*Fluid Inclusion Technologies*

# Fluid Inclusion Stratigraphy

## Application of FIS to Source Analysis and Unconventional Reservoirs

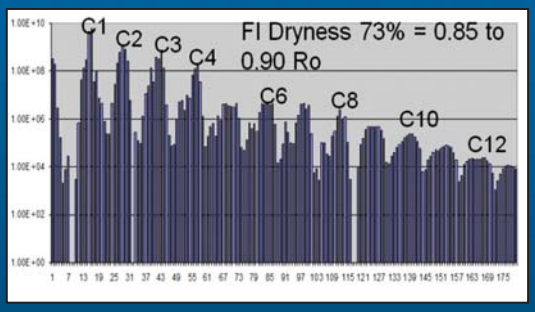


Fig. 1: Shale FIS Mass Spectrum

### Gas In Source Rocks:

*Source rocks contain appreciable trapped gas, which represents a combination of fluid inclusions in the conventional sense, but often more importantly adsorbed species and gas trapped in ineffective microporosity, including pores created from conversion of kerogen to oil and gas. The bulk FIS signal, which originates from a combination of these two sources, has been found to reflect kerogen maturity, and to contain compositional information that can be used to infer or predict produced fluid characteristics from these rocks.*

### Maturity, TOC, Produced Gas Composition:

*From FIS compositional analysis, the relative percentages of C1-C6+ (up to C13) can be calculated to create standard gas ratios. These can be empirically related to maturity through several methods, including principal component analysis (Fig. 2). Additional algorithms have been investigated to estimate TOC with promising results (Fig. 3). Here, an independent indicator of potential source rock presence is necessary (e.g., a GR log or visual cuttings descriptions), to discriminate reservoir sections (migration or charge) from these locally generated hydrocarbons (Fig. 3). Additionally, the source rock must be mature to have generated enough volatile species to be recorded on the FIS TOC log. In some cases, produced gas compositions can be estimated, perhaps including CGR.*

### Sweet Spots:

*Within horizontal penetrations through unconventional reservoirs, including tight gas sands, FIS data appear to reflect a combination of lithologic variation, fracture distribution and presence of intergranular porosity. This information can be used to help plan completions, verify wellbore path, and evaluate compartmentalization.*

### Ranking Well Performance:

*FIS data on unconventional wells within a geographically restricted area can be used to predict relative productivity. This information can be used to differentiate between wells that underperform due to natural characteristics, and those that have been ineffectively completed.*

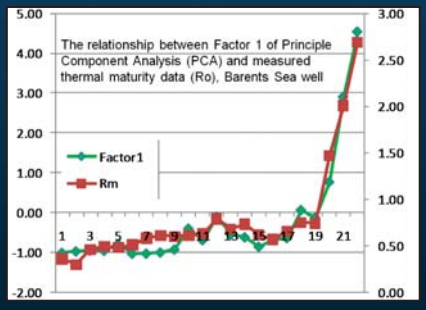


Fig. 2: Predicting Manturity with FIS

### Links with Microthermometry:

*Integration of FIS with fluid inclusion petrography and microthermometry can be used to deduce expulsion products, phase and saturation, API gravity, salinity and fracture timing.*

### Application summary:

- *Evaluate source rock maturity using standard gas ratios, empirical fis chemical relationships and chemometrics.*
- *Correlate gas chemistry with toc for mature, organic rich rocks.*
- *Predict produced gas chemistry in shales from unpreserved cuttings.*
- *Identify sweet spots in unconventional reservoirs (pilot and laterals).*
- *Verify wellbore path and define compartments.*

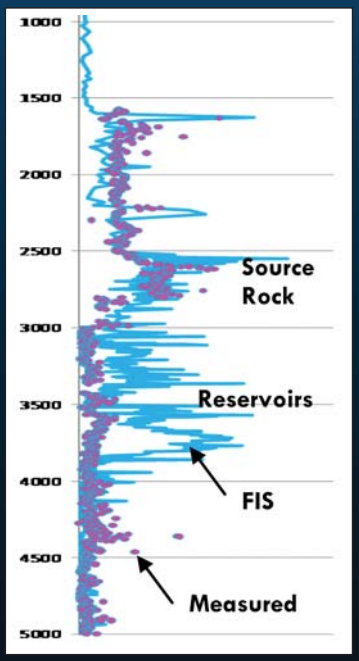


Fig. 3: TOC from FIS

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# Fluid Inclusion Stratigraphy

## Application of FIS to Tight or Fractured Unconventional Reservoirs

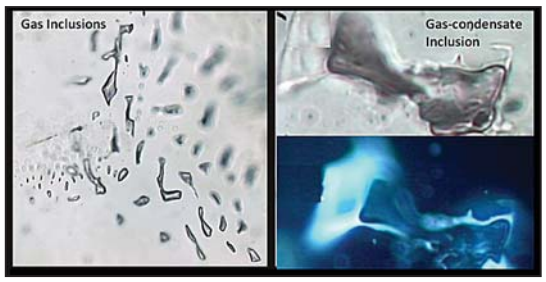


Fig. 1: Migrated Petroleum Inclusions in Tight Reservoirs

### Gas in Tight Reservoirs:

*Tight, low TOC rocks with producible hydrocarbons in matrix or fracture porosity contain hydrocarbon fluid inclusions that represent migrated fluids. Often, the abundance of these inclusions, as indicated by FIS signal strength, reflect the interrelated combination of reservoir quality, hydrocarbon saturation, residence time and lithologic variation.*

*Source rocks, on the other hand, contain appreciable trapped gas, which represents a combination of fluid inclusions in the conventional sense, but often more importantly adsorbed species and gas trapped in ineffective microporosity, including pores created from conversion of kerogen to oil and gas. The bulk FIS signal, which originates from a combination of these two sources, has been found to reflect kerogen maturity, and to contain compositional information that can be used to infer or predict produced fluid characteristics from these rocks (see related tech sheet).*

### Sweet Spots:

*Because of the relationship between FIS response and reservoir characteristics, vertical or horizontal penetrations through unconventional reservoirs, can be used to identify the most productive portions of the wellbore, help plan completions, verify wellbore path, and evaluate compartmentalization (Fig. 2).*

### Ranking Well Performance:

*FIS data from unconventional wells within a geographically restricted area can be used to predict relative productivity. This information can be used to differentiate between wells that underperform due to natural characteristics, and those that have been ineffectively completed (Fig. 3).*

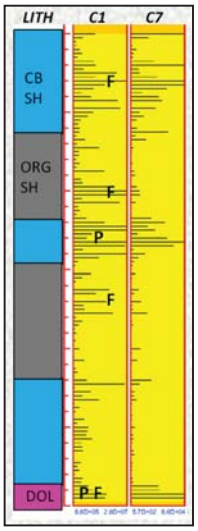


**Fig. 2: Defining Porosity with FIS**
FIS data are the combined result of lithologic variation, fracture distribution and presence of intergranular porosity. Bitumenlined gas inclusions in the basal carbonate unit suggests some conversion of early oil to gas in place. Bluefluorescent, uppermoderate to high gravity (45o+) light oil or condensate inclusions occur in the shallower section.
F = fracture;
P = intergranular porosity.

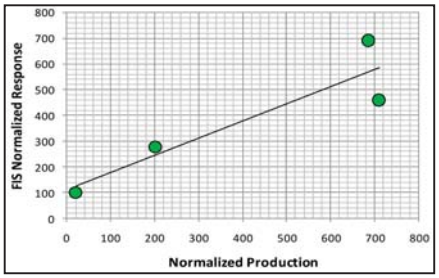


**Fig. 3: Predicting relative well performance**
FIS response from four horizontal wells compared to eventual production. The approach can be used to distinguish between a poorly drilled well and a poorly completed well.

### Application summary:

- *Identify sweet spots in unconventional reservoirs (pilot and laterals).*
- *Verify wellbore path and define compartments.*
- *Predict produced gas chemistry in reservoirs from unpreserved cuttings.*
- *Evaluate charge history, fluid type, saturation state, api gravity*

### Links with Microthermometry:

*Integration of FIS with fluid inclusion petrography and microthermometry can be used to deduce expulsion products, phase and saturation, API gravity, salinity and fracture timing.*