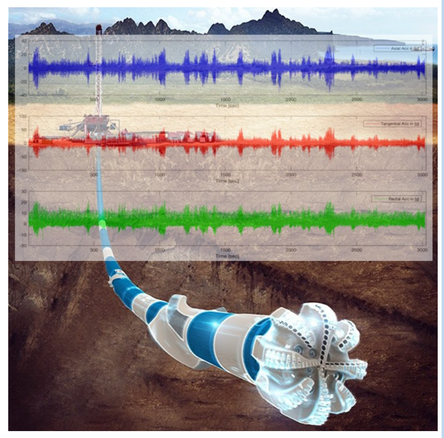
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Utilizing Downhole Drilling Dynamic Data to Characterize Geomechanics of Enhanced Geothermal Reservoirs

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INTRODUCTION

- **Enhanced Geothermal System development demands accurate estimation of rock properties and in-situ stress for :**
  - Wellbore stability analysis
  - Stimulation design optimization
  - Long-term reservoir performance optimization
- **Conventional approaches rely on:**
  - Density, sonic, porosity logs
  - DFIT / XLOT calibration
- **Key limitations:**
  - Sparse or missing logs (especially in geothermal wells)
  - High cost and operational constraints
  - Low vertical resolution or strong assumptions
- **Meanwhile, drilling generates rich, continuous data:**
  - Downhole vibration (near-bit sensors)
  - Surface EDR parameters



OBJECTIVE

Develop and validate a Drilling Dynamic Geomechanics (DDG) workflow to:

- Estimate continuous stress profiles (Sv, Shmin, SHmax)
- Predict rock mechanical and petrophysical properties

METHODS

Data Inputs

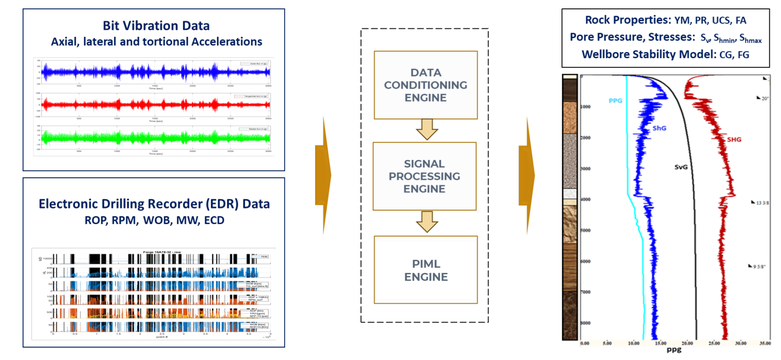
- High-frequency **3-axis vibration (near-bit accelerometers)**
- Surface **EDR data**: WOB, RPM, torque, ROP, MW, ECD

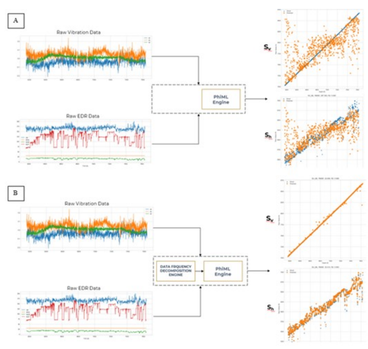
Workflow Overview

1. Signal Processing
- Wavelet-based denoising
- Outlier removal
- Time–frequency decomposition

2. Feature Engineering
- Statistical features (mean, variance)
- Frequency-domain features (STFT)
- Temporal patterns from time-series

3. Feature Selection
- Significance filtering (p-values)
- Collinearity control (VIF)





Modeling Approaches

1. Regression-Based Models
- Linear regression (baseline)
- Decision trees
- Random Forest (ensemble)

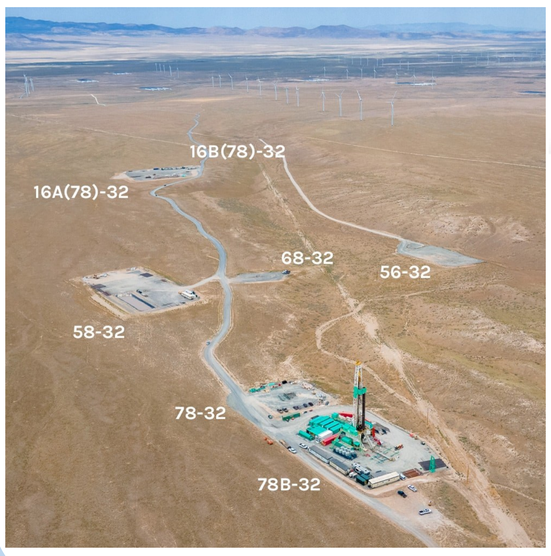
2. Time-Series Deep Learning
- Recurrent Neural Networks (RNN)
- LSTM for long-term dependencies

Time–Frequency LSTM (TF-LSTM)

RESULTS:

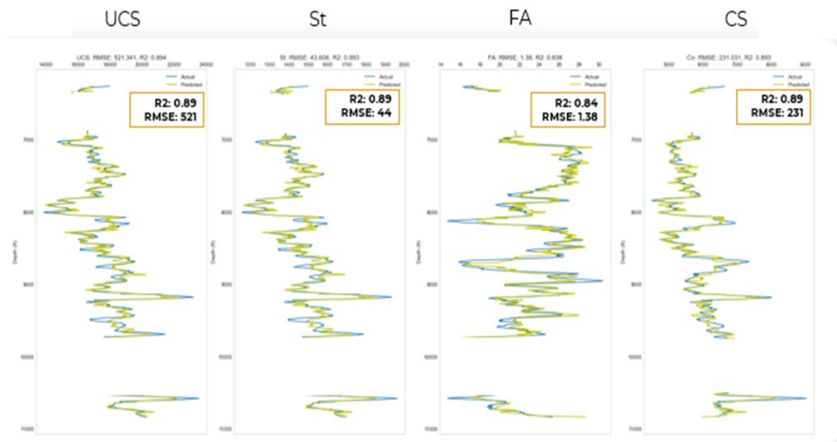
Case Study: Utah FORGE Well 16A(78)-32

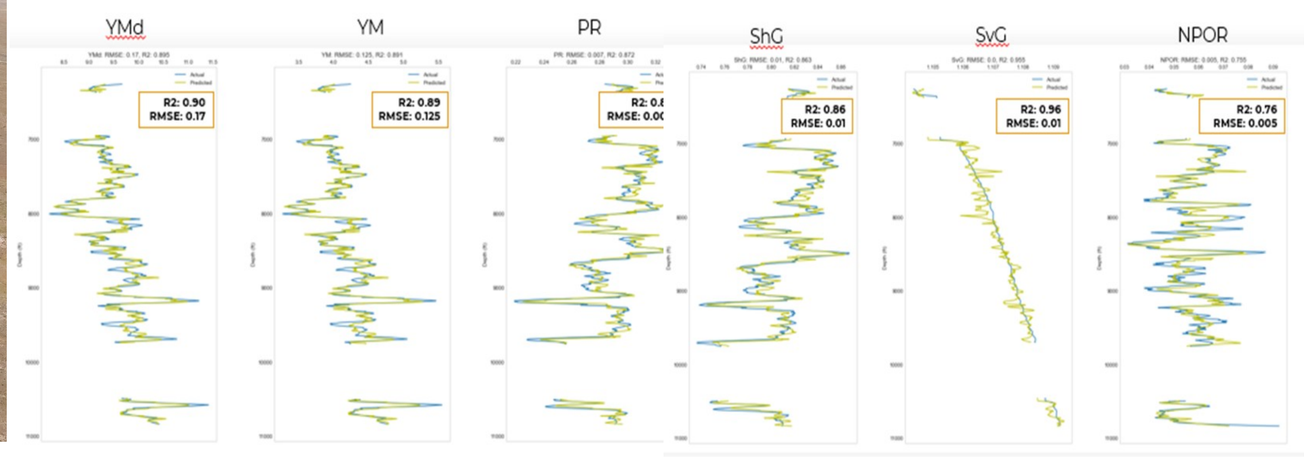
- **Datasets:**
  - Downhole vibration
  - EDR
  - Geomechanical logs
- **Blind-test validation applied**



Predicted Outputs

- **Elastic properties:**
  - Young's modulus, Poisson's ratio
- **Strength properties:**
  - UCS, tensile strength, cohesion, friction angle
- **Stress & reservoir properties:**
  - Sv, Shmin, SHmax
  - Stress gradients
  - Porosity





Model Performance

- ~90% prediction accuracy across parameters
- Strong agreement with measured logs
- Elastic properties: $R^2 \approx 0.9$
- Low RMSE relative to parameter magnitude:

Key Observations

- Reliable performance despite lack of raw vibration data
- High-temperature geothermal conditions did NOT degrade signal quality
- Demonstrates robustness in EGS environments

DISCUSSION

- Mechanical Sensitivity in Geothermal Systems DDG derives geomechanical properties from bit–rock interaction, where in-situ stress, temperature, and rock strength jointly control drilling response. In geothermal reservoirs, elevated temperature and fractured media directly influence vibration behavior, enabling stress-related signals to be captured through mechanical response.
- Stress Characterization in EGS Context In-situ stresses govern fracture initiation, propagation, and permeability evolution in Enhanced Geothermal Systems (EGS). The strong agreement observed in this study suggests that DDG can reliably capture stress variations relevant to stimulation design and fracture network development.
- Coupling with Rock Properties Elastic and strength properties (e.g., Young's modulus, UCS) are tightly linked to stress and deformation under geothermal conditions. Their consistent prediction supports the use of DDG for integrated geomechanical modeling in high-temperature reservoirs.
- Operational and Thermal Effects Drilling dynamics reflect both formation properties and operational conditions (e.g., WOB, RPM), as well as thermal effects unique to geothermal environments. While EDR integration mitigates operational bias, DDG measurements should be interpreted as formation-responsive and temperature-influenced signals.
- Measurement Domain in Fractured Reservoirs DDG represents an averaged response over the bit–rock interaction zone and may smooth thin layers or small-scale heterogeneity. However, this scale is consistent with the characteristic size of fracture networks relevant to EGS performance.
- Role in Geothermal Development DDG provides a continuous, drilling-based geomechanical measurement that complements logs and field

CONCLUSION

- DDG enables continuous, log-independent geomechanical characterization
- Achieves ~90% accuracy in geothermal application
- Works effectively under high-temperature conditions

Key Value:
- Real-time drilling insight
- Improved wellbore stability analysis
- Better stimulation and reservoir design

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- DOE Utah FORGE
- Geothermal Data Repository (GDR)

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