New Technology Developments in Mud Gas & Cuttings

Cost-Effective Solutions for Fluid Pay, Phase & Property Predictions

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Introduction

The need for new methods and technologies in assessing both mud gas and drill cuttings (DC) samples is driven by the need to minimize costs through identifying reliable alternatives to taking downhole samples. New methods also need to be flexible in their ability to provide insight even when severely impacted by oil-based mud (OBM) contamination, a frequent occurrence in drilling operations, and one of the biggest limitations to traditional geochemical approaches. Analysis of data available from the NPD shows that currently OBM dominates as the drilling fluid of choice, in the reservoir section (Figure 1), therefore any method developed must be able to provide useful information when OBM has been used.

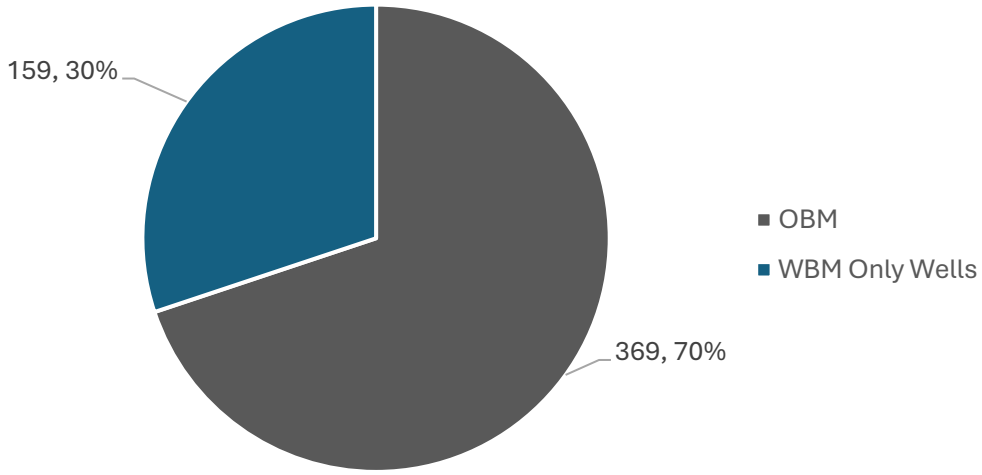

Figure 1. Statistics from the NPD showing the mud type used in all petroleum wells drilled post 2000 in the Norwegian North Sea.

APT offers two complimentary, and integrated, technologies (Figure 2) for fluid characterization, evaluation and property prediction (API, Viscosity, GOR, etc). APT Girasol is a novel, well site gas interpretation software package which can be run both near real time and post well for the prediction of pay, phase and GOR of the fluid in formation. APT's GPC analytical and interpretive workflow can be run on OBM contaminated cuttings for the prediction of density, viscosity and GOR properties without the need for downhole samples.

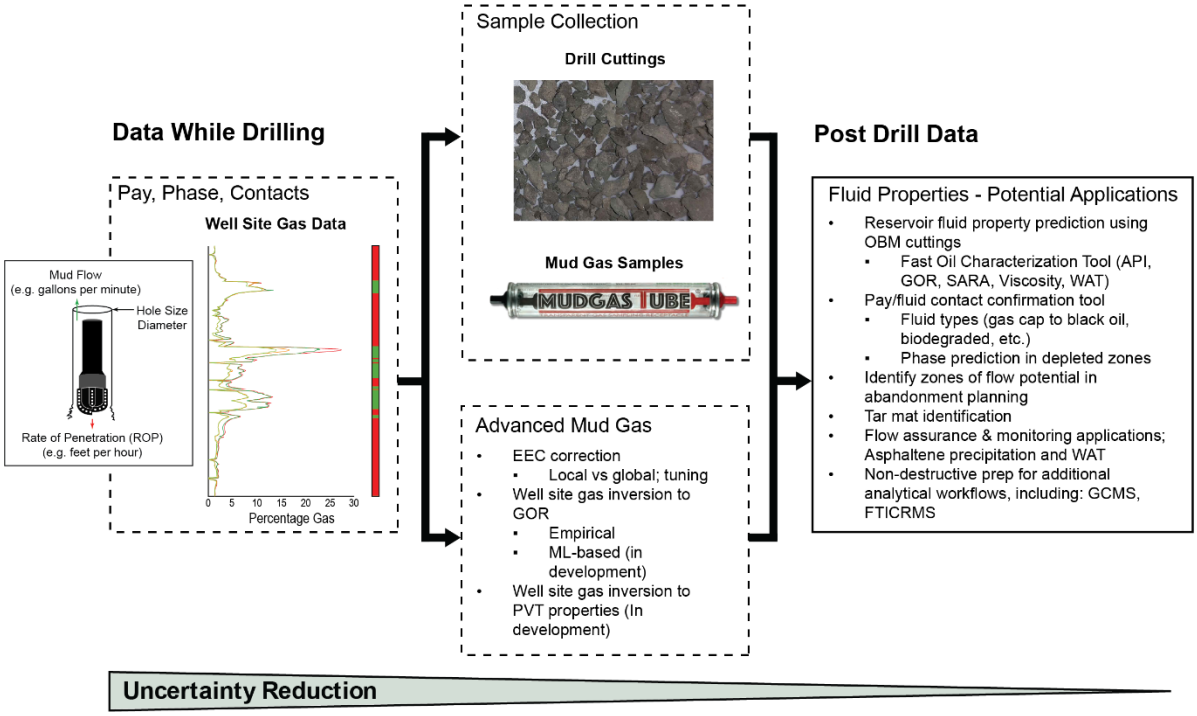

Figure 2. Integrated APT Girasol-GPC Workflow, while- and post-drilling, for the characterization, evaluation and property prediction of fluids within wells.

Integrated Technologies

APT Girasol

Measurement of hydrocarbon gases during drilling (mud gases) has been common practice since the 1950s but has been mainly recorded for safety reasons as overpressured zones, lost circulation and influxes can be quickly identified and rapidly remedied.

In recent years however, with the development of sophisticated measurement techniques (Fluid Logging and Analysis In Realtime – FLAIR) and drilling mud corrections, mud gases have begun to be utilized for estimating net pay and hydrocarbon phase prediction. The main complication when using mud gas data to estimate net pay, or predict hydrocarbon phase, is the impact any variations in drilling variables (ROP, mud flow etc) and the drilling muds themselves has on gas compositions and amount of gas measured. Normalising for drilling parameters and variations in mud are widespread but vary in complexity, effectiveness, and applicability.

APT Girasol (Figure 3) is a software toolkit designed around a novel approach which encompasses drilling parameter normalisation and Extraction Efficiency Coefficient (EEC) compositional corrections in combination to predict pay, phase & GOR, using a robust background gas method and built-in database. APT Girasol has been successfully deployed globally in exploration and development settings both near real-time and post-well evaluation (Jones *et al.,* 2023). A significant advantage of this approach is the near real-time interpretation, which generates a large business impact for real-time well decisions.

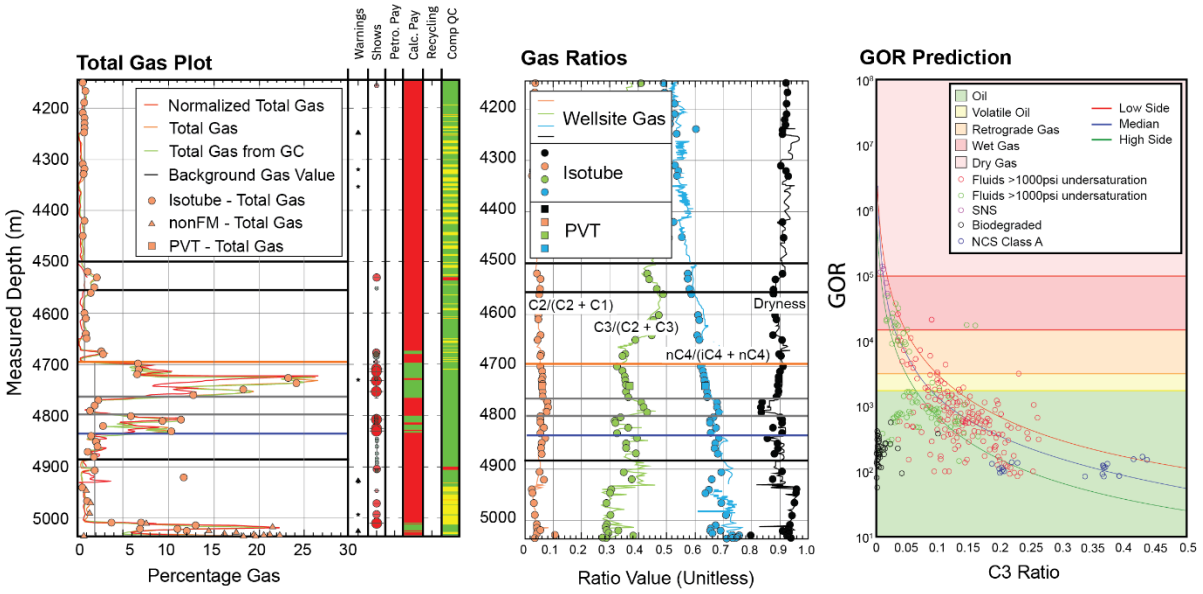

Figure 3. Example output from APT Girasol, including the GOR prediction plot utilizing the C3 Ratio.

Gel Permeation Chromatography (GPC)

Drill cuttings (DC) are generally collected as standard for most wells. Traditional geochemical analysis has previously been employed to estimate key oil properties, such as API (density) and viscosity (Cutler *et al.,* 2022). However, these workflows require DC to be drilled with water-based mud (WBM), which severely limits deployability. Therefore, there is considerable business demand for being able to better utilize DC samples drilled with OBM.

APT, in collaboration with our partners at Equinor, have been exploring, and developing, the potential for gel-permeation – refractive index – ultraviolet (GPC-RI-UV) chromatography to overcome OBM contamination issues in the prediction of reservoir fluid properties (Yang *et al.,* 2024a, b). Although this method is a mature technology in the polymer industry, deployment for upstream oil & gas applications has been limited.

GPC is an analytical methodology that separates compounds based upon their size and/or molecular weight and provides information on compound class (saturates, aromatics, resins, asphaltenes) that can be related to fluid properties (density, viscosity, etc.). When fluids are passed through the GPC column the larger molecules come out first and the smallest come out, and are detected, last. All molecules are detected by an ultraviolet (UV) absorbance detector which is two-dimensional, with both elution time and signal strength, when a fixed wavelength is applied.

Through building a database, of well characterized PVT training fluids, it is possible using multivariable data analysis and machine learning (ML) to build universal predictive models, for OBM drilled cuttings, from GPC data for oil density, viscosity, SARA, and GOR using dead oil samples. The method exploits chemical ranges between the extract and oil which show minimum overlap with typical OBM compositions (Figure 4). It is also possible for specific molecular weight fractions to be collected for subsequent detailed geochemical analysis (GC, MS, etc) as needed offline, opening up a host of additional applications for OBM DC samples.

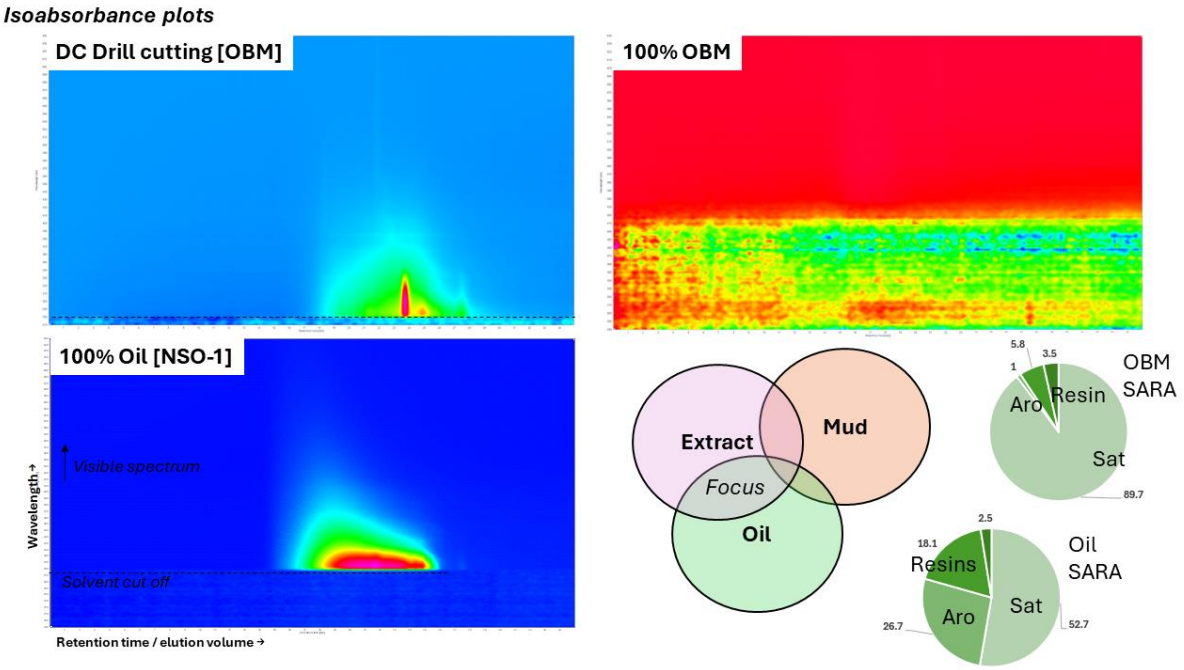

Figure 4. GPC Isoabsorbance plots of an extract, oil and OBM sample with a conceptual Venn diagram illustrating the approach taken to isolate the uncontaminated oil signature.

Case Study Example: *Gulf of Mexico*

An integrated pilot project was carried out in the Gulf of Mexico where interpretation of phase and confirmation of pay had significant commercial impact on forthcoming well decisions, but column thickness and phase were unclear. Drill cuttings (DC) were available from the section of interest and initial analyses was by conventional geochemical methods, but the results were swamped by OBM contamination, offering no interpretational value. No downhole samples or pressure measurements had been taken in the interval of interest.

The extracts were analysed via GPC and the results were helpful to confirm gas caps, pay thickness and in the prediction of fluid properties to aid field development. Gas caps in reservoirs are unlikely to contain much asphaltene or resins unless some residual oil exists from prior oil column displacement. Therefore, GPC, that can observe asphaltene presence, has the potential to confirm gas caps. API gravity and GOR predictions were made on the extracted material from DC with no sample preparation (Figure 5). Calculated API gravity of a shallow sample from within a suspected gas cap, averaged from 5 machine learning (ML) models, was 56±3. GOR averaged 21500±11000 scf/stb for the same sample, confirming the presence of a gas cap at this location. The deeper sample, within a potential residual or oil pay interval, was modelled at 43±3 API and 2100±1600 scf/stb GOR.

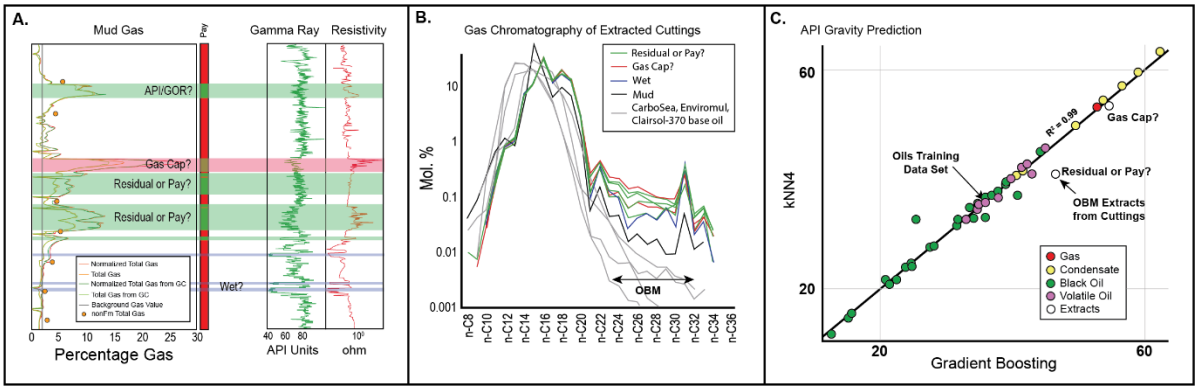

Figure 5. Pay, Phase & Property Prediction Results for a Well in the Gulf of Mexico. (A) GOM pay intervals from logs and mud gas interpretations. (B) Example of over print of OBM on extracted hydrocarbons using gas chromatography. (C) API prediction from multiple models using GPC-RI-UV data. Training data are shown relative to the drill cuttings extract data.

Adding Value

The methods developed by APT provide a cost-effective and rapid approach for evaluating fluid pay, phase and properties, without the need for downhole samples. This creates various opportunities, not limited to rapid turnaround of results, potentially impacting operational decision-making; ML-based methods for fluids physical property QA-QC; lower costs enabling the expansion of databases providing higher resolution datasets in producing assets. Both technologies are applicable to legacy, as well as fresh, samples and datasets and are deployable globally to all assets where such technology would be beneficial.

References

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