drilling
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Wellbore Tortuosity Analysed by a Novel Method May Help to Improve Drilling, Completion, and Production Operations

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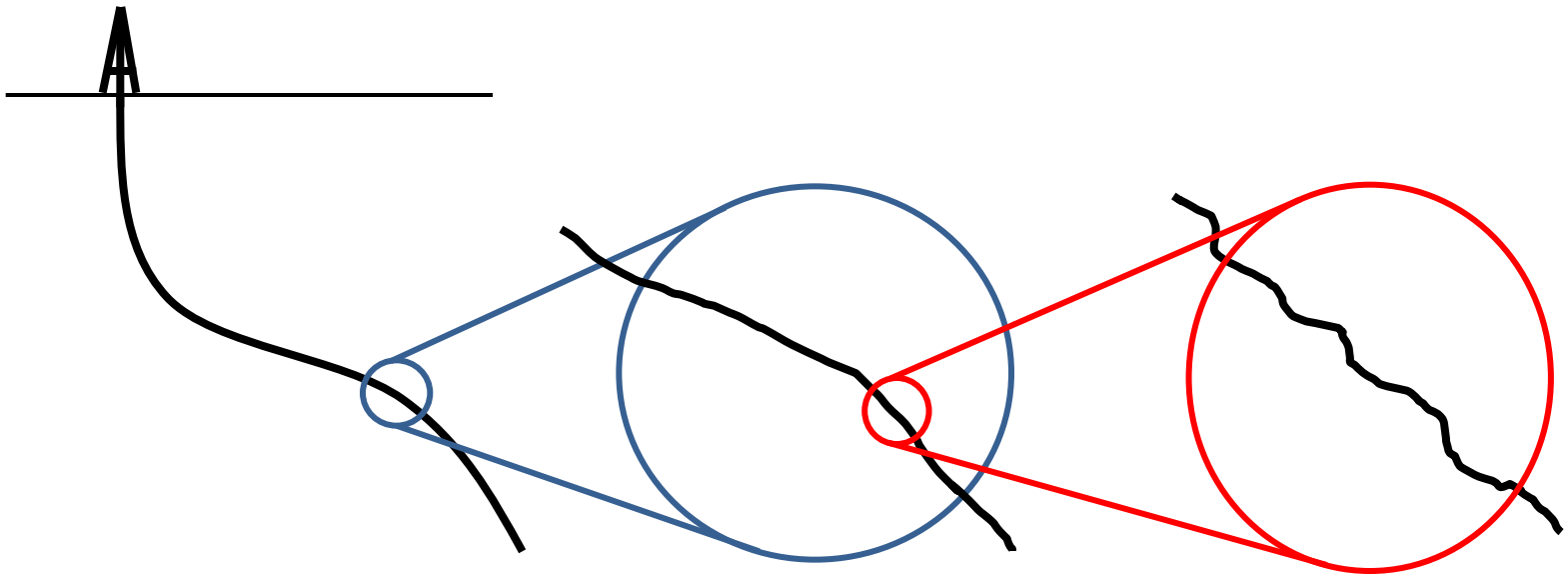
- Background
- Description of analysis
- Examples of field results
- Conclusions

Background

Tortuosity = any deviation from straight hole
=> analysis of geometric shape



Large scale
(wellbore)
100-1000m

Medium scale
(survey interval)
10-100m

Small scale
1-10m

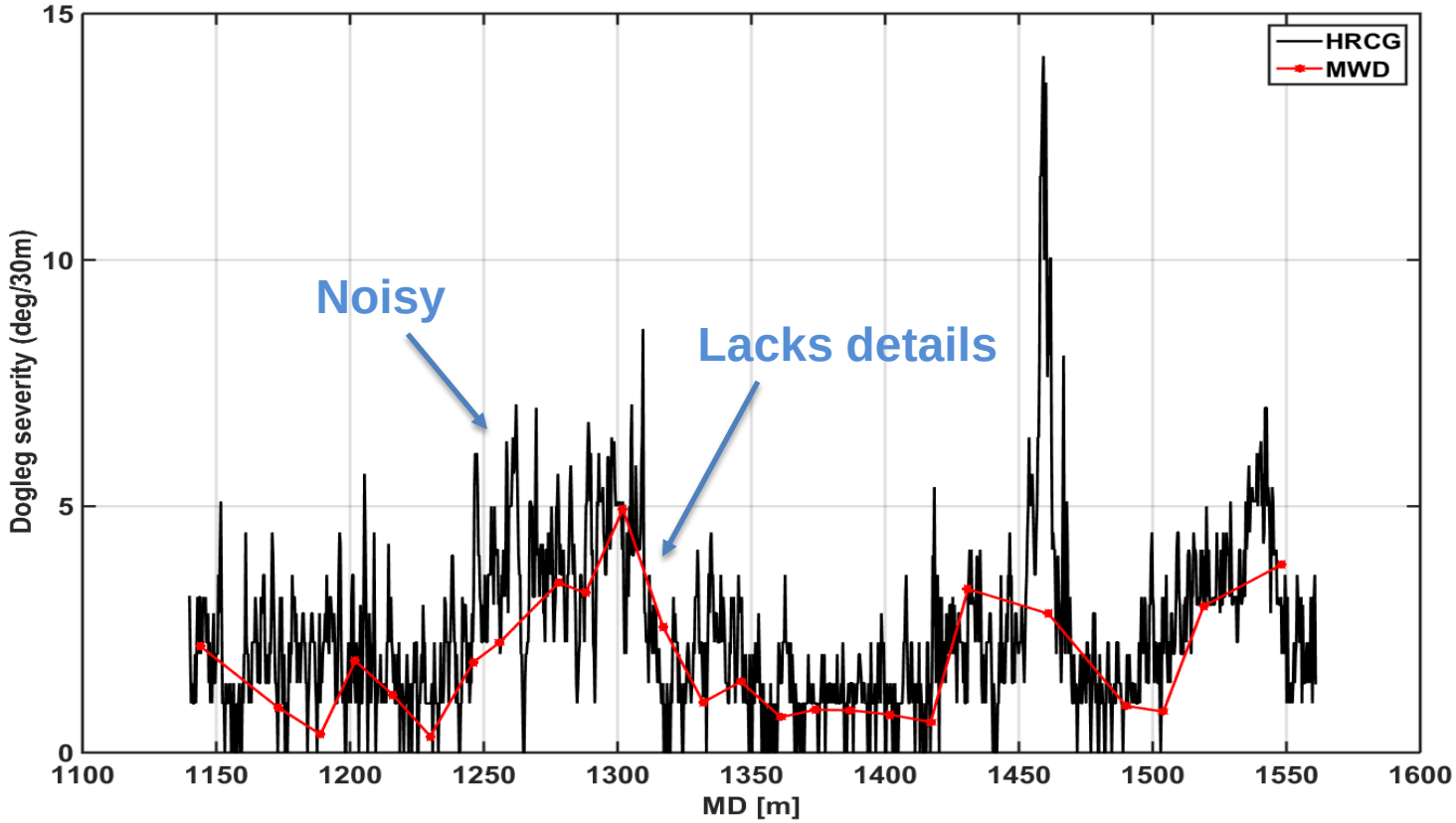
Medium and small scale tortuosity cause problems

	Drilling	Completion Production
High friction, high torque and drag	X	
Stuck equipment Drill pipe, casing, liner, compl&prod equipment	X	X
Reduced drilling length	X	
Excess bending, increased wear Casing, tubing, rods, rod guides	X	X
Damage, premature failure of equipment Electrical submersible pumps (ESP)	X	X

Consequences:

- Increased energy consumption
- Equipment failure
- Increased work-over frequency
- Loss of production
- Increased costs, reduced profit

Dogleg severity – not good enough



No simple way to «upscale» from short to long intervals

Novel tortuosity processing

Three output parameters, resolution >~1 ft

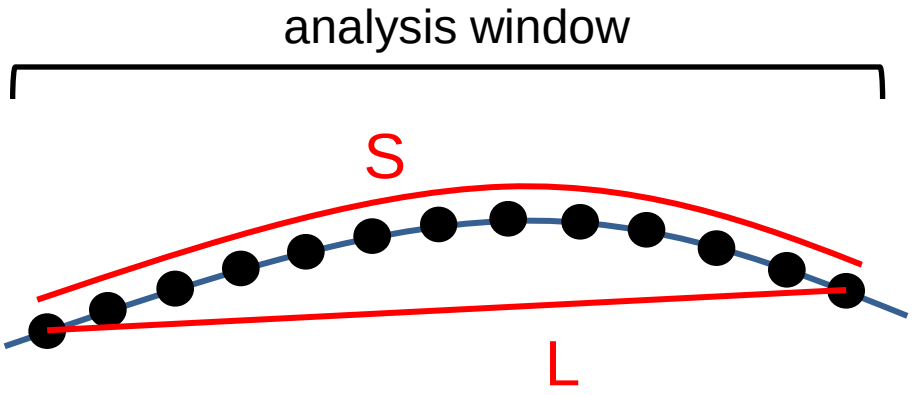
Input: High resolution survey data

- Continuous gyro; interval ~1 ft
- Standard survey operation
- Standard conversion to position co-ordinates

Single external parameter

- S = length of analysis window
  = length of equipment (physical device)

1. Tortuosity parameter: T

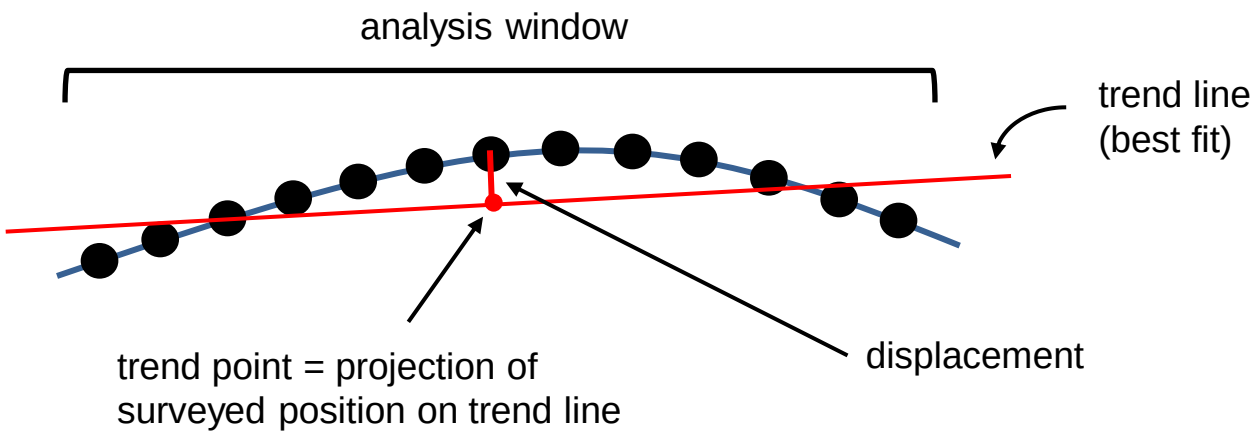


$$T = (S - L) / L$$

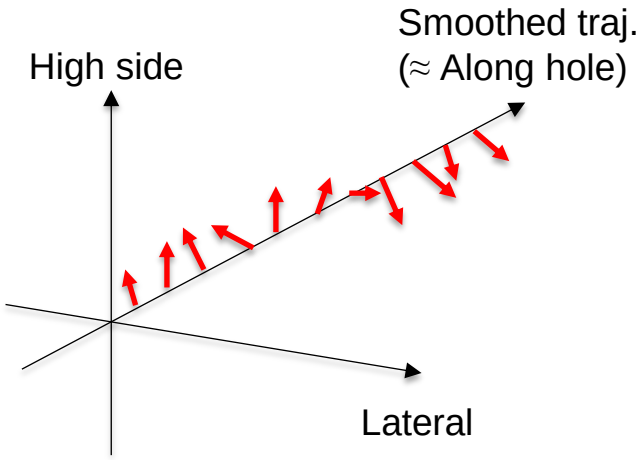
- S = along-hole distance = ΔMD
- L = straight line distance (end to end)
- T = relative elongation
  = deviation from straight trajectory on length scale S
- T is typically within [0 … 0.001]

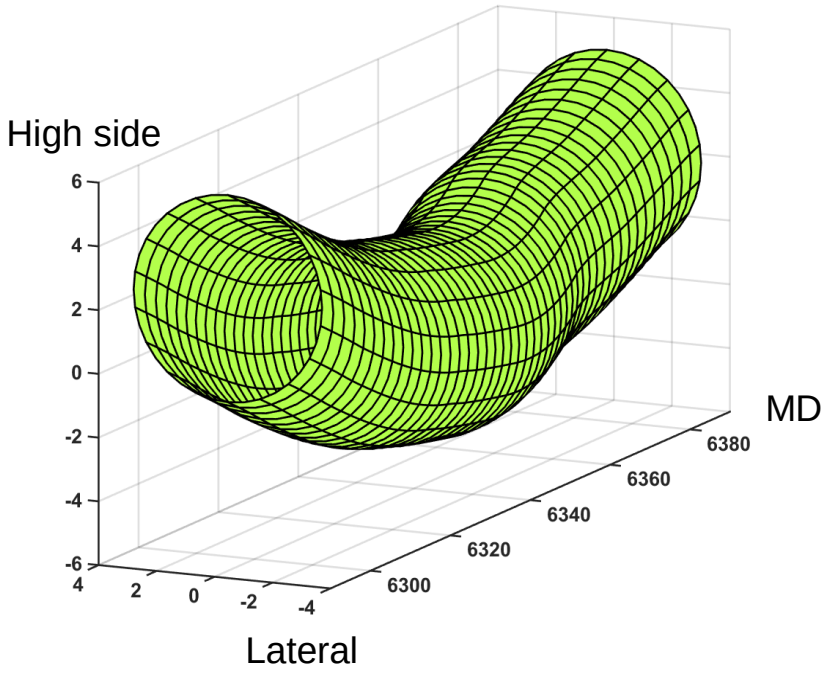
2. Trend + displacements

Surveyed positions = wellbore trend (smoothed trajectory)
+ transverse displacements



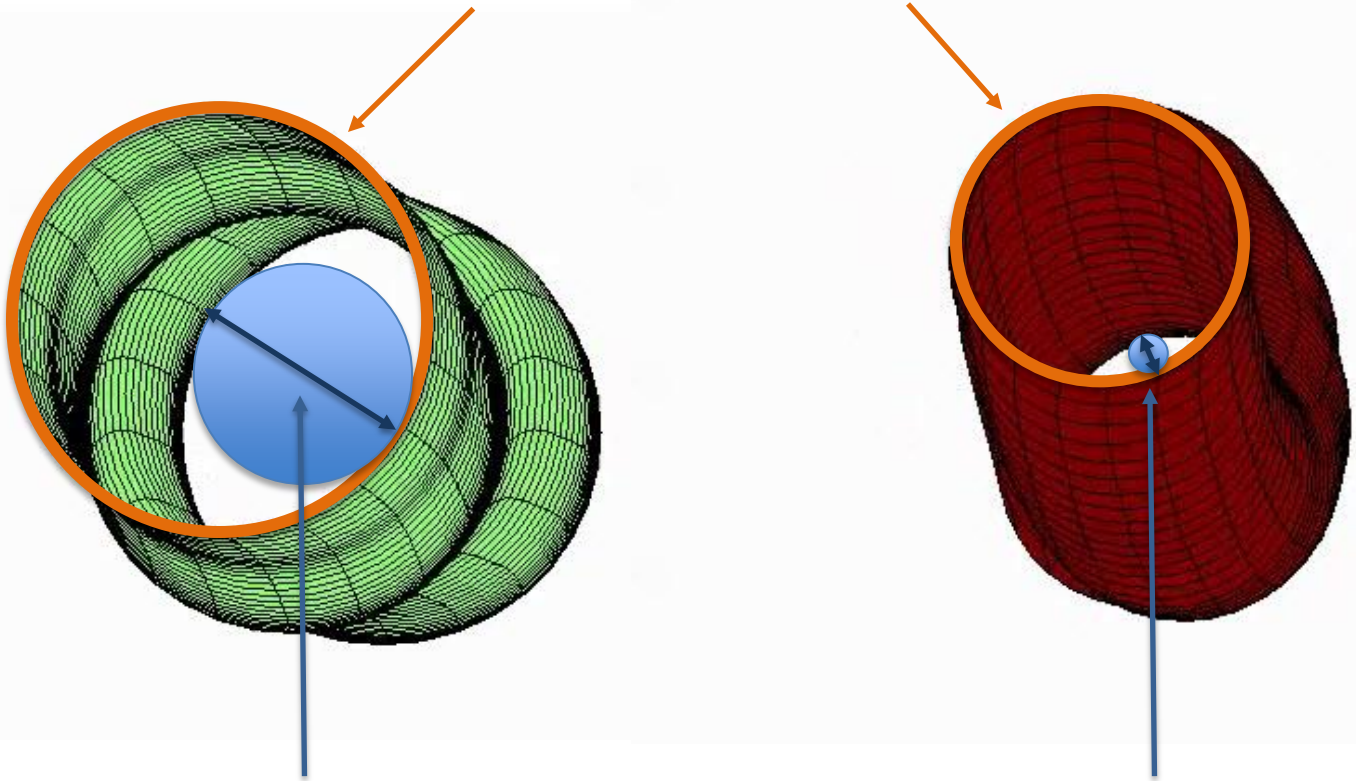
Trend + displacements





3. Effective diameter: D_{eff}

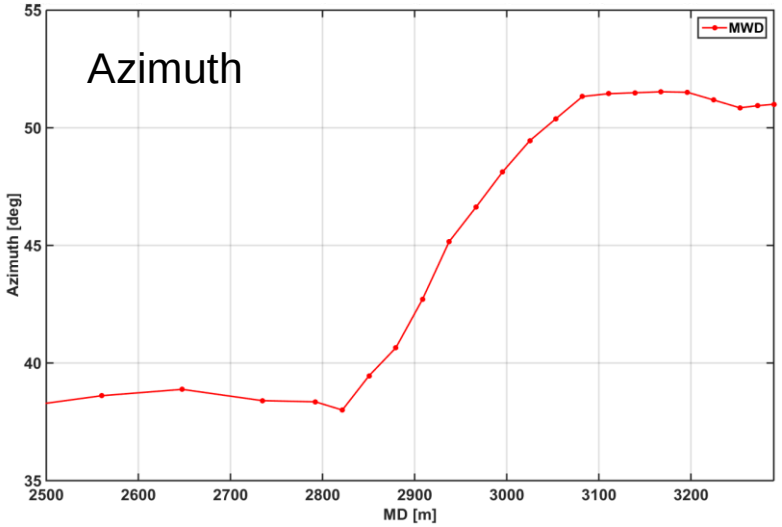
Casing / wellbore ID = D_0

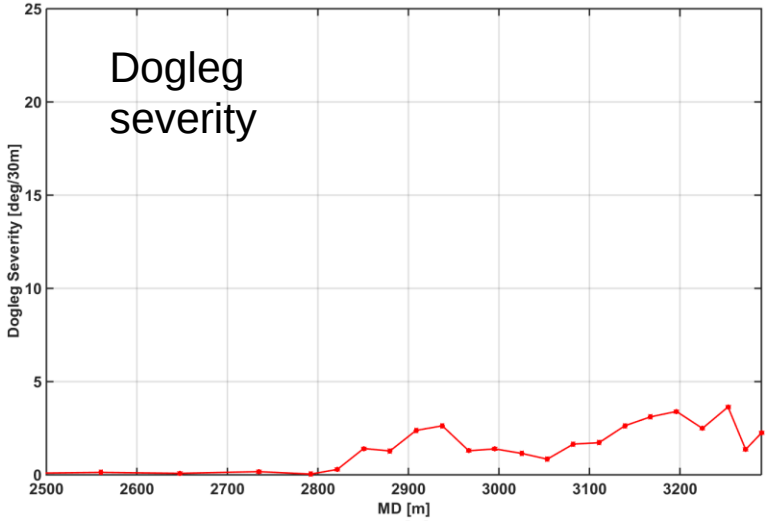


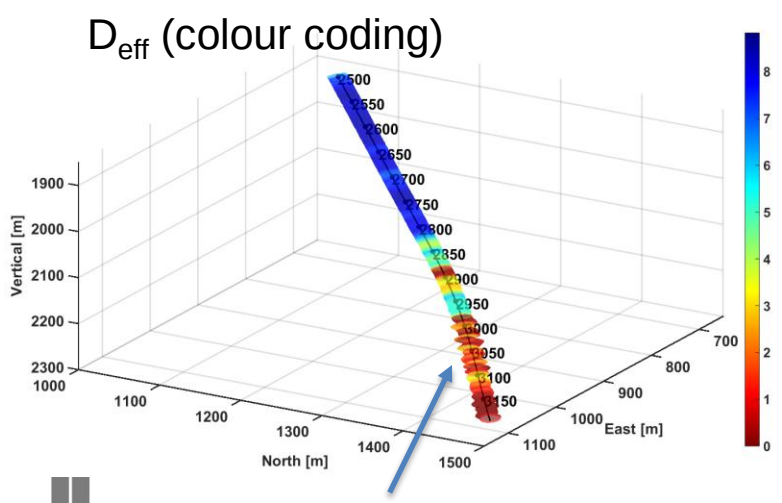
$D_{eff} \approx D_0 / 2$

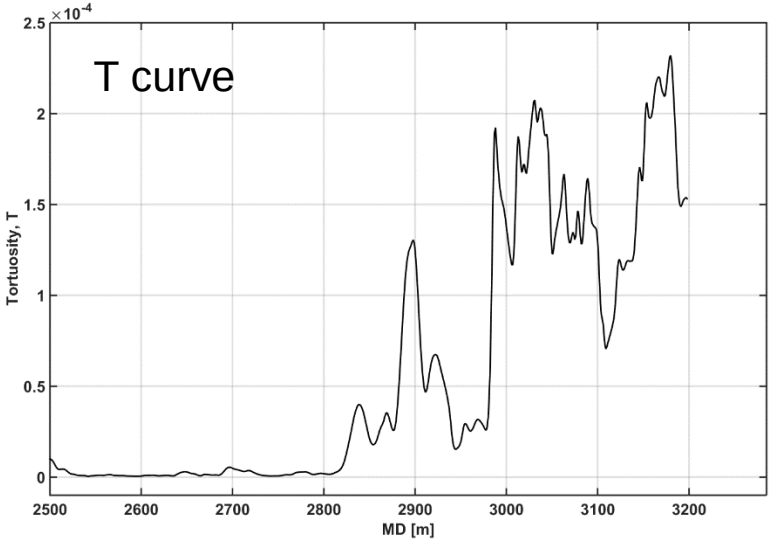
$D_{eff} \approx D_0 / 6$

Field case 1: Stuck casing, pump failure

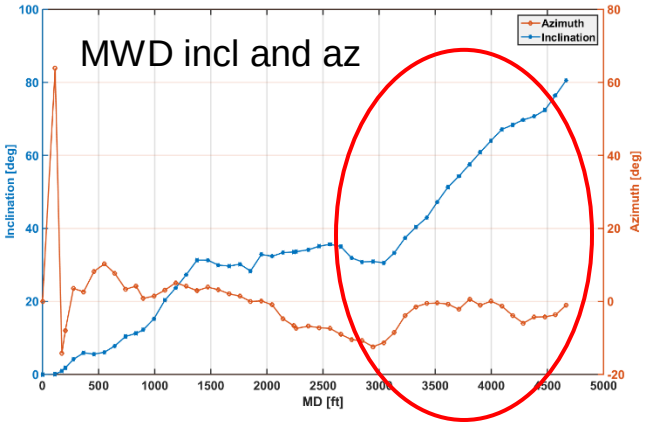




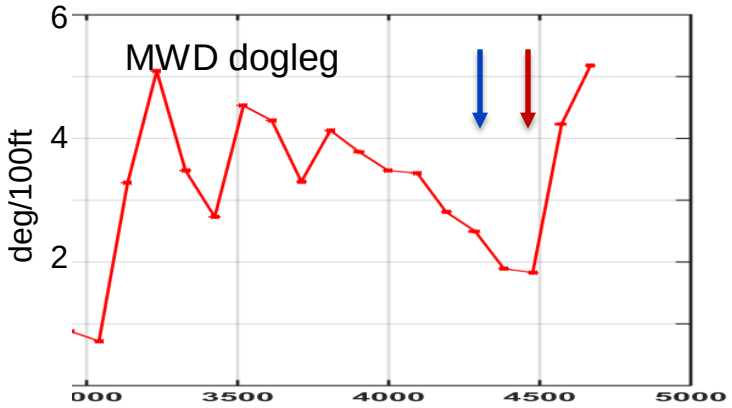


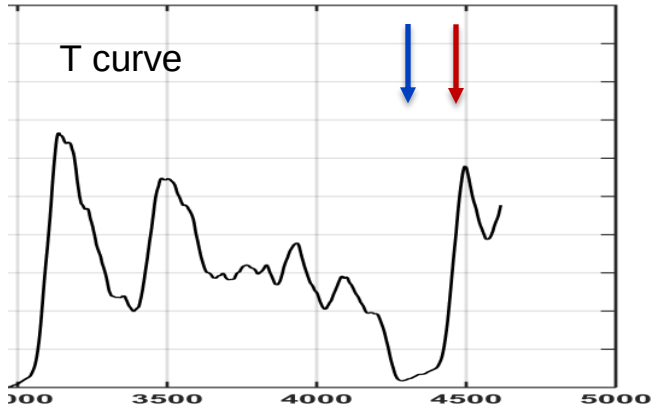


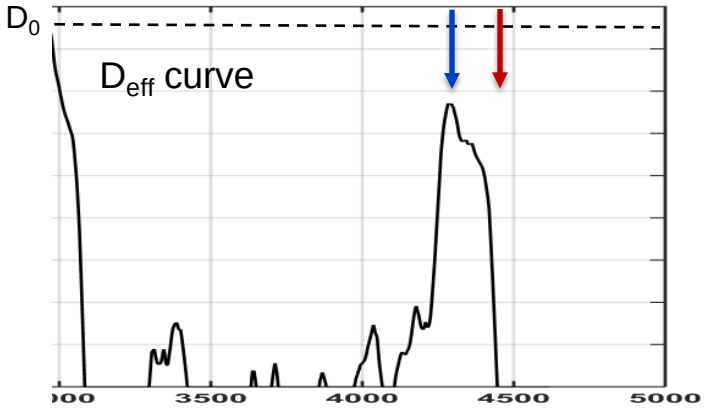
Field case 2: Pump placement

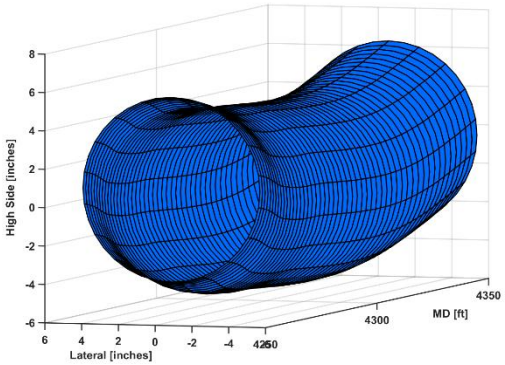


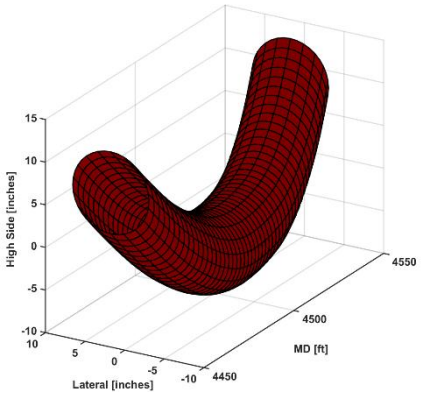
Pump length: 100 ft





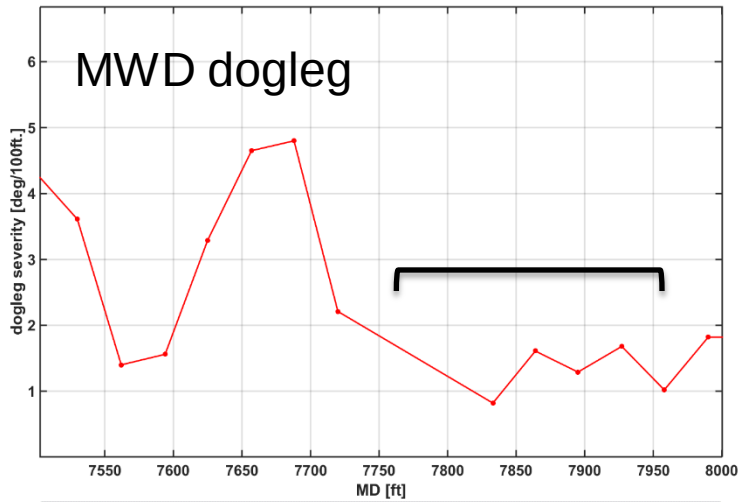


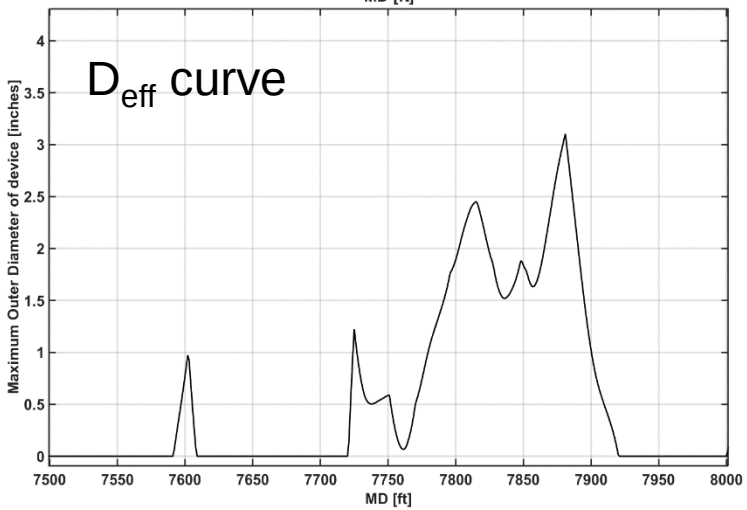




Wellbore shape,100 ft section

Field case 3: Pump placement





- Nominal ID = 6.28inches
- ESP (124ft / 4in) to be installed in horiz. section (below 7500ft)

← MWD dogleg suggests 7750-7950ft

← Maximum D for device length 124ft is 3.1in, at 7880ft.

- Pump size and location were reconsidered

Conclusions (1)

- New method for analysis of wellbore tortuosity
  - Three outputs: T, trend+displacements, D_{eff}
  - Single external parameter => device length
  - Intuitive interpretation of results
  - Improvement over existing Dogleg severity criterion

- Standard surveying procedure
  - High resolution data, survey interval ~1 ft
  - Continuous gyro survey

Conclusions (2)

- Applications
  - Drilling: Evaluation of bottom-hole assembly (BHA) and drilling process
  - Completion, Production: Optimal locations for equipment
    - Casing, completion equipment
    - Electrical submersible pumps (ESP)
    - Rod-guide, tubing sleeves for rod based surface pumps
- Benefits
  - Normal (i.e., within spec.) operating conditions and power consumption
  - Reduced wear, reduced failure rate
  - Reduced work-over frequency
  - Reduced idle time and production losses
  - Increased profit by reducing production costs

Acknowledgments

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Rob Shoup, Gyrodata

Gyrodata Inc.

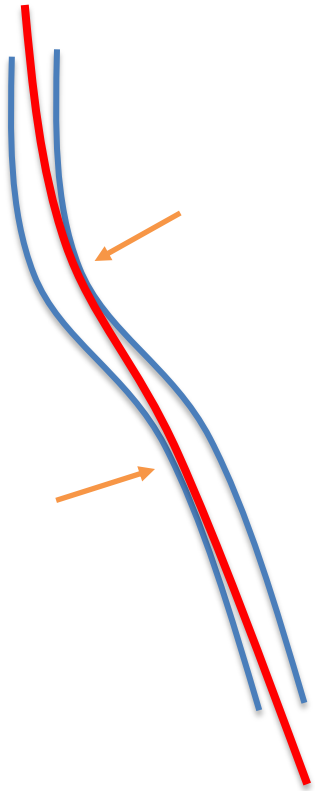
SandRidge Energy

Thank you

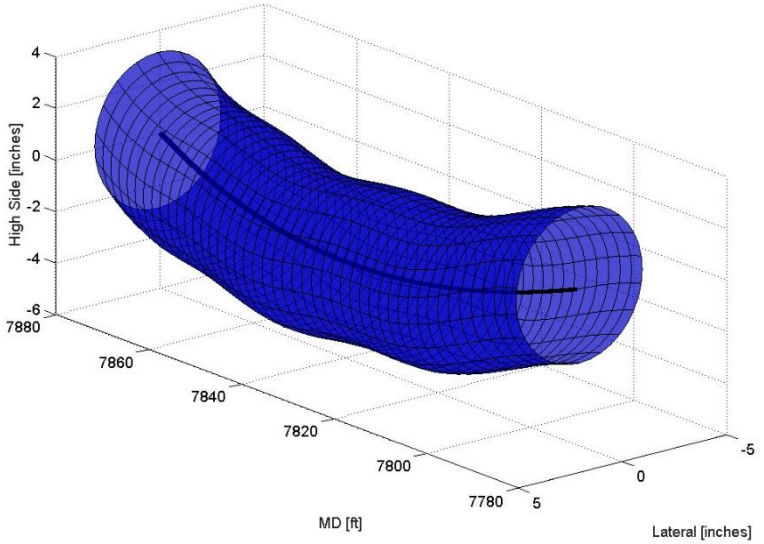
Appendix
(in case of questions)

Further developments

Rod guide placement

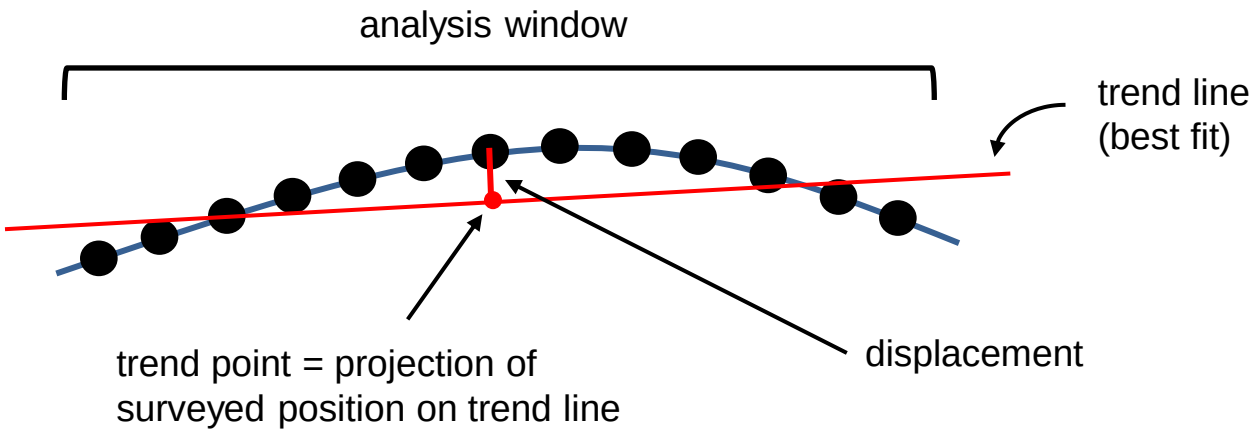


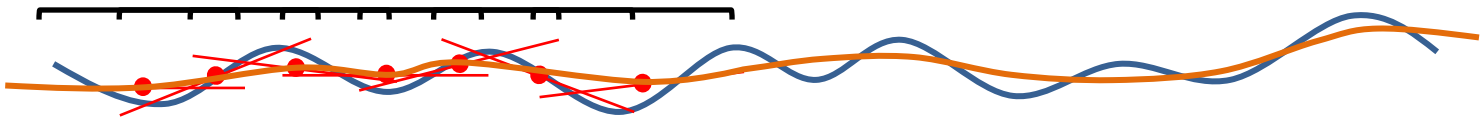
Permanent (acceptable) bending of device



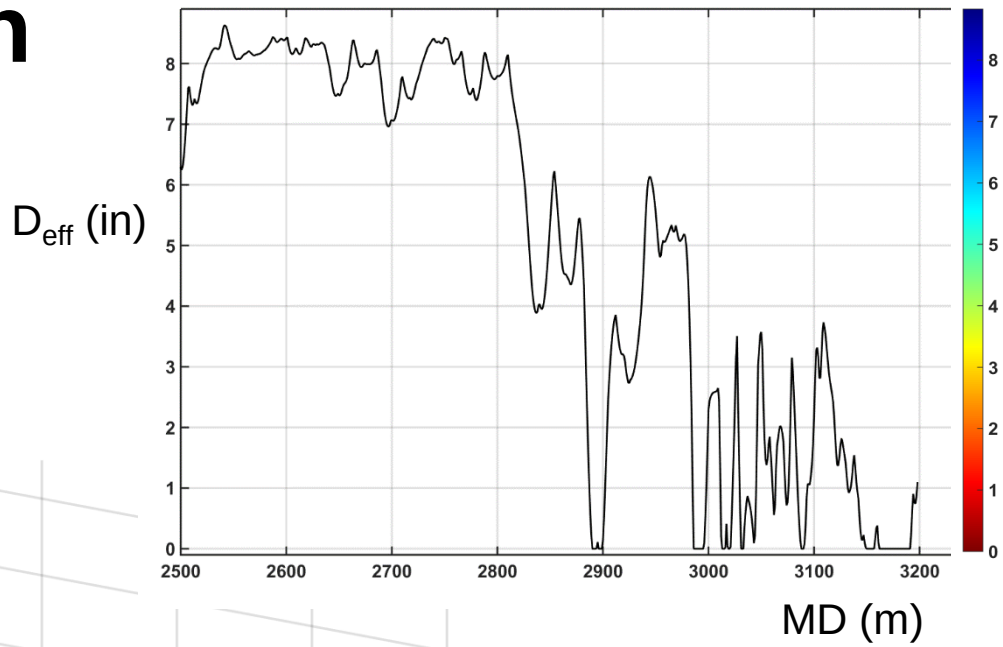
Local trend + displacements

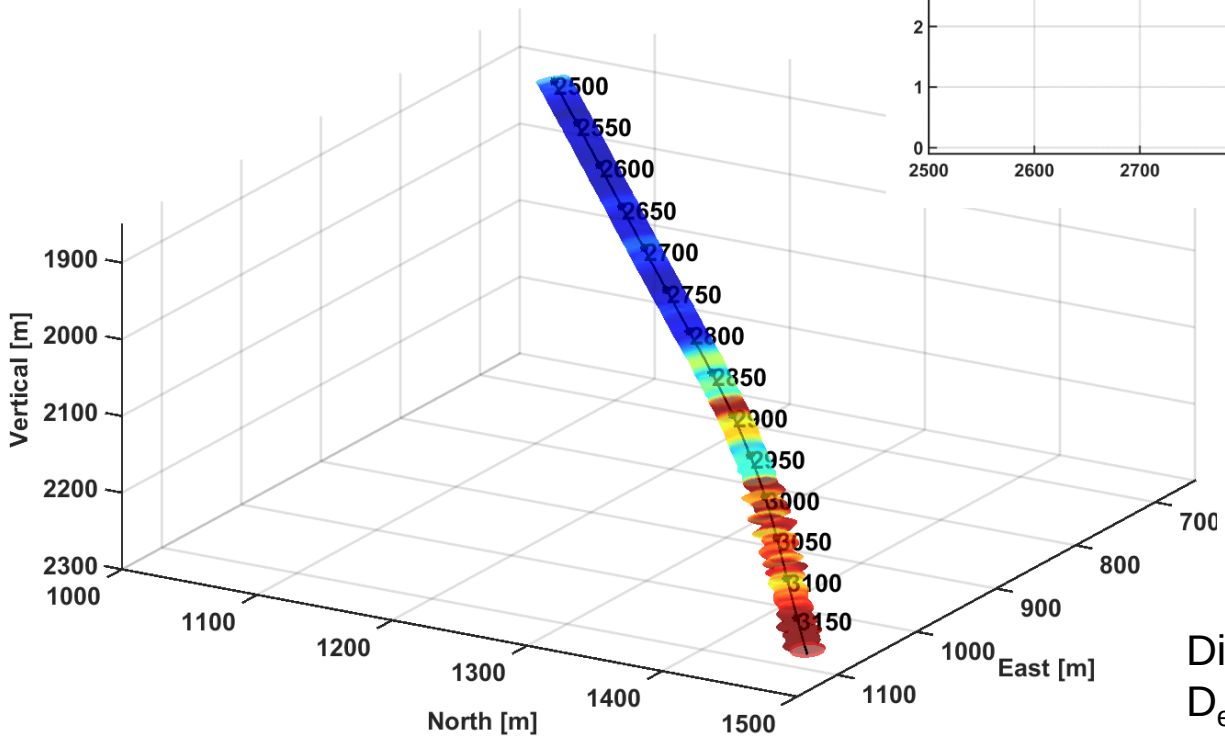
Surveyed positions = wellbore trend (smoothed trajectory)
+ transverse displacements





D_{eff} versus depth





Displacements x100;
D_{eff} shown by colour coding

Tortuosity result parameters

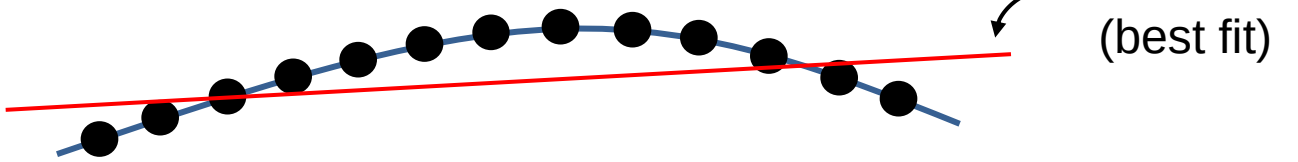
	No tortuosity	Low tortuosity	High tortuosity
T (= relative elongation)	0	near 0	«large»
Transverse displacements	0	small	«large»
D_{eff} (= effective diameter)	D_0	near D_0	small ($\rightarrow$ 0)

D_{eff} and T are appr. complementary

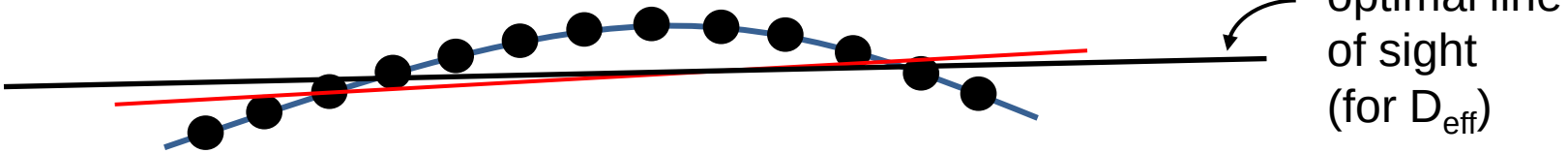
Wellbore shape (local)	Relative elongation T = (S-L) / L	Displacement span	Effective diameter D_{eff}
———————	0	0	D_0 (= max.)

D_{eff}: Trend line vs. line of sight

Trend line = least squares fit; displacements are «evenly» distributed around trend line



Optimal line of sight may differ slightly (~0.1 deg.) from trend line; requires small adjustment calculation



Single external parameter: S

S = length of analysis window (along MD)

- Window must cover >~ 10 survey stations
- User-defined
- Interpretation: S = tortuosity length scale
  ≈ length of device