Experimental Simulation for Shale Oriented Drilling Performance Evaluation

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Outlines:

Part I:

- **Oriented Drilling in Shale**
  - Introduction: Shale strength Anisotropy (Sh-Str. ANISO.)
  - Scale Ranges
  - **Experimental setup and shale sample preparation**
  - Data types and sensors
  - **Data analysis and results**
  - Summary of part I

Part II:

- **Shale Hydraulic Fracturing (SH-HF)**
  - Sh-ANISO VS. Efficient Sh-HF
    - Optimizing Hydrocarbon Recovery (RF%).
    - Minimizing Water breakthrough timing
  - Summary of part II

Part I

Laboratory evaluation of oriented drilling in shale

Introduction: Shale strength Anisotropy (Sh-Str. ANISO)

- Many great researchers in drilling engineering during 50s, 60s, 70s, and 80s such as Bradly, McLamore, Brown, and others reported that the three main factors for wells to be deviated are:

1. Drillstring mechanics:
   - How flexible is the drillstring?
   - How the drillstring behaves mechanically?

   The less flexible the drill string (more rigid), the less tendency of well deviation.

2. Bit rock interaction:
   - Is the bit angular cutting mechanism same and balanced?
   - Is the forces distribution balanced?

   The more agreement and balance between the drill bit and the rock, and between the well-distributed cutters and the angular cutting mechanics, the less impact of this factor on well deviation.

3. Rock Anisotropy (R-ANISO.):
   - Is the rock ANISO. Symmetric (i.e. Vertical Transverse Isotropy, VTI and Horizontal Transverse Isotropy, HTI) or is it different?
   - Are the plane of the lowest surface of the cutters and the rock lamination plane parallel? With respect to the horizontal plane.

   Has less impact when the above two factors are controlled and well managed.

- Q: What if all the above factors are controlled, will there be a relationship between the Shale strength Anisotropy and the shale oriented drilling performance?

Sh-Str. ANISO, Cont.,

- The more testing points would form the U-Strength Curve with two side wings.
- Any three points of an interest can form a syncline Str. Curve, but each point is representing different part of the U-Strength Curve.
- This work is selecting 0˚, 45˚, and 90˚, representing vertical, diagonal and horizontal drilling.
- Q: what is the relationship between Syn-Strength-Curve and the drilling rate of penetration?

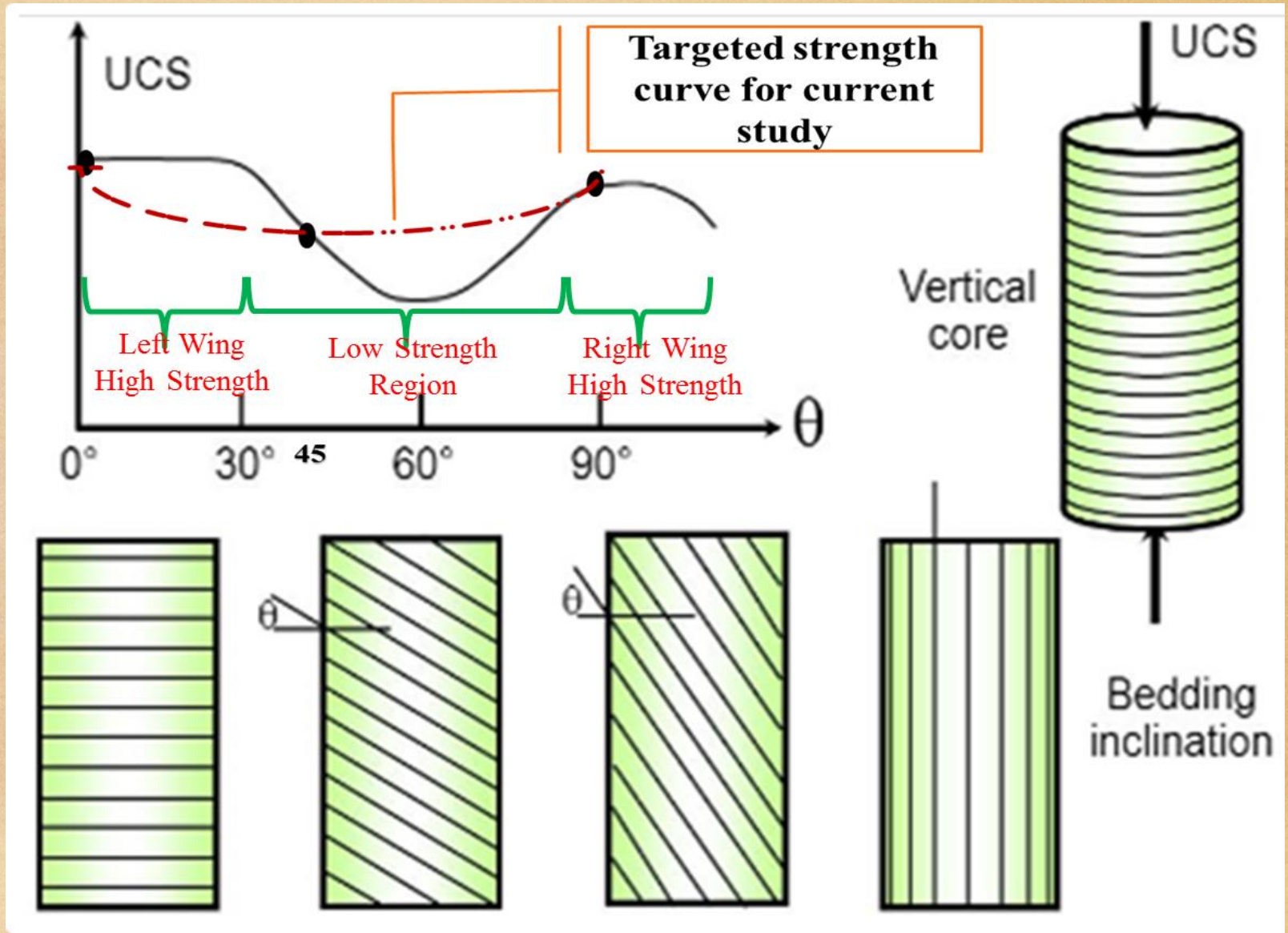


Figure 1. Laminated rock strength anisotropy. After Maurice Dusseault.

Experimental setup and scales. (Lab vs. field)

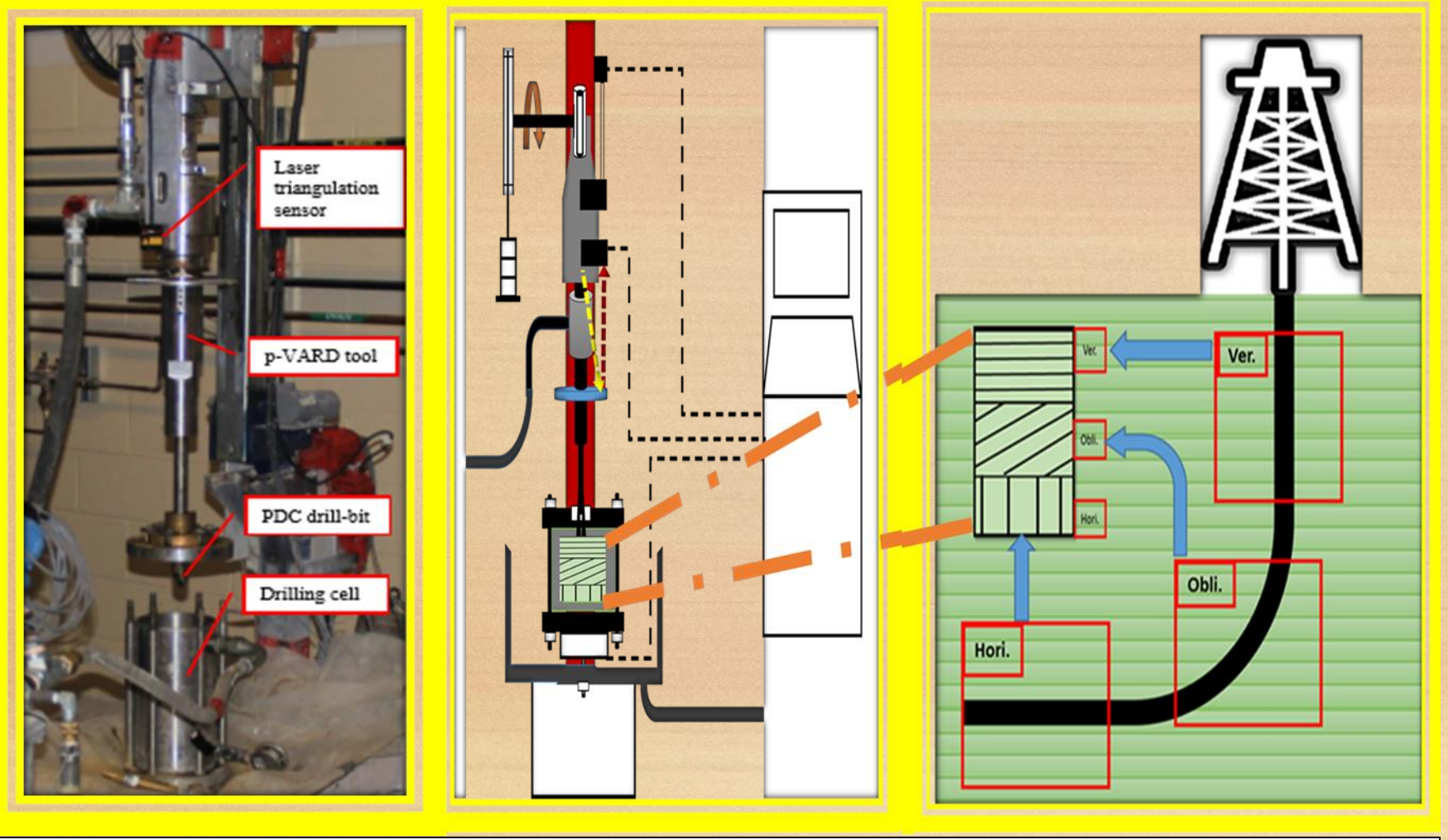


Figure 2. Lab scale drilling setup vs. field representation of oriented shale formation.

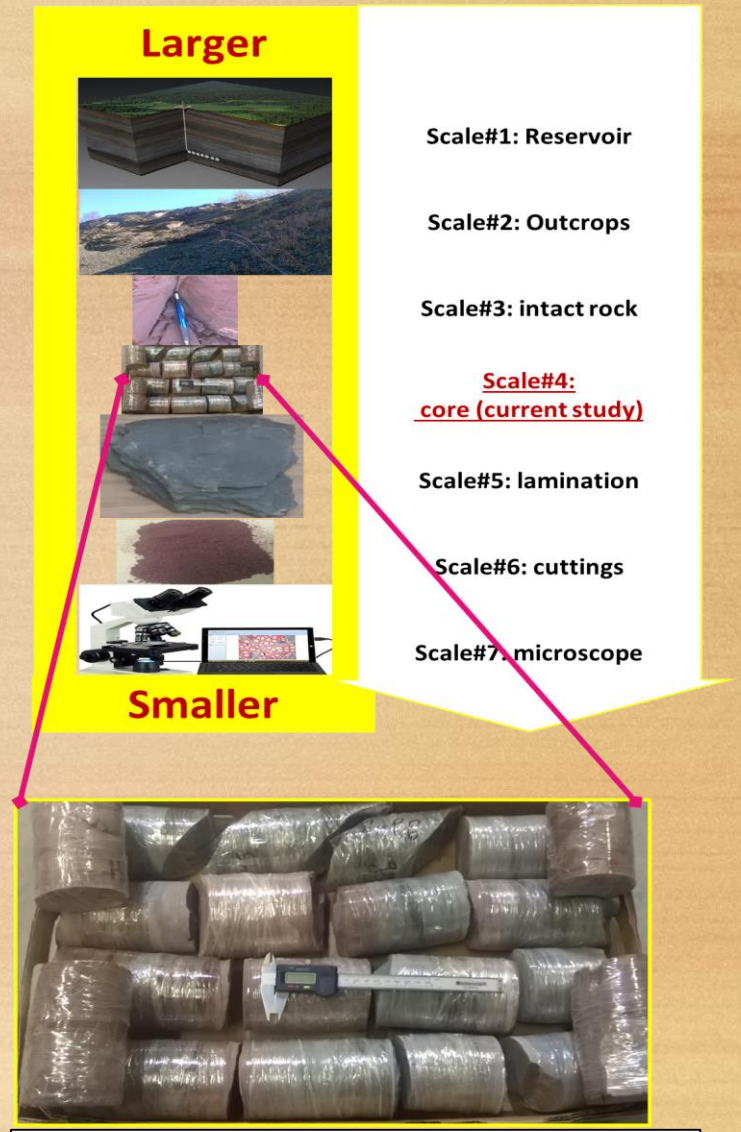


Figure 3. Shale scales range.

Field Scenarios of oriented drilling in laminated formation

- **In one complicated geological structure, all scenarios of oriented drilling with respect to the formation layer inclination can be encountered, Fig 4.**
- **Considering the possibility of encountering various, multiple or single set of lamination inclination before drilling, would assist in determining the optimal well trajectory towards the target.**
- **<u>Q: Is the drilling performance when drilling same intervals under same conditions equal in the three scenarios?</u>**

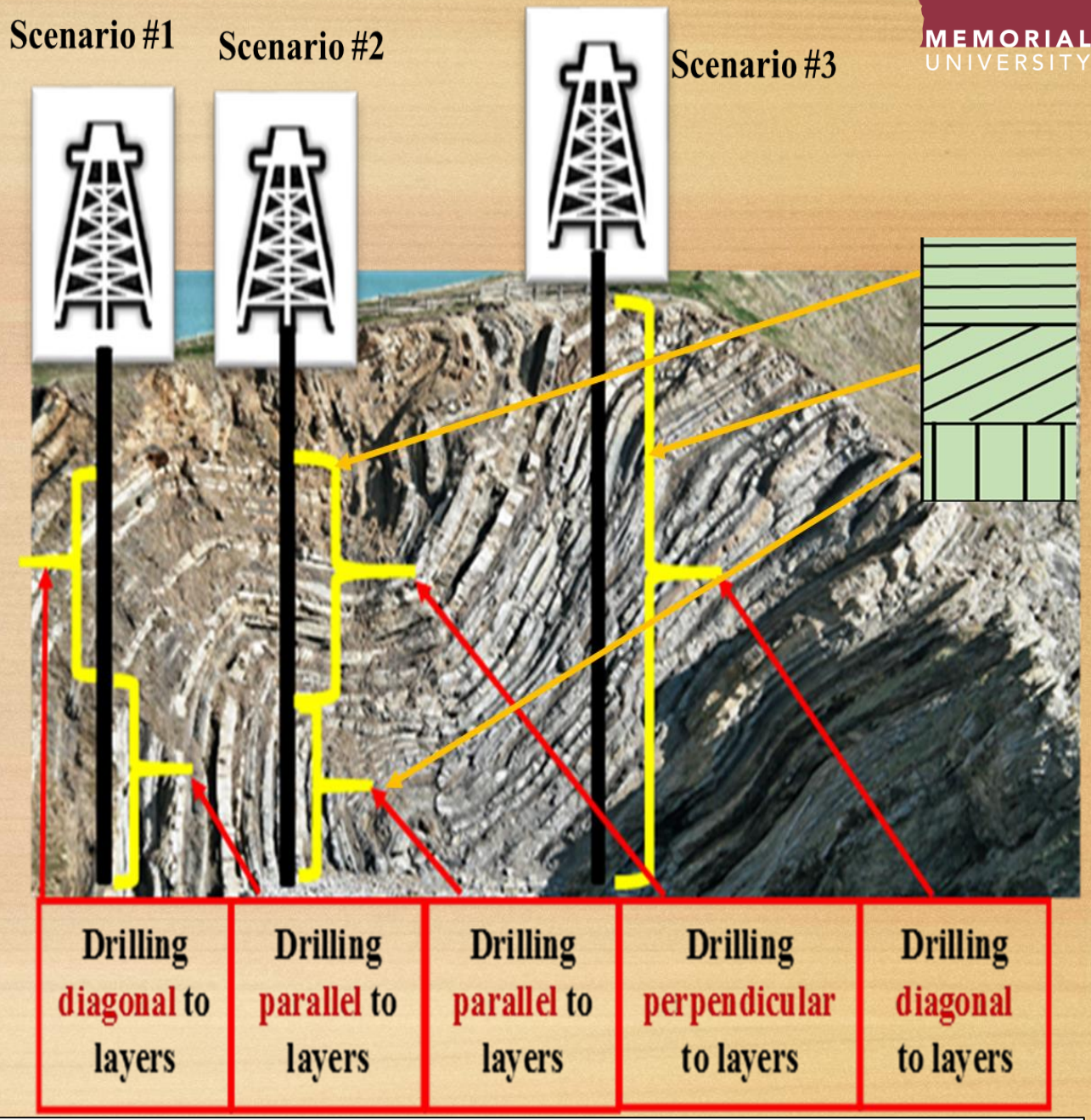


Figure 4. Scenarios of field oriented laminated formation.

Type of Recorded Drilling Data

Types of Data Recorded: RPM, Dyn-WOB, Current, Bit travel, etc.

Types of parameters Calculated: DOC, Torque, ROP, MSE, etc.

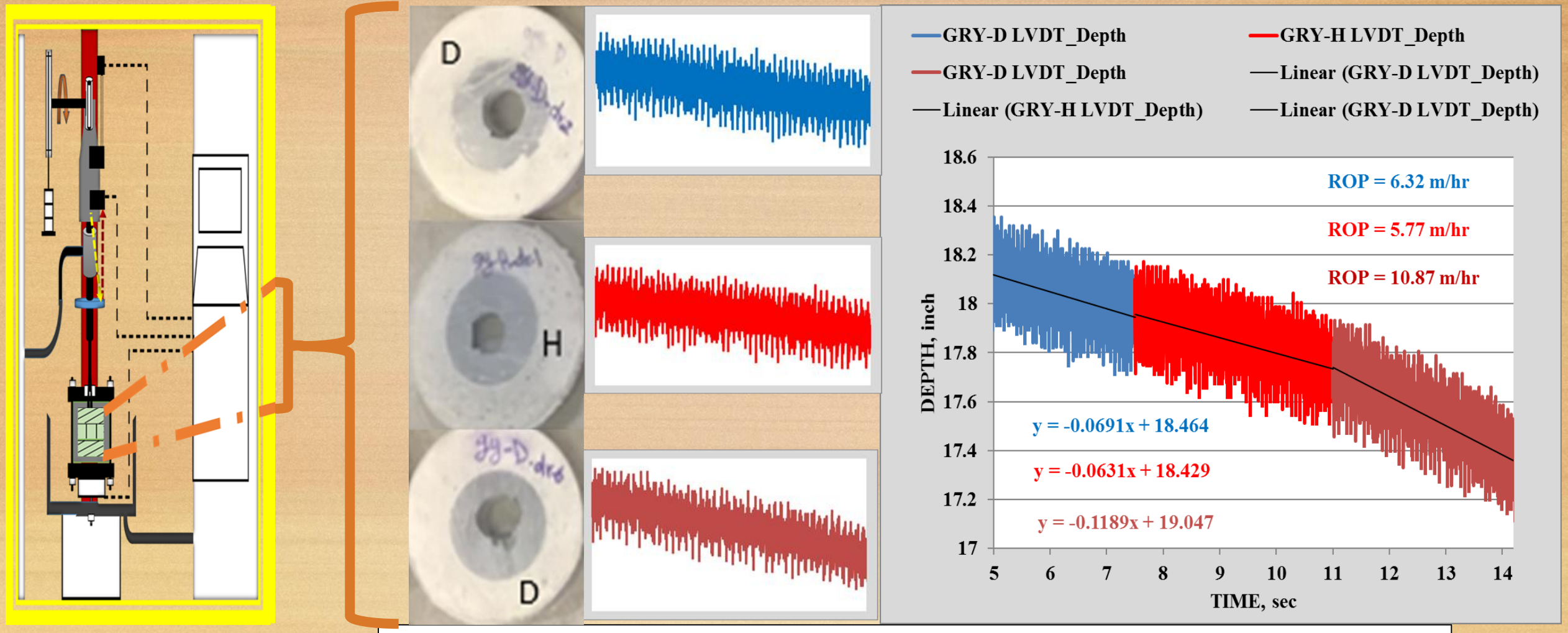


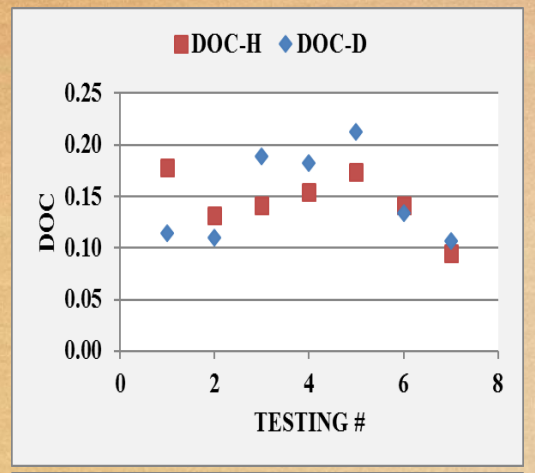
Figure 5. drilling procedure, drilled shale samples, and recorded data analysis.

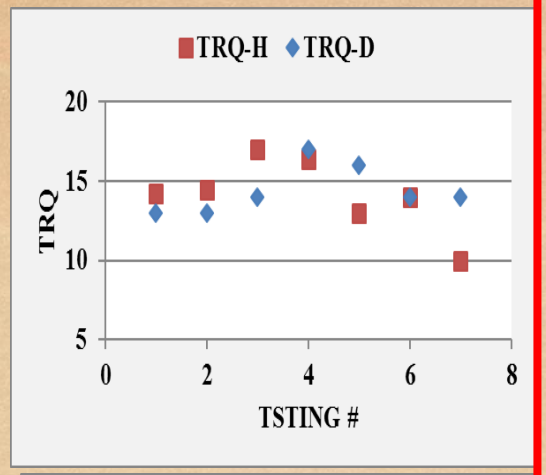
Data Analysis

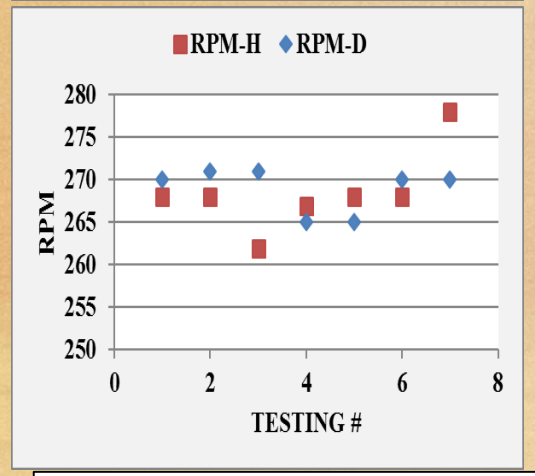
Single Parameter Analysis

Diagonal

Horizontal







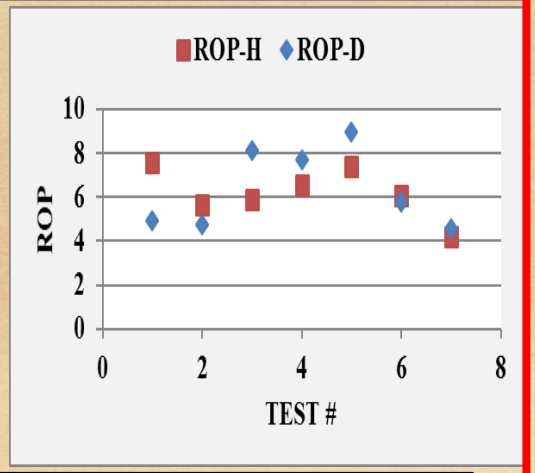
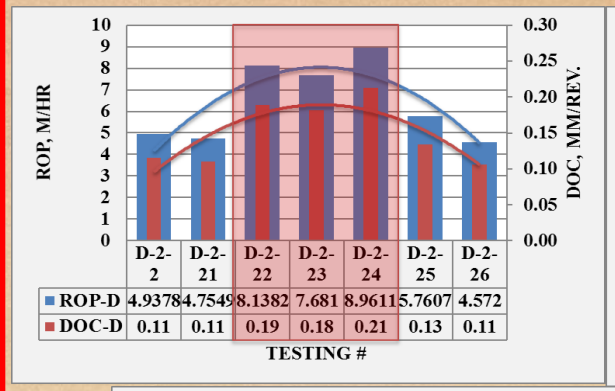


Figure 6. single parameter analysis w.r.t. two orientations.

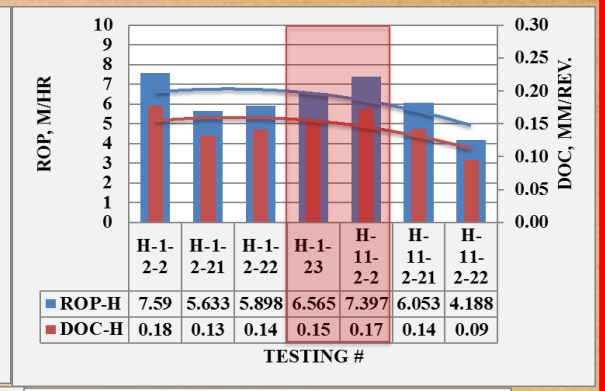
Double Parameter analysis

Diagonal

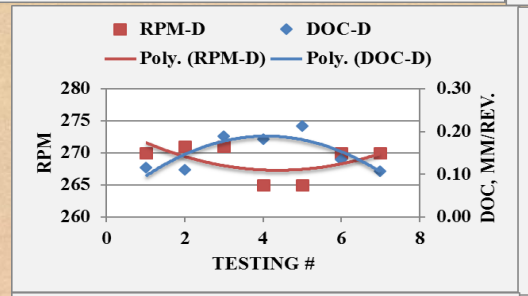
Horizontal

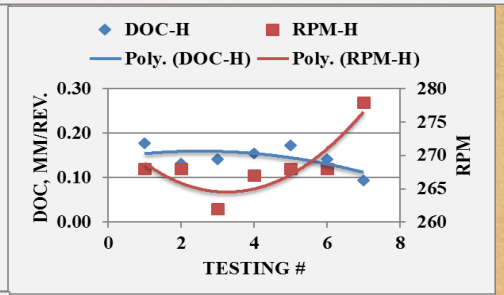


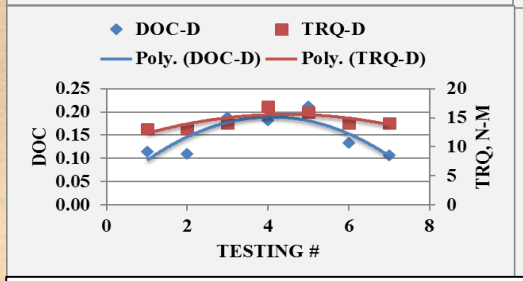
	D-2-2	D-2-21	D-2-22	D-2-23	D-2-24	D-2-25	D-2-26
ROP-D	4.9378	4.7549	8.1382	7.681	8.9611	5.7607	4.572
DOC-D	0.11	0.11	0.19	0.18	0.21	0.13	0.11



	H-1-2-2	H-1-2-21	H-1-2-22	H-1-23	H-11-2-2	H-11-2-21	H-11-2-22
ROP-H	7.59	5.633	5.898	6.565	7.397	6.053	4.188
DOC-H	0.18	0.13	0.14	0.15	0.17	0.14	0.09







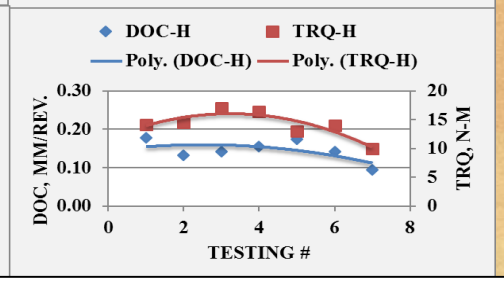


Figure 7. Double parameter analysis w.r.t. two orientations.

Data Analysis, Cont.,

- For further and more precise oriented drilling data analysis, the following procedure was adopted:
  - DOC was taken as a criterion or a condition for data validation.
  - If DOC is less than the cutter chamfer depth, then data is not considered.
  - If DOC is more than the cutter chamfer depth, then data is considered

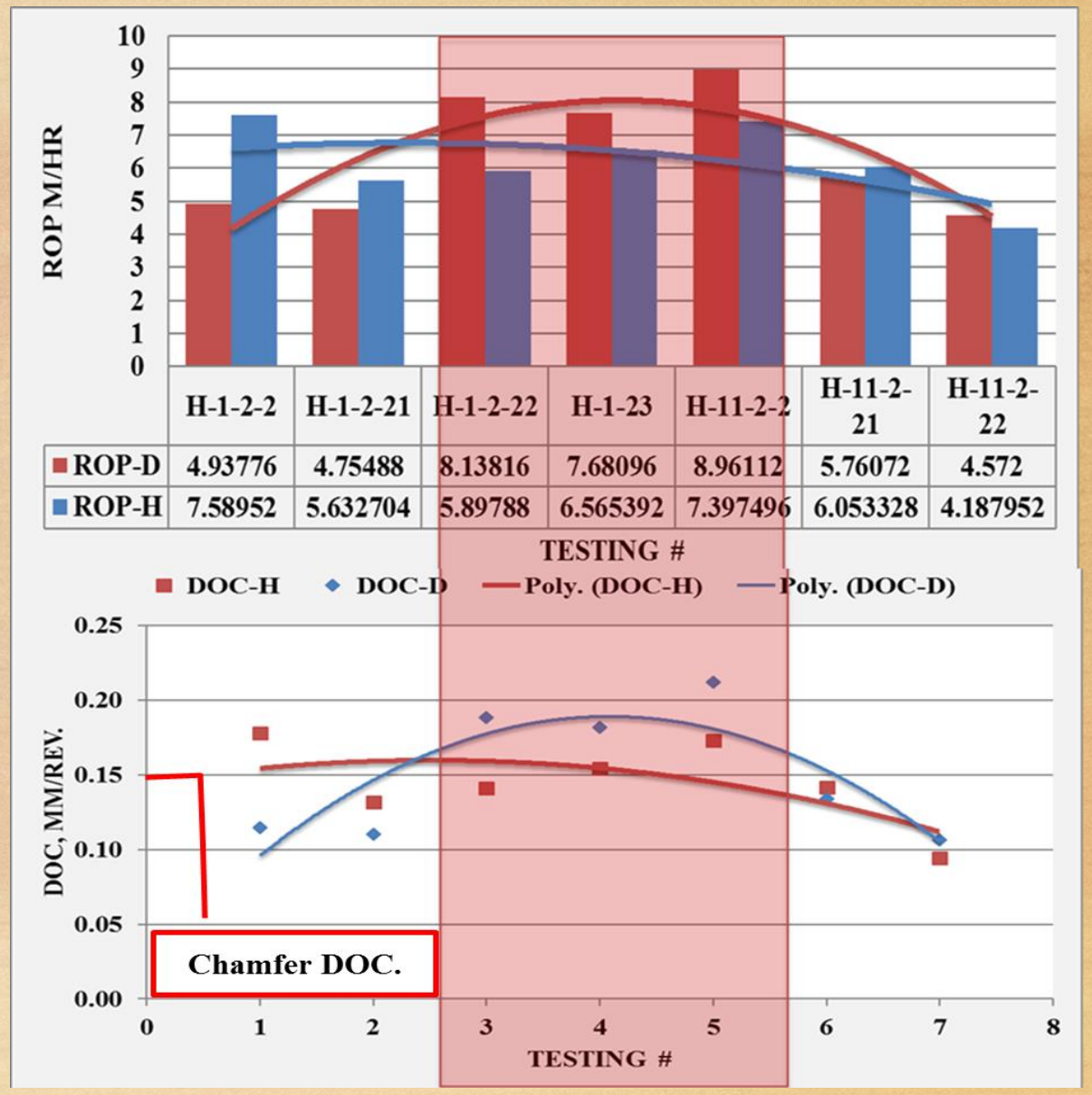


Figure 8. criterion of data consideration.

Summary of Part I

- The relationship between shale strength anisotropy and ROP investigated by adopting a controlled and fully instrumented lab-scale drilling set-up.
- The investigation involved several drilling parameters that have major influence on drilling performance (i.e. RPM, TRQ, and DOC, etc.).
- The ROP in the diagonal direction was found to be higher than that in the horizontal direction matching the oriented shale strength variations.
- Based on the U- strength Curve, the strength in the vertical direction is as high as in horizontal direction, therefore, the ROP in vertical direction is also low.
- These observations may assist in selecting the well trajectory of a higher ROP, w.r.t. SH-ANISO.

Part II

Theoretical relationship between Shale Anisotropy (SH-ANISO) and Shale Hydraulic Fracturing (SH-HF).

SH-ANISO VS. HF

For Optimal HC recovery

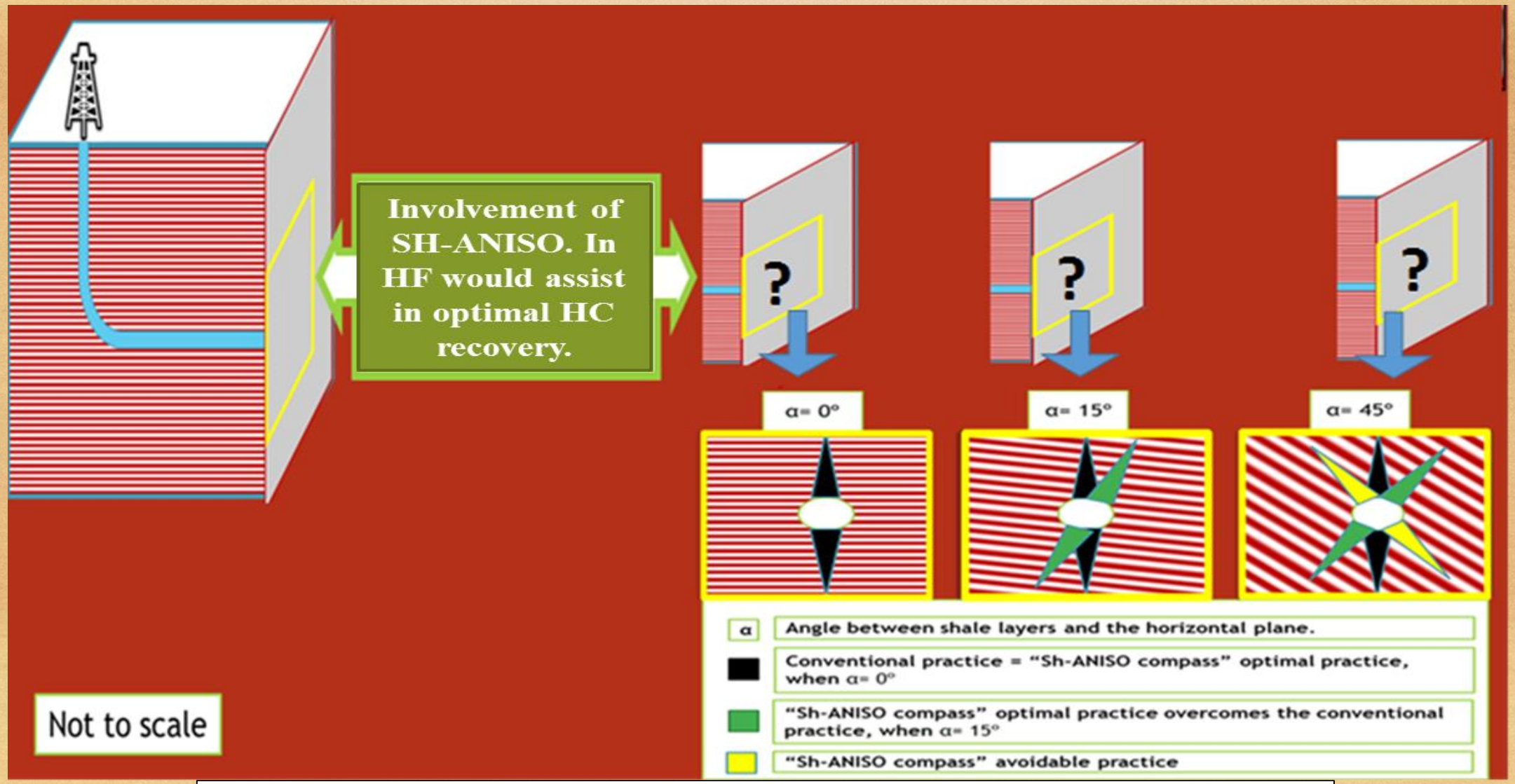


Figure 9. Theory of SH-HF vs. SH-ANISO. for optimal HC recovery.

SH-ANISO VS. HF, Cont.,

Optimal HC recovery and late water breakout

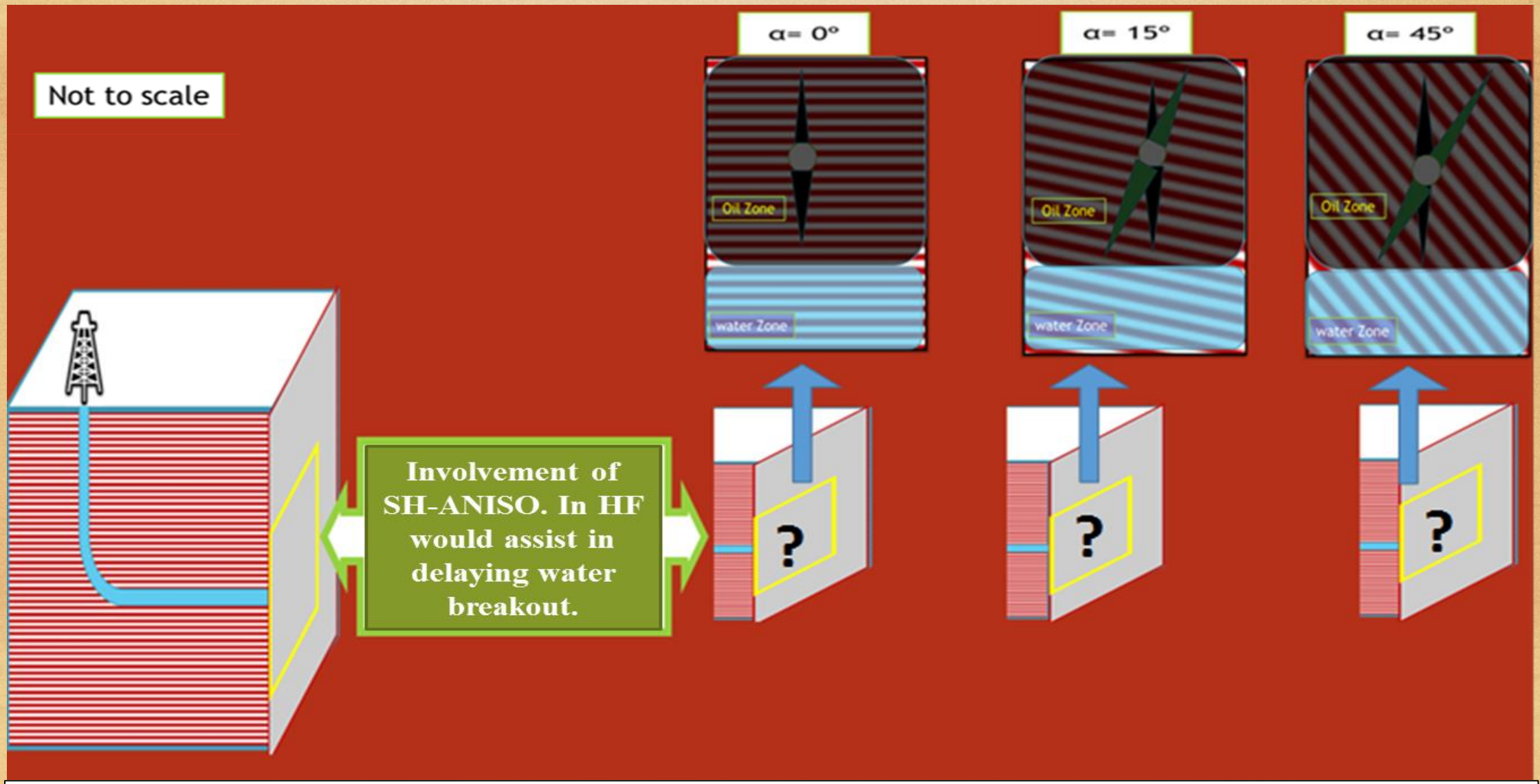


Figure 10. Theory of optimal SH-HF vs. SH-ANISO. For optimal HC swabbing and late water breakout.

Summary of Part II

- Considering SH-ANISO in HF efficiently, could have huge positive impact (on shale HC recovery) due to the following points:
- Maximizing shale layers fractured.
- Utilizing efficiently the fracture pressure in optimizing the fracture dimensions (Length, width, etc.).
- When fracturing parallel to max. horizontal stress in multi-fracturing stages, the fracture can be optimal propagating away from the water zone underneath, providing efficient HC swabbing, and delaying water breakthrough time.
- This theory is evaluated in the ongoing simulation and experiments.

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Thank you very much for your attention

Questions

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