
- Currently does not fit in the traditional Error Model framework

Thank You

Questions