

## Advanced Analytical Tools to End Oilfield Mysteries For Drilling Fluids

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### Abstract

New analytical methods eliminate uncertainty in root cause analysis, differentiating fluid-induced issues from other issues, such as mechanical failure. This promises to extend operating times and accelerate solution development across drilling disciplines.

Frequently downhole issues are attributed to drilling fluid without a wholistic view of the drilling system. This leads to incorrect assumptions or lingering uncertainty as to the origin of the issue, increasing the risk of repeating preventable events.

This paper highlights the critical role of specialized analytical tools and methods, going beyond standard drilling fluid testing equipment and analysis to provide a deeper insight into fluid composition, stability, and performance. Additional methods are reviewed, including tool failure investigation, metallic debris characterization, and elastomer failure modes.

The authors will review the application and value of several key analytical techniques and corresponding equipment, along with case studies where these tools determined the root cause of wellsite issues.

Each of these instruments provides vital, high-resolution data essential for effective troubleshooting, robust QA/QC protocols, and the accelerated research and development of next-generation drilling fluid systems. This paper will detail the specific capabilities of an analytical lab and present case studies demonstrating how these tools were used to solve real-world drilling challenges.

### Introduction

Traditional drilling fluids laboratories focus on drilling fluid properties. Basic fluid properties, while fundamental, only capture one dimension of the drilling system – a system in which drilling fluids touch every other component.

The equipment in a basic drilling fluids laboratory remains a foundation, but to address drilling performance requires a wholistic approach using additional equipment to understand fluid interactions with formations and drilling tools that goes beyond a single domain.

A basic mud check provides insight into trends, but it cannot capture nuances within the fluid or potential interactions with other aspects of the circulating system. This requires additional tools for investigation and root cause analysis.

In isolated domains, fluids are left separate from solids

control, surface equipment, the drilling assembly, and the formation. In the event of a failure, blame is readily passed between domains without the definitive evidence of the root cause. The recipient of said blame lacks the knowledge to counter any claims, and everyone moves past the problem to focus on the next well.

With longer wells and greater economic pressures, the cost of failure continues to increase (Toomes and Offenbacher, 2024).

Advanced analytical tools, with methods adapted to root cause analysis, are essential to the next phase of drilling efficiency.

### Basic Drilling Fluid Laboratory Equipment

Most drilling fluids laboratories feature a suite of basic equipment to perform mud checks and basic product evaluation. The contents of Table 1 is subjective but intended to illustrate a typical support laboratory to contrast them with advanced analytical tools in the discussion.

In some areas, advanced equipment is a standard requirement. For most field locations, the ability to perform basic mud checks and pilot testing is important for quick response times. These tests may provide immediate relief, but often they fail to provide the root cause to detect and prevent an issue in the future.

**Table 1: Basic drilling fluid laboratory equipment**

Equipment	Function
Materials for API-13B-1 and 13B-2 mud checks (Viscometer, filtration units, titration materials, MBT, retort, etc)	Replicate field checks and basic analysis
Digital balance	Prepare lab-scale pilot testing
Multi-mixer or similar	Mix/shear samples
Static/Dynamic Ageing Oven(s)	Expose fluids to downhole temperatures
Lubricity Tester	Rudimentary lubricity testing

### Advanced Analytical Tool Overview

Most advanced tools, by their very nature, require additional expertise and training to operate. They usually feature higher costs and are not required by operators who may lack knowledge of what the equipment can do or if it even exists. The discussion to follow is intended to characterize practical challenges with accessing equipment and practical applications

for drilling fluid challenges.

### Objectives

Analytical tools provide measurements, but without context these data sets are lacking. Operational context and drilling fluids expertise narrow broad information into actionable items. In many cases, more than one instrument is required, but the ultimate goal is to identify the root cause of an issue.

Most drilling fluid measurement equipment allows for a chemist to iterate through samples until desired properties are achieved or regained. Analytical tools, for the purposes below, determine the origin of an issue instead of trial and error approaches that may or may not yield definitive results.

### Equipment Access

Many of the equipment in this discussion have significant costs for purchase and maintenance. Some require substantial space and supporting equipment (chillers, gas supply). This may require sufficient work volume to make ownership of equipment practical.

Third-party partnerships with commercial labs or universities make acquiring data possible, but there are potential limitations when the laboratory lacks drilling fluids experience. Retesting increases cost and delays the timeliness of results.

### Personnel Requirements

The ideal case is to have full-time access to an analytical chemist with proper training and background with equipment of interest. Many equipment providers offer training classes for their equipment, but it may be too general for many drilling fluid use cases.

It is the experience of the authors that background training and an additional six months of practical use of an analytical tool provides high levels of confidence to acquire consistent and reliable results. With proper work instructions and training, multiple personnel with different skillsets can operate most equipment.

### Methods

Method development is the process of developing a test method to detect and quantify a material of interest using an analytical tool. In many cases, this requires multiple iterations testing known samples and comparing the results with unknown samples.

There are many published methods, including standard methods which can be adopted or adapted to a particular use case. Method development is easiest when there is full access to a particular piece of equipment for repeated iterations and direct observation throughout testing.

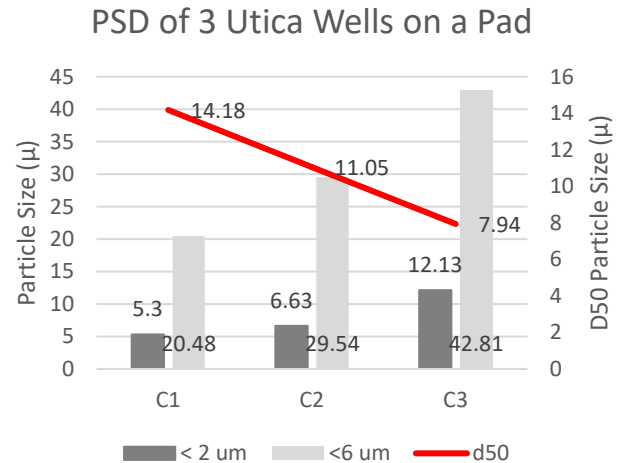
### Equipment

Each instrument provides key insight into particular properties of a sample. In some cases, the equipment complements other equipment.

### Laser Particle Size Analysis

Laser light scattering is a familiar measurement technique to many drilling fluid specialists. Regular particle size distribution analysis facilitates solids control equipment performance evaluation and verifies necessary dilution when fines accumulate.

In the figure 1, particle size distribution illustrates the accumulation of fine solids while drilling multiple wells on the same pad. By the last pad, there is a significant increase in fine solids versus the initial well. This information is used to show the operator the need to recondition fluid before the next pad.



**Figure 1: Particle size distribution comparison using laser light scattering**

### Gas Chromatography-Mass Spectroscopy (GC-MS)

GC-MS provides detailed composition of chemicals. GC-MS provides information on different base oils and contaminants.

Diesel describes a broad array of hydrocarbon materials. Many sources for oil-based drilling fluid are off-specification or contaminated diesel that cannot be used for combustion, but has potential use as a non-aqueous phase for drilling fluid.

Diesel variances can require increased product consumption to achieve drilling fluid properties and risk incompatibility with elastomeric materials in drilling equipment. During failure analysis, GC-MS provides composition information and the potential to connect a diesel sample to a vendor.

Figure 2 provides a comparison of four diesel samples used in a failure investigation. These were compared to the hydrocarbons present in drilling fluid samples to demonstrate there was no relationship between base oil sources and tool issues.

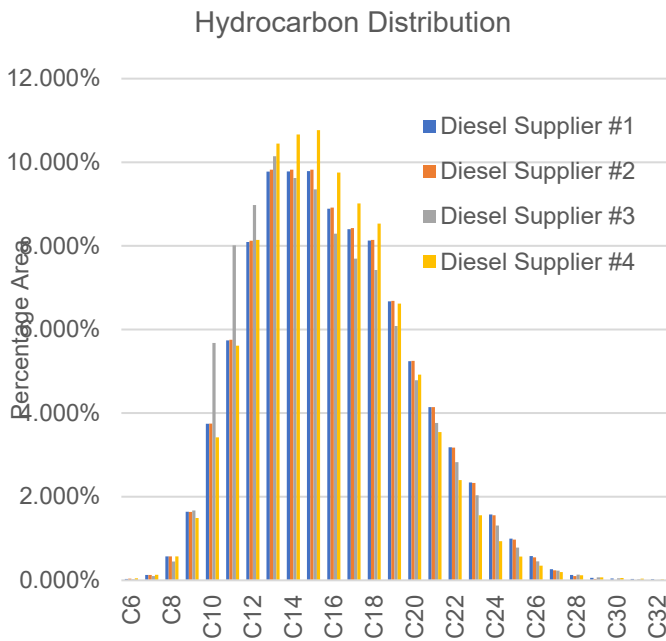


Figure 2: GC-MS comparison of different diesel samples

While drilling, hydrocarbon influx can impact fluid stability. Condensate can break invert emulsions or induce gas-stripping to cause barite sag. Lubricants interact with heavy hydrocarbons to create thick sludge. On the surface, these events may appear as any number of issues. GC-MS of materials provides definitive evidence of the root cause for treatment and prevention planning.

Figures 3 and 4 show GC-MS data of three field samples. Sample #1 is prior to drilling and Sample #2 and Sample #3 are after a suspected hydrocarbon influx. The closeup in Figure 4 captures the presence of lighter hydrocarbons, such as condensate.

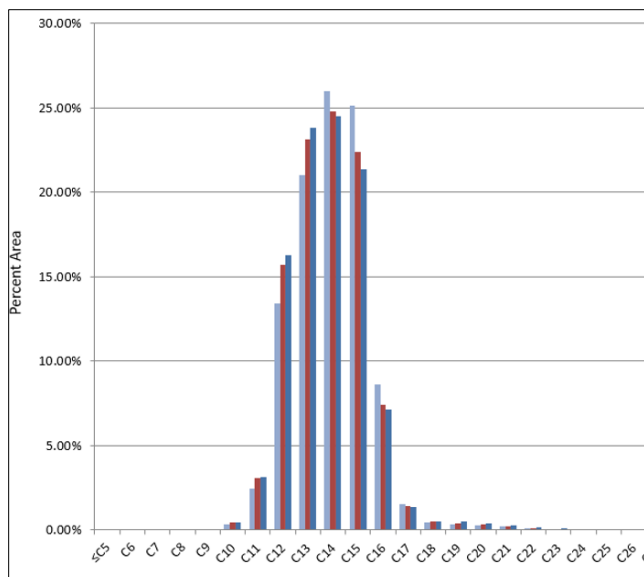


Figure 3: GC-MS of samples prior to and after a hydrocarbon influx event

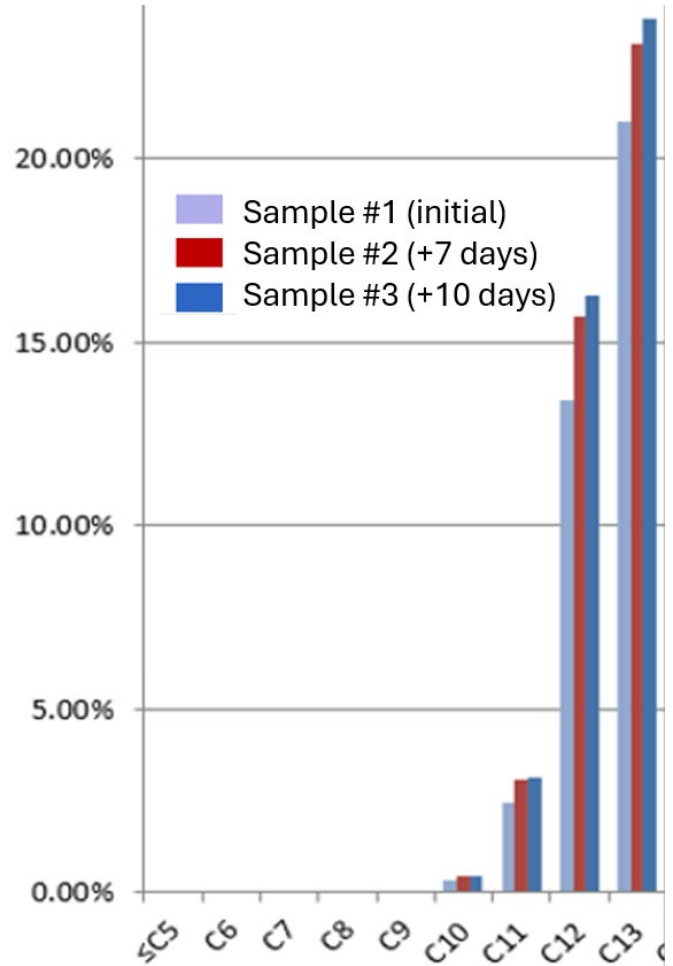


Figure 4: Close-up of Figure 3 where Sample #2 and Sample #3 indicate additional hydrocarbons present

**X-Ray Diffraction (XRD)**

XRD provides mineralogy using crystallography. It is a common method to characterize formations, and additional steps can be performed for detailed clay characterization.

XRD can determine the composition of drill cuttings. In one scenario, an abundance of quartz confirmed the source of diminished shaker screen life. On another well, a damaged drill bit was attributed to pyrite in the formation (Table 2).

Table 2: Mineralogy of sample

Mineral	Abundance (weight %)
Quartz	31.6
Kaolinite	0.2
Illite-Mica	8.0
Mixed Layer Illite/Smectite	0.5
Feldspar	1.5
Calcite	20.9
Ankerite	23.1
Pyrite	14.4

### X-Ray Fluorescence (XRF)

XRF provides quantitative elemental analysis. A sufficiently powered unit has detection thresholds of many elements as low as a few parts per million.

XRF has proven essential in tool failure analysis, particularly rotary steerable systems (RSS), which are essential for longer laterals. In Scott et al (2025), analysis of high-powered magnet systems identified much higher concentrations of metallic debris within drilling fluid system. XRF was an essential tool to confirm that the material matches casing and tool metallurgy (Table 3). Prior to this analysis, directional drillers repeatedly claimed RSS failure was drilling fluid materials.

**Table 3: Elemental analysis of recovered debris via x-ray fluorescence reveals presence of common tubular alloys**

Element	Abundance
Si	14.6 mass %
P	1210 ppm
Ti	1070 ppm
Cr	1660 ppm
Mn	1830 ppm
Fe	15.3 mass %
Co	93.0 ppm
Ni	193 ppm
Cu	209.0 ppm
Zn	173.0 ppm
Nb	71.3 ppm
Mo	197.0 ppm
W	412.0 ppm

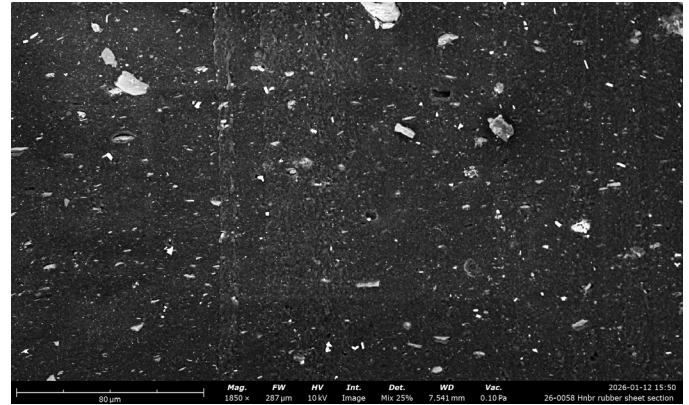
XRF methods were refined to detect low levels of thorium associated with “hot gamma”, linking rheology and screen blinding issues with volcanic ash material to downhole formations (Dai et al, 2026).

### Scanning Electron Microscopy (SEM)

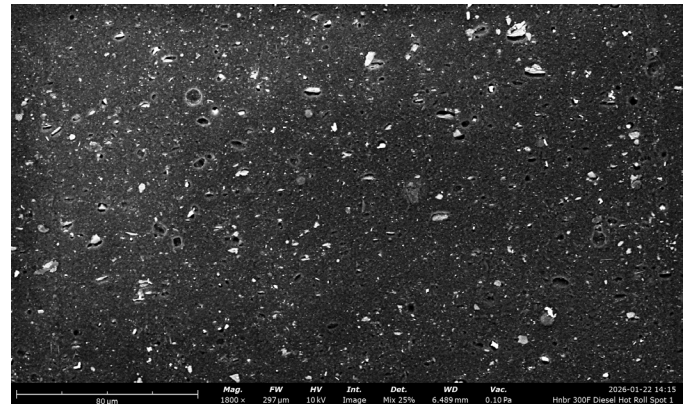
The scanning electron microscope provides visual insight beyond powerful optical microscopes. SEM aids formation characterization – including visual confirmation of fines in reservoir rock which allows engineers to design fluids to avoid mobilization. When equipped with energy-dispersive x-ray spectroscopy (EDS), elemental analysis corresponds with the image.

SEM shows promise to characterize elastomer failure modes. Figures 5, 6, and 7 micrographs which illustrate the thermochemical impact of diesel oil on HNBR seal components under high-temperature conditions.

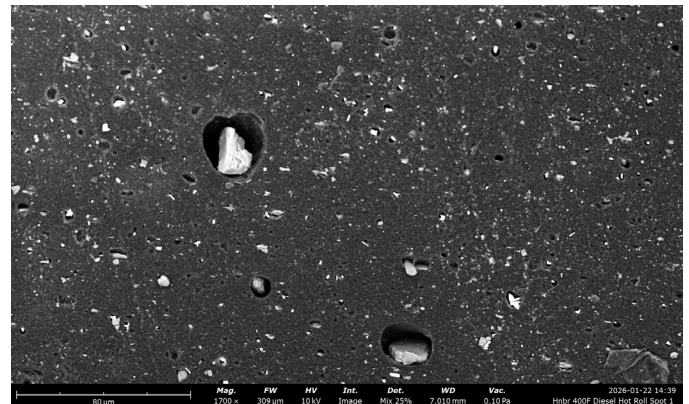
The transition from 300°F to 400°F highlights a critical failure point where the affinity between the elastomer matrix and its reinforcing fillers is compromised. As the bonding agent weakens, the formation and subsequent coalescence of pores suggest a path for fluid ingress, which ultimately reduces the effective sealing pressure and mechanical longevity of the elastomer in downhole environments.



**Figure 5: SEM cross section image of HNBR (control)**



**Figure 6: SEM cross section image of HNBR after 16 hour aging at 300°F**



**Figure 7: SEM cross section image of HNBR after 16 hour aging at 400°F**

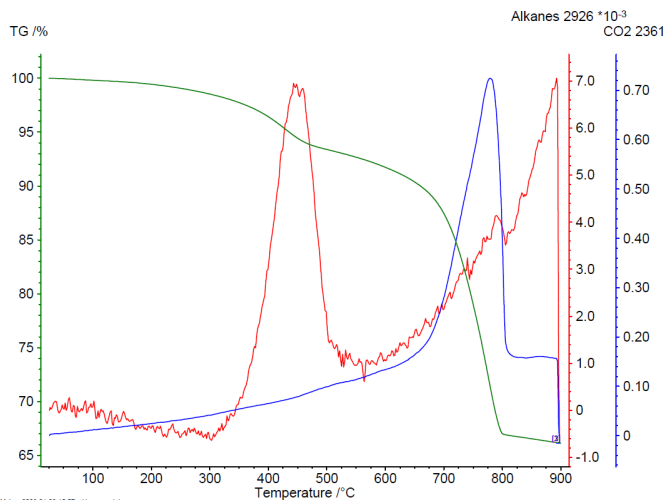
### Fourier Transform-Infrared Spectroscopy and Thermogravimetric Analysis) FT-IR and TGA

FT-IR is a simple and fast technique measure the infrared absorbance properties of a material. It is common for quality control and product verification. It also reveals aspects of material composition.

TGA aids material identification through mass loss as a sample is heated. Because different chemical bonds break down at different temperatures, it is possible to narrow suspected materials by mass lost versus time.

Coupled FT-IR and TGA allow the emitted gases to be characterized for more definitive identification. In one application, invert emulsions appeared stressed while drilling in a specific area. Products were adjusted to improve stability, but the root cause appeared to come from formation material. In this case, it appeared that hydrocarbons present in the formation interacted with drilling fluid additives to impact fluid properties.

Figure 8 provides an exhibit of the evolved gas analysis utilized during the troubleshooting phase. The red peak shows a small mass loss (green) with an abundance of alkanes appearing – a sign of hydrocarbon evolution. The mass loss corresponding with the blue peak shows an abundance of carbon dioxide – likely carbonate decomposition.



**Figure 8: Evolved gas analysis to identify hydrocarbons in formation material**

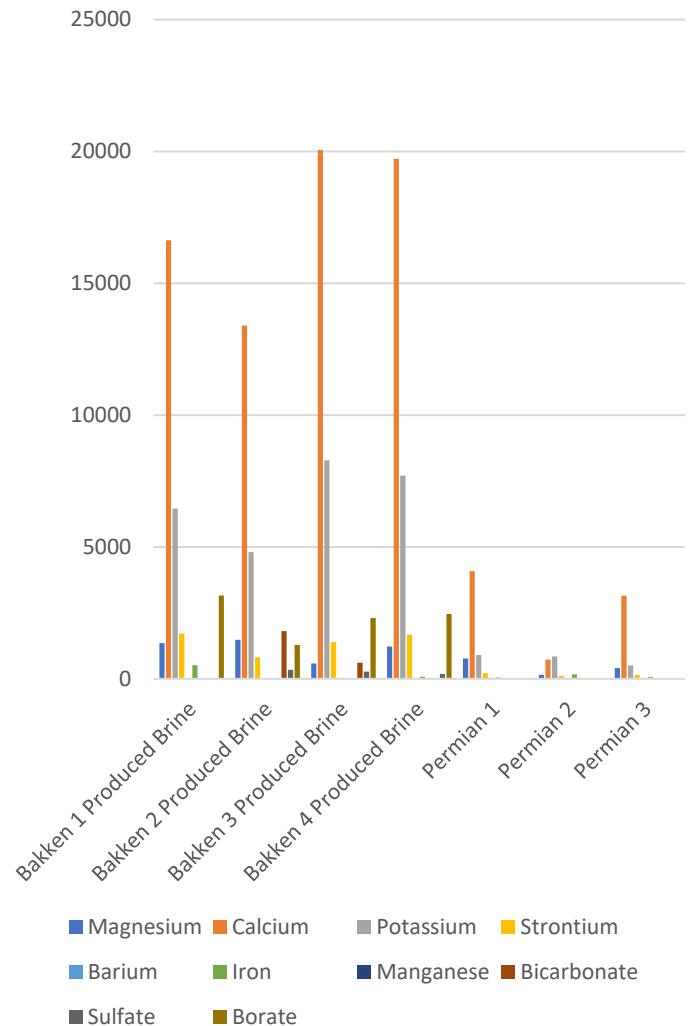
### Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

ICP-MS provides another method to quantify elements, but is suited to liquid analysis. ICP-MS provides insight into formation water and produced water for potential reuse as a drilling fluid.

Detailed water composition enables better product design and identifies incompatibility risks. Figure 9 shows ICP-MS results for several produced brines. As is widely known, Bakken produced brines have significantly higher presence of cations and anions relative to typical Permian Basin brine sources.

Elevated levels of strontium, borate, and among others require proper treatment to avoid incompatibilities with common drilling fluid additives such as lubricants and polymers. Phosphate and sulfates, known to promote foaming, are also quantified without the need for separate titrations.

### Select Cations & Anions of Produced Brine Using ICP Analysis



**Figure 9: ICP-MS testing results of various produced brine samples inform potential incompatibility and treatment requirements for use in drilling fluid applications**

### Other Equipment

The equipment discussion is not exhaustive, but highlights key proven tools. There are others, including nuclear magnetic resonance (NMR) and liquid chromatography-mass spectroscopy (LC-MS), that aids product identification, but at some point these tools cross into theoretical research and have fewer direct ties to rigsite challenges.

It is the hope of the authors that drilling fluid technologists continue to develop new methods using equipment of all kinds for more precise answers to oilfield questions.

## Conclusions

As the drilling fluids industry and the drilling domain look to future performance, system-wide thinking is essential to identify the origin of problems to influence future design.

- Advanced analytical tools extend drilling fluid support beyond traditional properties-focused troubleshooting and promote root cause identification
- These tools require additional resources and knowledge, but support can be facilitated through third party labs or partnerships if equipment costs are prohibitive
- The tools can work in isolation or together to provide new knowledge that can improve drilling fluid and equipment design to eliminate silos and improve well performance and reliability

## Acknowledgments

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## References

- Dai, C., Gray, L., Offenbacher, M., et al. 2026. "New Techniques Identify Ash Bed Contamination to Mitigate Drilling, Fluid, and Production Risk." Prepared for presentation at the AADE Fluids Technical Conference and Exhibition, April 7-8, 2026. AADE-26-FTCE-092
- Scott, P., Samuell, J.G., Offenbacher, M., et al. 2025. "Engineered Magnet System Reveals True Quantity of Metal Contamination in Drilling Fluid." AADE National Technical Conference and Exhibition, Midland, Texas, April 15-16, 2025. AADE-25-NTCE-054
- Toomes, R. J., and Offenbacher, M. 2024. "The 5<sup>th</sup> Mile: A Review of the Limiters to Reaching Further in Unconventionals." AADE Fluids Technical Conference and Exhibition, Houston, Texas, April 16-17, 2024. AADE-24-FTCE-059