*Finding a niche in fluid inclusion*

# Free at Last! Unlocking Trapped Volatiles

By LOUISE S. DURHAM, EXPLORER Correspondent

Mention fluid inclusions in subsurface rocks to someone, and it's quite likely to conjure up thoughts of fluid-filled pores.

Not so.

"Trapped fluids, which we refer to interchangeably with volatiles, are basically anything that occupied the pore at one time and got trapped in rock – but as a fluid," said AAPG member Don Hall, president of Tulsa-based Fluid Inclusions Technology (FIT), which was founded about 17 years ago as a spinoff of the old Amoco Technologies Center.

The company's forte includes lab-based chemical analysis of micron-size trapped fluid samples in rock material, i.e. fluid inclusion stratigraphy (FIS).

Among other specialties, it also focuses on analysis of entrained volatiles in drilling fluids, i.e. mud gas, with direct quadrupole mass spectrometry (DQMS). This instrumentation is uniquely suited for organic-based mud systems, which ordinarily hinder data analysis from other devices.

Hall elaborated further on the esoteric fluid inclusions, which quite often can be a major assist to geoscientists.

"These inclusions are microscopic traces of past or now-existing subsurface fluids that became entrapped in rocks during burial," he noted. "They are completely encapsulated within their host minerals and, consequently, are distinctive from adsorbed or residual fluids in open porosity.

"The result," he said, "is they are not subject to evaporation during sample storage, loss of light ends during sampling from depth, or contamination from the mud system."

### Small, But Important

A crucial aspect of these fluid inclusions, according to Hall, is that they endure in the geologic record although the parent fluids move on. As a result, a given sample contains the fluid history of the area.

In other words, despite being microscopic they're jam-packed with information.

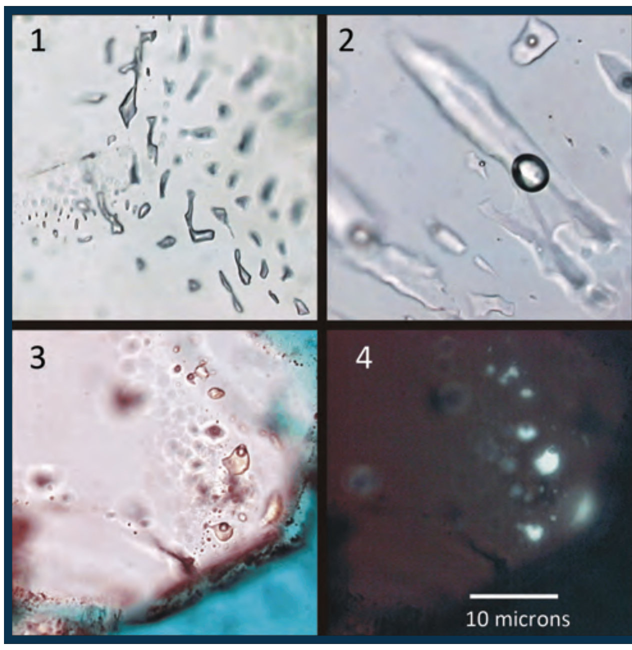
Specific tests can be done on these inclusions to study processes occurring within the earth, such as migration and accumulation of oil and gas.

"We analyze what you can volatilize in a vacuum chamber under elevated conditions," said Mike Sterner, vice president of R&D at the company. "Because you're opening up (rock material) in a vacuum, the solids are left behind as evaporative residue, so we're truly looking at basically fluids.

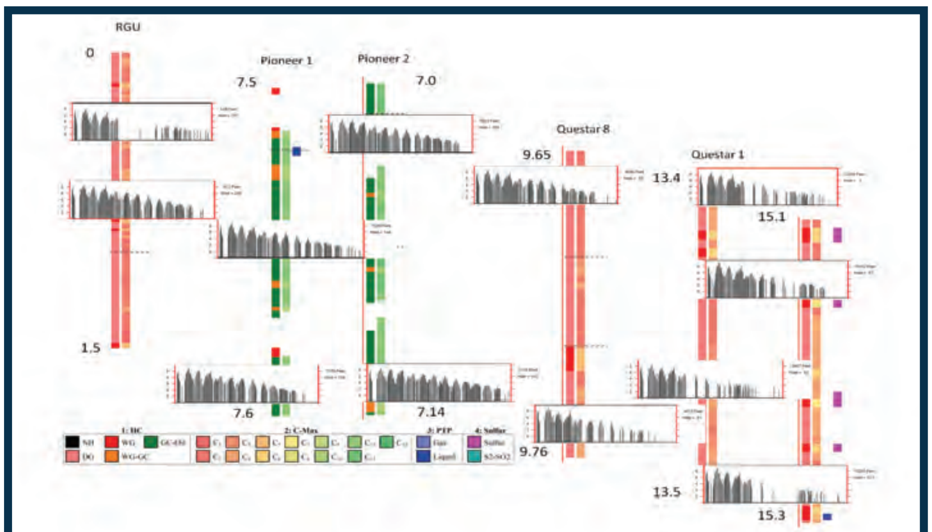
"Virtually any question that involves the present or past distribution of petroleum, its chemical characteristics, and relationship to the rock/pore system can be addressed using FIS," Sterner added.

The array of applications include:

- Migration, charge/paleo charge, fluid contacts.
- Petroleum type, quality, multiple charges.
- Inference of nearby undrilled accumulations.
- Microseepage, deeper potential.
- Seals, compartmentalization.




*Fluid inclusions in sandstone under a petrographic microscope: 1) dry gas; 2) brine; 3) moderate gravity oil under plane light; 4) same image under ultraviolet illumination.*




*FIS-derived trapped fluid composition (hydrocarbon type) and representative mass spectra from Mancos Formation cores, Utah. Numbers are measured depths divided by 1,000. Data can be used to evaluate distribution of fluid types within emerging plays at an early stage using archived samples from old wells.*

## FIS Helps Find Sweet Spots

By LOUISE S. DURHAM, EXPLORER Correspondent

Fluid Inclusion Stratigraphy (FIS) has been used for decades to successfully evaluate critical aspects of petroleum systems, such as reservoir content, phase state, seal effectiveness and migration pathways, according to AAPG member David Wavrek, president of Petroleum Systems International in Salt Lake City.

FIS entails rapid complete analysis of volatiles trapped as fluid inclusions in cuttings, core or outcrop samples using quadrupole mass analyzers attached to an automated attached, high-volume sample introduction system.

"In conventional reservoirs, most volatiles will have been trapped as fluid moves through rock, or warehoused in the porosity in the rock," said AAPG member Don Hall at Fluid Inclusion Technologies.

"Because unconventionals are self-sourced, the fluids we're looking at there are more likely to be related to the process that created the hydrocarbons in the first place," he said. "So part of them got entrapped in some kind of pore space and got crystallographically sequestered by some process.

"All diagenetic minerals are growing from a fluid," he noted. "That fluid gets trapped in the mineral itself sometimes because there could be little aberrations in the crystal, and the mineral can't get its act together and kind of overgrows that piece, leaving part of the fluid behind.

"That would be fluid inclusion," he said.

"If you fracture a rock, the fracture surface will be invaded by fluid that most likely won't be able to get out of the fracture completely," Hall noted. "The fracture will heal like a wound and leave behind this little residue that's crystallographically encapsulated within the fracture plane.

"In unconventional rocks, some of the pores, porosity or whatever that collect these fluids are nanopores that basically are partly converted kerogen," he said. "They take on a spongy looking, holey network that people have imaged.

"Those are so tiny and disconnected that they can't enable themselves to flush out fluid effectively," he continued. "So in unconventional reservoirs, a lot of the fluids we're analyzing are effectively encapsulated in these nanopores that aren't released until you crush the rock, or when drilling is complete and you create a bunch of introduced fractures that try to connect these little pore spaces together."

even prior to leasing.

The increasing use of advanced geochemical techniques is paying off for those companies choosing to implement them not just for evaluation of conventional reservoirs but the always-challenging unconventional as well, according to Hall.

With regard to unconventionals, those unavoidable by-products of drilling – borehole gas and drill cuttings – play a big role.

The most practical applications of cuttings volatile data to these type reservoirs zero in on predicting fluid type, composition, quality and volume in tight rock. Additionally, these data can be used to identify variability that occurs along the laterals to exploit them for more effective completions.

Hall noted that one of the most promising new methodologies is the complementary combination of:

- Advanced mud gas analysis in the field using gas chromatography, mass spectrometry, or a coupling of the two.
- Comprehensive cuttings analysis for trapped fluids and elemental and mineralogical content in the lab.

Operators have a leg up with unconventional plays, which ordinarily are the scene of many historical vertical penetrations. This means that rock-fluid databases can be established quickly and cost-effectively early on without drilling new wells, using small amounts of readily accessible archived cuttings.

The new PetroFecta application is the latest technology in the fluid inclusions toolkit. This new package combines XRF, trapped fluid analysis and high-resolution photography of the entire wellbore from well cuttings or core samples of any age.

It's been used successfully on certain shales, whether cores or cuttings.

In one instance, an operator wanted to better define the thermal maturity in the rocks and across a basin being studied and was getting some conflicting signals from some other data.

"Validating gas shale thermal maturity assessments based on standard source rock data is advisable," Hall said. "It's particularly prudent where you're modeling the composition of the hydrocarbon fluids within the reservoir, and the regional thermal maturity is believed to straddle the oil, wet-gas/condensate and dry gas windows.

"In a frontier basin such as this, where data are sparse, we added mass spectroscopic evaluation of hydrocarbon fluid inclusions and fluid inclusion thermometry to pull added information from the few well samples available," he noted.

"The goal was to understand how potential fluid compositions might vary across the basin with maturity.

"Fluid inclusion fluorescence revealed two populations of inclusions, highlighting differences in the timing of inclusion formation," he said. "This was in sync with two heating periods and essentially underscored the belief that the original basin assessment was basically on target.

"It was time to discount the varied data that had provided conflicting information early on."

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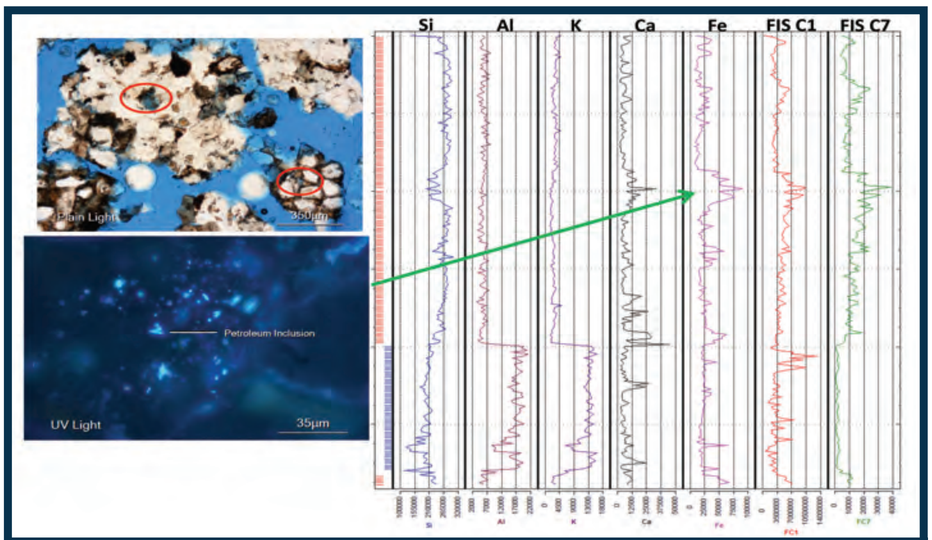


*FIT's approach to identifying sweet spots, Cardium Sandstone, Alberta. Better FIS gas and liquids response is related to porosity facilitated by siderite cement, which is chemically mappable via XRF. Arrowed zone had highest initial production.*

# FIT

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### Seeking an Advantage

Regarding the company's dq1000 mud gas mass spectrometer, which provides advanced mud gas analysis at the well site, Sterner said it is applied via companies who lease the equipment.

It has been used in a variety of locales, including the high profile Haynesville shale.

"It's extremely sensitive instrumentation," he said.

Rife Resources in Calgary has applied the on-site gas analysis methodology with success but concentrates for the most part on the advantages that the FIS lab-based analysis provides.

"In various different companies I've been involved with, we've used it on different rock types and different depositional environments and stratigraphic settings," said AAPG member Scott Hadley," president of exploration at Rife and former colleague of Hall at Amoco. "We currently have an unconventional project going in the Montney, where we're analyzing cuttings.

"One of the things that's a challenge is that we have to do more things with the rock itself," Hadley emphasized.

"It's very expensive to put logging tools in these horizontals," he said. "Even though everyone would want to have this, it's usually not a reality at the end of a very expensive well.

"One thing we're kind of guaranteed during drilling is we'll be bringing rock material to the surface," he commented. "I like these fluid inclusion techniques because it's a thing we can do with the rock that's relatively cost effective.

"We're looking for changes or relationships we can tie back to anything that might give us an advantage with respect to placement of wells or designing fracs relative to what we've seen in the rocks," Hadley noted.

"We can do what I liken to a chemical stratigraphic profile of a well – what's actually in the rock based on the fluid inclusion component.

"We can drill a vertical stratigraphic test and chemically profile it," he said. "We can typically acquire a log easier in the vertical well than the horizontal, so we can tie the fluid inclusion/chemical stratigraphy back to the log response and other things you might characterize as being in the system."

### The Preferred Spot

Based on all of these analyses, he noted that they can pick the preferred spot to land the horizontal.

"If there is a more chemical signature, maybe a zone with an abundance of fluid inclusions that show liquids-rich gas or condensate, that would be something we could integrate.

"We could tie back and say we want to drill horizontal targeting that chemical profile," Hadley said. "As we drill laterally, we get cuttings and can compare/contrast relative changes in that chemical profile back to our vertical and kind of situate where we are in that geological space."

He sees this as preferable to placing expensive logging tools in the wellbore, which can lead to expensive rig time along with the potential risk of losing tools downhole.

With cuttings being a by-product of drilling, there are plenty of opportunities and time to design the sample frequency, which can be every couple of feet or whatever. And there's no time spent trying to convince management to ok the deployment of logging tools.

"We must be able to explore some of these technologies that are rock-based solutions that will compare and contrast the type of response you get back and try to explain the differences we see in certain trends," Hadley said.

"We like to use it as a tie to the environment we're in," he said, "as well as trying to understand the vertical profiling and layering that might be in these big thick unconventional sequences." E