Automation Provides Unique Insights of The Rock Record and Subsurface Through the Delivery of a Robotic Sample Collection and Analysis Device

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Topics

• Sample Collection
• Automation
• XRF Analysis
• Landing Zone Selection
• Geosteering
• Smart Completions
Traditional Sample Collection & Analysis

The Mudlogging Geologist will then make a visual inspection of the sample under a microscope and make an estimation of the % of each lithology present.

Samples are bagged, labeled, shipped then stored.

Mudlogging Geologist/ Sample Catcher collects the sample from the Shale Shaker and conducts some preliminary sieving and cleaning.

Typical MudLog
One of the key risks Associated with mudlogging Is slips trips & falls. The repetitive nature of Collecting the samples manually, presents a significant risk.
The ROP Challenge

- Higher resolution rock collection and record
- Improved stratigraphic correlation
- Improved understanding of geo-mechanical properties
- Assistance with picking landing zones
- Improve models for depositional environment
- Improved wellbore containment
- Optimized Completions

Manual Sampling Frequency at 240 ft. / hr. and one sample every 20 minutes – 80 ft resolution

ARM Sampling Frequency at 240 ft. / hr. and one sample every 1 minute – 4 ft resolution
Qualitative Sample Analysis

The visual inspection and estimation of the rock composition is qualitative and can vary from logger to logger, day shift to night shift, well to well.
Automated Remote Mudlogging Device*

- ARM* = AUTOMATION
- Industry only fully automated sample collection device
- Sampling triggered by lag calculation via WITS
- Stores up to hold up to 350 samples for later retrieval
- Real time access for process control and images

* Patented System
ARM – Automated Remote Mud Logging – What is it?

Sampling Points

NEMA 4 Explosion Proof Housing

Extraction ARM

Aggregate Sample Board

Lower vein at unexpected higher pressure. KICK occurring. Mud Pit fills. Shut-in well.

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ARM – Automated Remote Mud Logging

Sample Collection device

Sample Intake House

Return Flow to pits

5 Minutes to Change Reel

Industrial Seal wrap

UV Light

High Resolution Digital Microscope

635um Mesh

Sample Collection Reel

350 Samples/ Reel

Water/Diesel Intake Lines 2.25GPM

WITS Fed Depth drives Drum and Internal DAQ Calculates LAG

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Realtime & Post Well Sample Evaluation

Dual Resolution Images

UV light for fluorescence

Each sample is labeled and stored for further analysis
Results

Well 1
• Approximately 12,000 ft of rock was collected at 10 and 20ft intervals with a 94% success rate.

Well 2
• Total interval to collect was 4718’ and included 1150’ during coring operations.
• The ARM System collected 508 samples with 479 samples 15gms or greater. 94% success rate.
• ARM system collected at 5’ & 10’ intervals vs. 30’ from mudloggers.
• Average ROP of 100’/hr. gave the ARM 10 collections per hour, vs. 3 collections per hour from mudloggers.
Excellent Correlation Between Trace Metals Ni and TOC. Discrepancy with V shows need for basin specific calibration.

Green lines are XRF measurement taken on this cored section showing very strong agreement with ARM collected samples analyzed with XRF.

ARM samples collected at 5-10 ft Intervals.
Redox Elements Proxy for TOC

- No H2S
- +H2S
XRF Measurements on Drill Cuttings

Sample Quality

- Are the cuttings on depth?
- Do they represent the interval drilled?
- Elemental GR (U+K=Th) vs MWD GR
Real-time viewing of images
  (remote Co. Geologist, Co. Man, Mud Logger)
High frequency samples at high ROP’s
Accurate samples of interval drilled
10-30 grams per sample
23 wells completed in total
Reduced personnel onsite
Reduced exposure to hazards / risks
Weather agnostic
High Resolution Collection of the Rock Record from Drill Cuttings

- Organics
  - Pyrolysis
  - TOC
  - API Gravity
  - TMAX
  - S1/S2/S3

- Inorganics
  - Elements
  - XRF
  - ICPMS
  - LIBS

- Inorganics
  - Minerals
  - XRD
  - FTIR

- Microscopy
  - Hyper – Spectral
  - EDS - SEM

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XRF Run on manually collected samples to identify kick off point for a Lateral

Integrated Geochemical XRF Log

Target Zone
Geosteering with XRF and GR
Application: Optimize Frac-stages for “Engineered Completions” designs

Eagleford Lateral Well

Chemomar stratigraphy, Mineralogy, Brittleness, & TOC
Derived from Cuttings-Based Elemental Data

From Tonner et al. 2012

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Potential for Personnel Reduction
Lower cost lower HSE risk

Service Efficiency Evolution

- Remote ML
- Geo-steering
- Remote DD / Survey Management / Anti-Collision Monitoring
- 24/7 RTOC

ML
Data Engineers
Sample Catchers
Recent Deployment

- Statoil – Equinor Eagleford
- ARM Logged and collected samples from 12800 MD. Collecting 10 foot samples through landing point.
- 30 foot samples until 18400 MD.
- 10 foot samples until 18700 MD
- >25 grams / sample
- 80% collection efficiency
Future Improvements

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Summary

• ARM has proven to be a viable and robust method of collecting and storing drill cuttings with minimal human intervention.
• 300% improvement in sampling frequency whilst also improving sample integrity
• High resolution sampling and applying Elemental analysis provides the opportunity to improve reservoir characterization, optimize completions and enhance wellbore placement.
• Significant opportunity for Reduction in HSE Risk and increase efficiency
• Machine still requires manual intervention – Learning ongoing
• Future enhancements to include Real Time element and mineral analysis integration with Bid Data, ML and AI.

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