Applied Geoscience Conference

Laboratory Modelling of Salt Deformation and its Correlation with Drilling Mechanics of Record Hybrid Drill Bit Runs in the Gulf of Mexico

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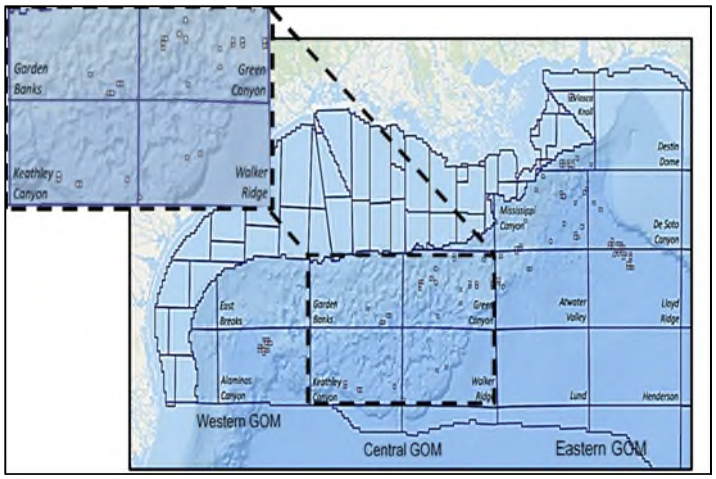
Outline

- Introduction
- Background and motivation
- Challenges of salt drilling
- Work flow and existing understanding
- Laboratory testing of salt deformation
- Hybrid bit and successful runs in Gulf of Mexico salt
- Drilling mechanics of hybrid bits
- Conclusion
- Acknowledgement

Introduction

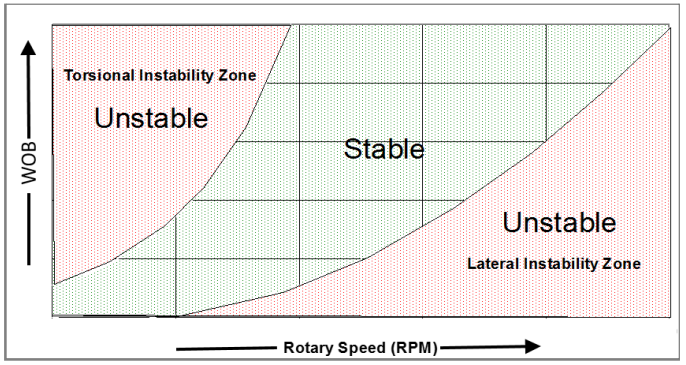
- GOM wells routinely penetrate salt.
- Drillability of salt is not well-established.
- Most operators take a holistic view.
- Salt is drilled with 26-in., 18⅛-in. and 16½-in bits.
- 18⅛-in. and 16½-in. bits are run with reamers



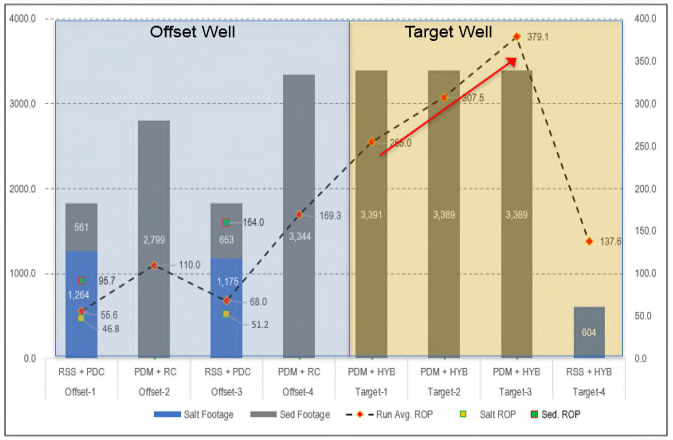
Location of the blocks in Gulf of Mexico represented under current study

Background & Motivation

- Operators continue to investigate new drilling technology to drill salt faster.
- Drilling salt faster requires higher axial force (WOB).
- PDC drill bit at higher axial force are generally produce high torque and torsional instability.
- Early use of hybrid bit technology was successful.
- Salt provided homogeneous medium for modelling.



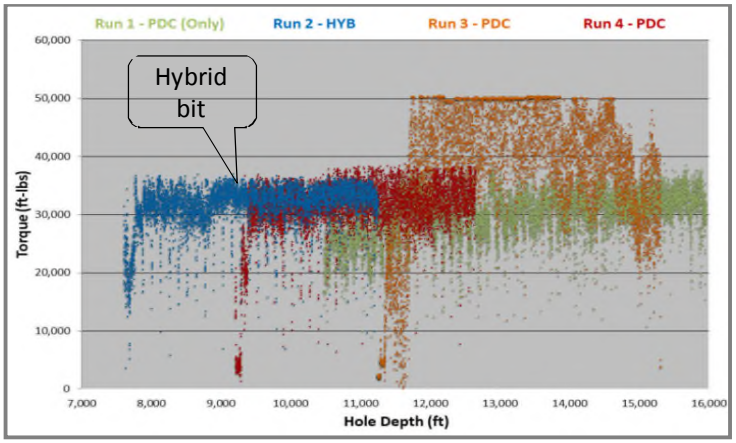
Generic stability window of PDC bit, AADE-17-NTCE-068



Drilling performance improvement using hybrid technology, SPE-178052

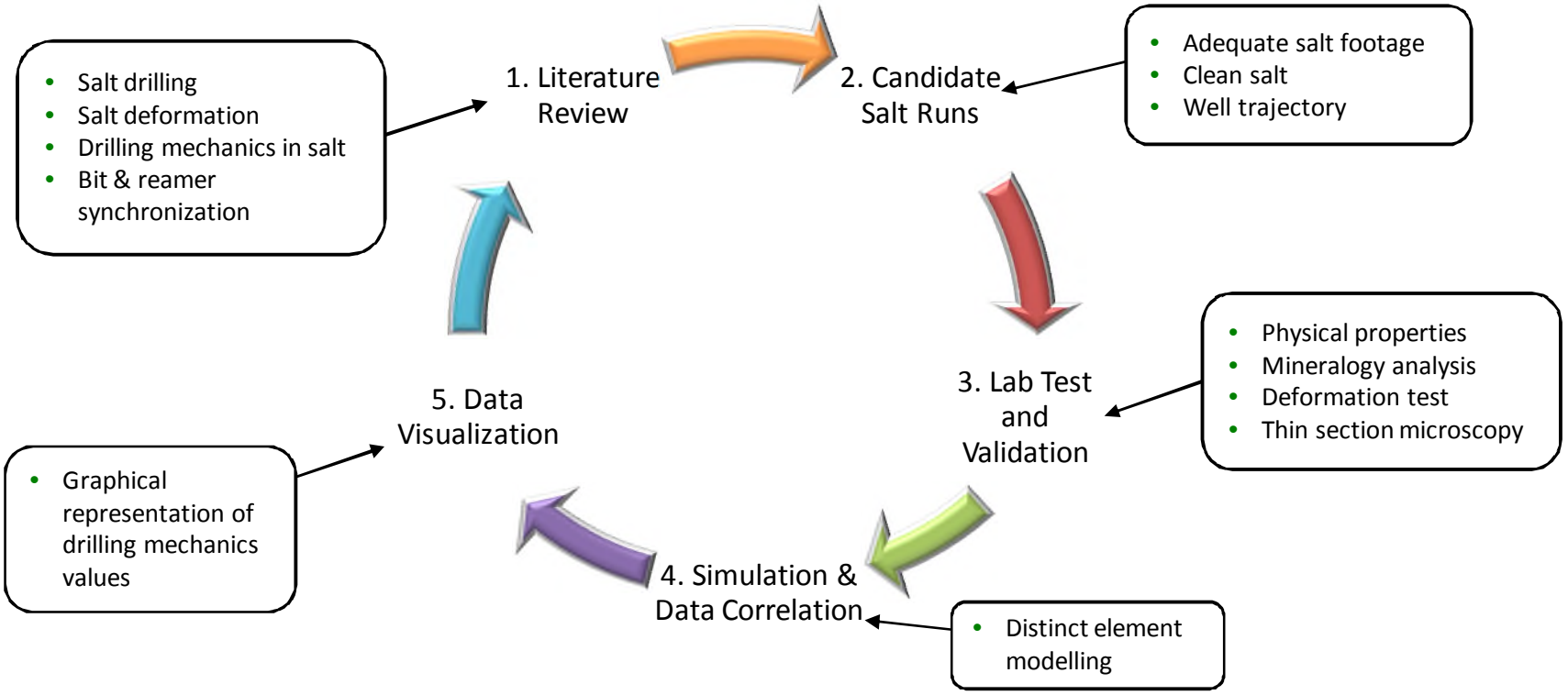
Challenges of Salt Drilling

- Ductile nature of salt required high WOB.
- Bit / BHA stability at high WOB.
- Over-torqued tubulars caused NPT.
- Potential stress distortion at salt boundary created unstable zone.
- Ability to creep required fast drilling and casing.
- Reamer and bit aggressiveness matching



Torque response of PDC and Hybrid drill bit , SPE-180342

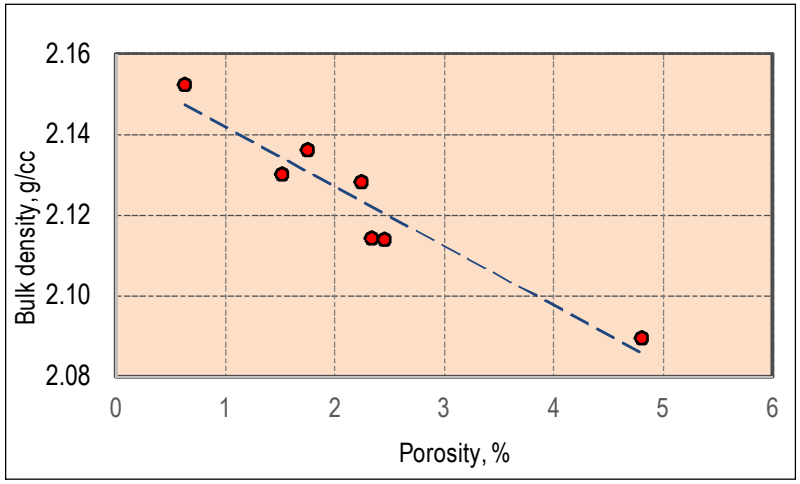
Workflow and Existing Understanding



Laboratory Testing of Salt Deformation

- Core Plugs
  - Plugs 1.5-in. x 3.0-in.
  - Mineral oil used in coring
  - Helium porosimetry

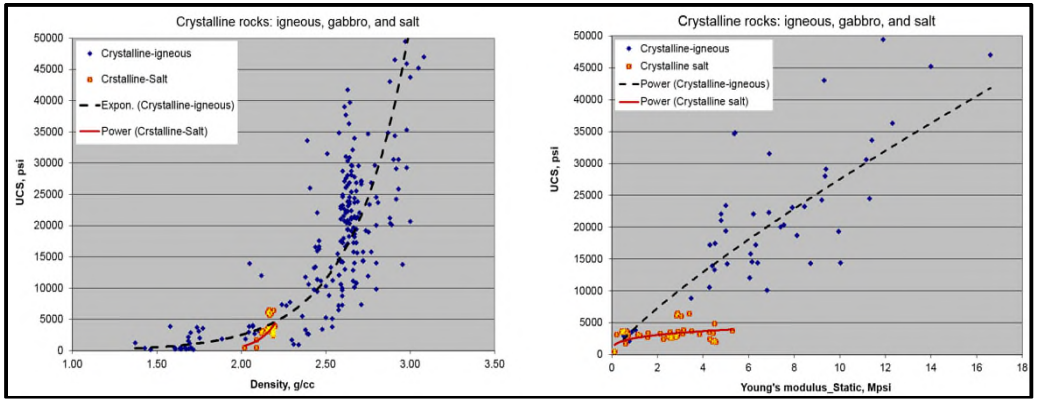
- Results
  - Bulk Density: 2.09 - 2.15 g/cc;
  - Grain density: 2.16 - 2.17 g/cc;
  - Porosity: 0.6% - 4.75%
  - Halite with minor quartz, calcite, dolomite etc.



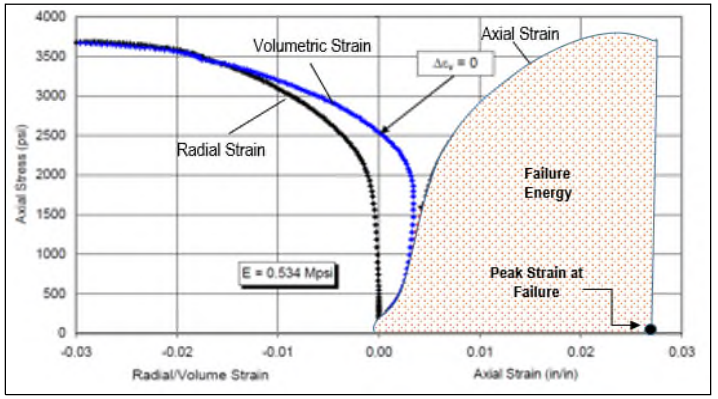
Density – Porosity of Salt Plugs

Laboratory Testing of Salt Deformation…2

- Weak nature
  - Low strength, low modulus
- Large strain & energy inputs



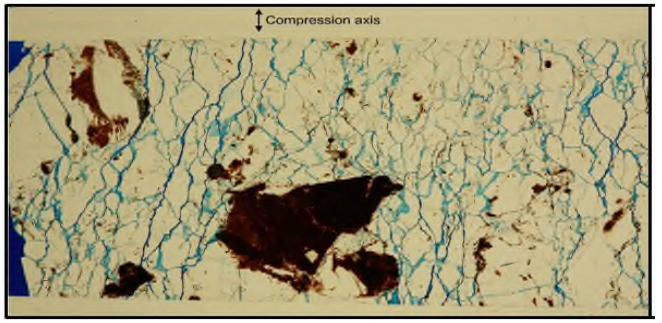
Compressive Strength against Density & Youngs Modulus



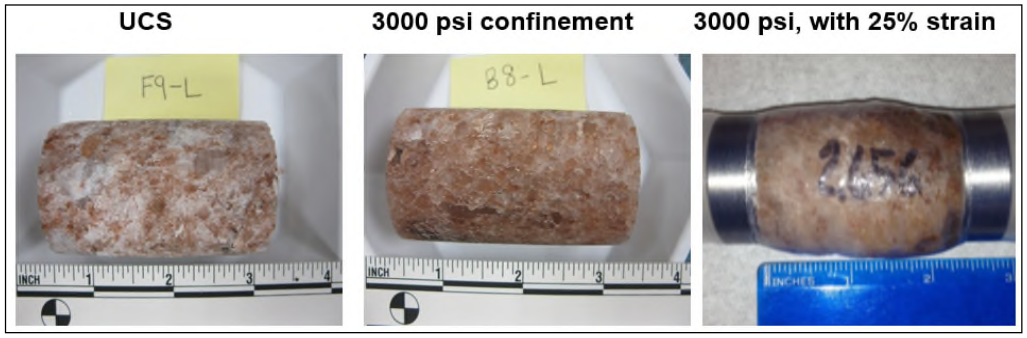
Axial, Radial & Volumetric Strain - Stress

Laboratory Testing of Salt Deformation…3

- Post deformation observations
  - Crystalline nature
  - Fracture along loading axis
  - Ductile / Plastic behavior



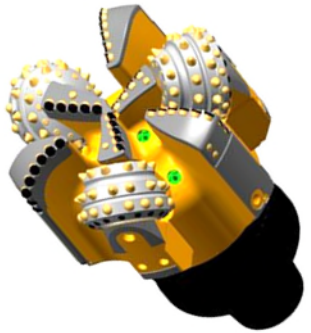
Thin section After Compression Testing

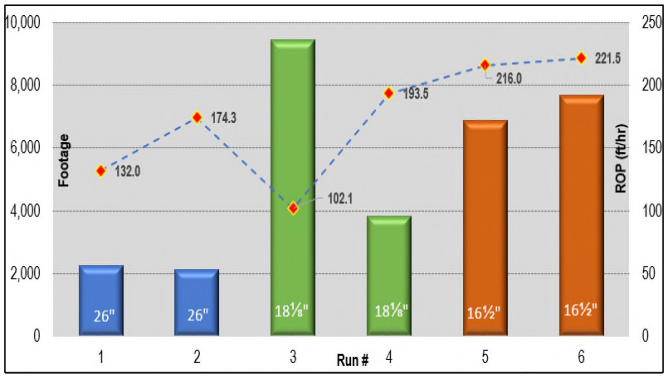


Visual Observation of Ductile Behavior

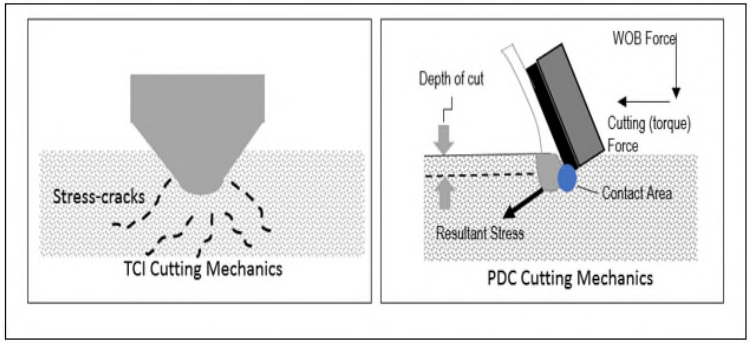
Hybrid Bit and Successful Runs in Gulf of Mexico Salt

- Dual cutting/shearing mechanics
- TCI cutting elements create larger pre-stressed volume of rock
- PDC elements shear the stressed rock





Successful hybrid bit runs in salt



TCI and PDC Cutting Element Buried in Rock Highlighting Pre-stressed Area

Drilling Mechanics of Hybrid Bits

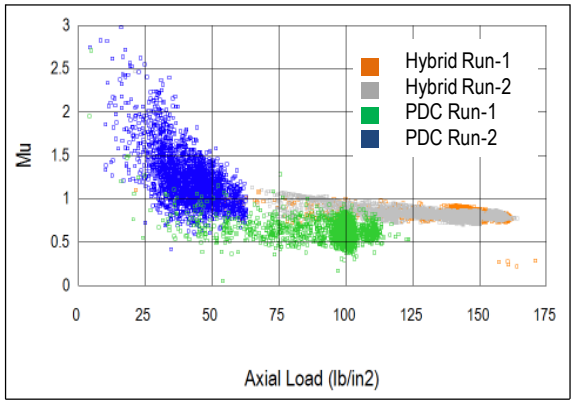
- Salt needed higher axial load to drill efficiently
- PDC's unable to reach comparable axial load for operational reasons
- Hybrid bit delivered consistent aggressiveness
- Hybrid bits operated with higher drilling efficiency

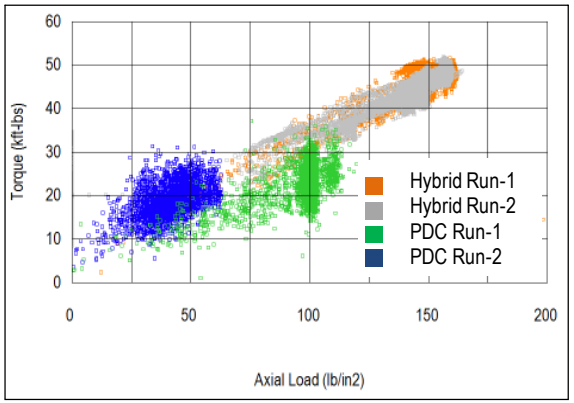
$$Axial\ Load = \frac{WOB}{Area}$$

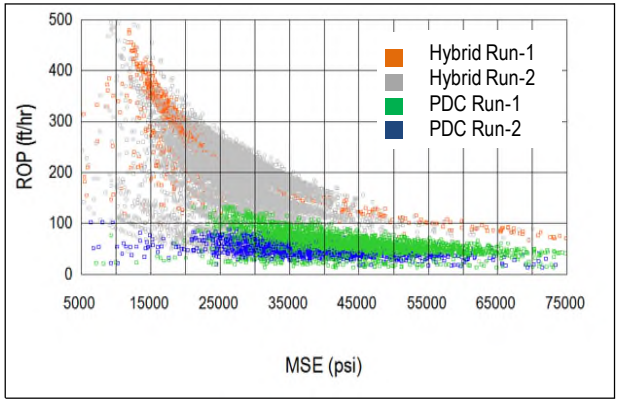
$$Mu\ \ (\mu) = \frac{36 * Torque}{D * WOB}$$

$$MSE = \frac{WOB}{Area} + \frac{13.33 * \mu * WOB * RPM}{D * ROP}$$

MSE (psi)	*= Mechanical Specific Energy*
Mu	*= Aggressiveness*
WOB (lbs.)	*= Weight on bit*
D (in)	*= Diameter*
Area (in²)	*= Cross sectional area of bit*
ROP (ft/hr.)	*= Rate of penetration*
Torque (ft-lb)	*= Drilling torque (ft-lb)*







Conclusion

- The tri-axial test of salt plug confirms high strain at failure suggesting high energy requirement for deformation.
- Laboratory tests re-confirms the low density, low porosity and low Young's modulus of salt.
- High axial load needed to drill salt is due to high strain at failure.
- Hybrid bits have a higher drilling efficiency and drills salt with lower MSE compared to PDC bits.
- Due to linear and lower spread value for torque, hybrid bits have improved torsional stability.

Acknowledgement and Questions

- Baker Hughes for supporting the work.
- HGC for opportunity to present.
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- Baker Hughes SMEs' for guidance.