PS Insights into Gas Geochemistry of Large Tight Gas Sandstone Reservoirs from Fluid Inclusions*

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Abstract

The composition of gas produced from large tight gas sandstone reservoirs in the Rocky Mountains varies areally and stratigraphically within fields and between fields. At Jonah Field (Green River Basin), for example, gas wetness (fraction C2+) varies from 0.00 to 0.38, and the carbon isotopic composition of methane ranges from -27.7 to -44.0 per mil. These differences can be attributed to varying contributions from different sources, gas generation at varying thermal maturities, migration effects and biogenic alteration of gases.

We have investigated the gas composition of fluid inclusions in cuttings samples from two major tight gas fields in the Rocky Mountains: Jonah Field and the Mamm Creek-Rulison-Parachute-Grand Valley complex in the Piceance Basin, Colorado. This is one component of a major project applying gas geochemistry to understand reservoir filling processes and compartmentalization in large tight gas sand fields. Fluid inclusions contain samples of gases that migrated through the reservoir in the past; by comparing their composition to produced gases, we gain insight into the effects of changing thermal maturity.

At Jonah Field, fluid inclusion gas compositions within the Lance reservoir are distinctly wetter in proximity to the southern fault bounding the structure, a pattern not reflected in present-day produced gases. This fault bounds the Jonah pressure compartment; we suggest this fault in the past had served as a migration pathway for relatively deep Type II source rocks that contributed wet gas and light oil. In the Piceance Basin fields, fluid inclusions record much wetter gases in the eastern field (Mamm Creek), similar to production gas compositions. The Piceance data also record a paleo-oil-water contact in the area of wet gas production, suggesting a complex history of filling, leaking and refilling from increasingly mature source rocks.

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OBJECTIVES:

Apply Fluid Inclusion Stratigraphy, Petrography, and Microthermometry techniques on trapped organic volatiles from cuttings to address:

-Migration history
-Regional variables in composition
-Compartmentalization
-Fluid trapping temperatures and phase
-Salinity

ABSTRACT:

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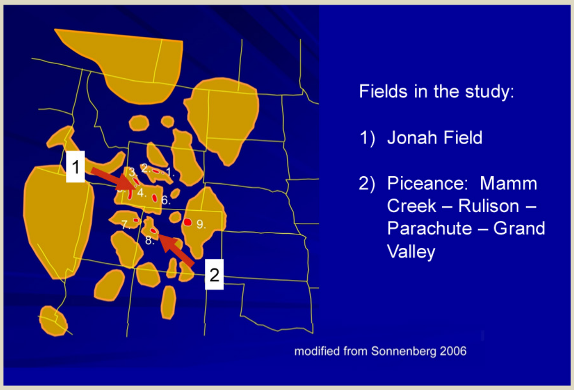


Tight Gas Sand Fields:

- Low permeability (< 0.1 md) in tight gas reservoirs

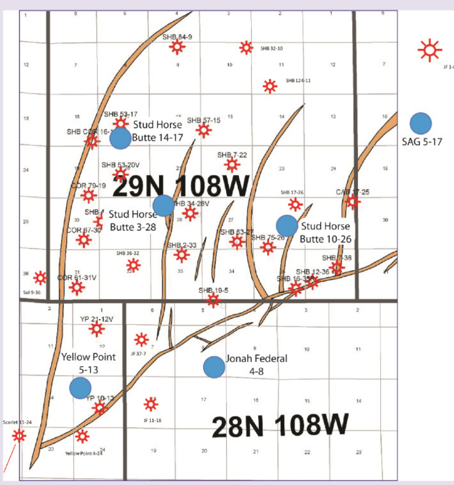
- An indistinct transition to non-commercially producible gas, instead of a distinct top seal

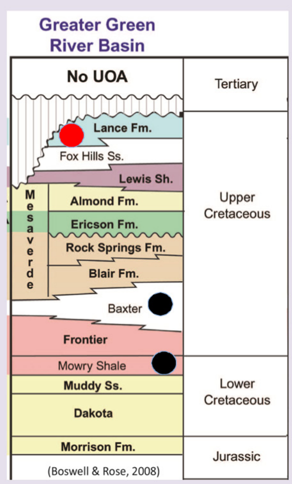
- A top of gas that cross-cuts stratigraphy and is often variable in depth and stratigraphy across the field

- Commonly overpressured (less often underpressured)

Jonah Field

= Study Wells

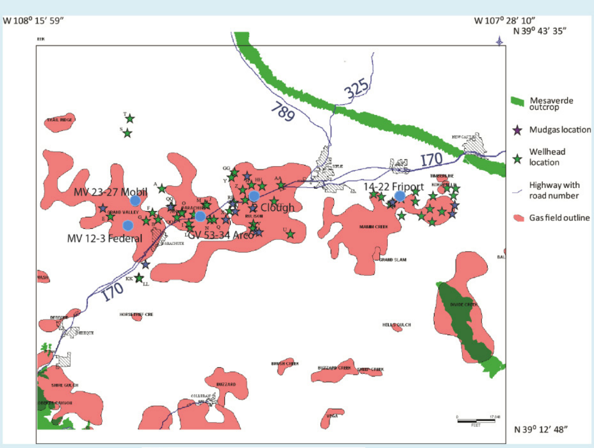




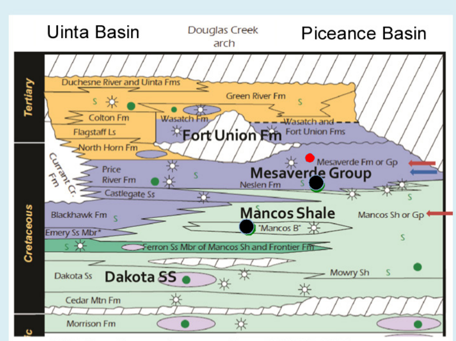
Mesozoic and Lower Tertiary section in the Green River Basin.

The principal reservoir is the Lance Formation and a secondary reservoir is the Ericson Formation. Overbank mudstones in the Lance Formation and the Baxter Shale constitute possible Type III source rocks and the Mowry Shale is a Type II source rock.

Piceance: Mamm Creek – Rulison – Parachute – Grand Valley



= Study Wells



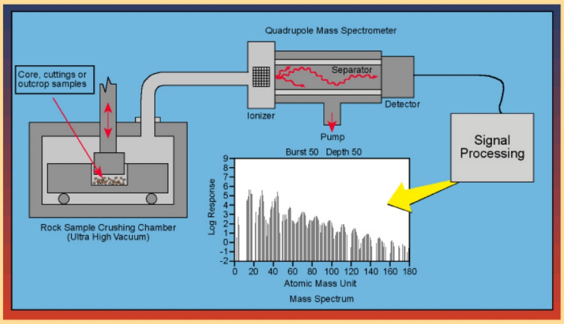
Upper Cretaceous - Tertiary section in the Piceance Basin. Reservoir section is the Mesaverde Group.

The source rocks are coals at the base of the Mesaverde or the marine Mancos Shale.

Analytical Methods:

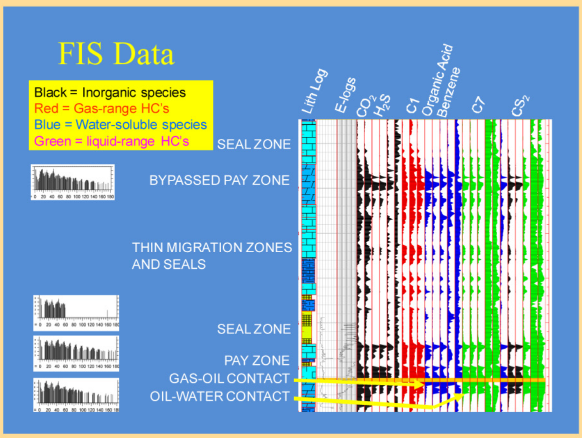
Fluid Inclusion Stratigraphy (FIS) - cuttings volatile analysis

FIS Schematic



▪Fluid events leave trace evidence as “fluid inclusions”: micron-scale sealed fluid-filled cavities in diagenetic cements and healed microfractures. These fluids may also fill nano porosity in unconventional organic rich rocks.

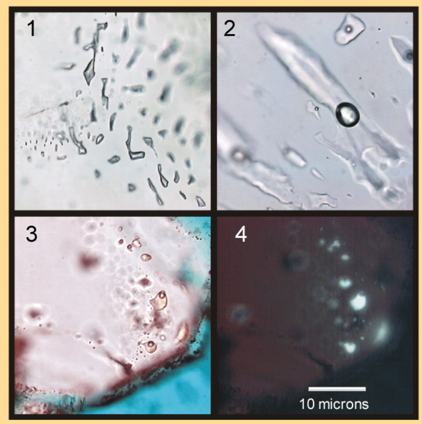
▪Fluid inclusions are not identified during drilling or conventional show analysis and are commonly present even in the absence of these classical “shows”.



Examples of Fluid inclusions

- 1: Gas
- 2: Water
- 3: Liquid Petroleum (Plane Light)
- 4: Liquid Petroleum (UV Light)

All photos are from polished thick sections of sandstone.



Fluid Inclusion Petrography/Microthermometry (FIPM)

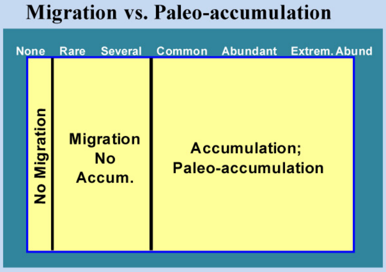
▪Optical examination of thick polished sections of rock material under plane light and with UV (365 nm) excitation

▪Documentation of inclusion types, distribution, abundance, and relevance

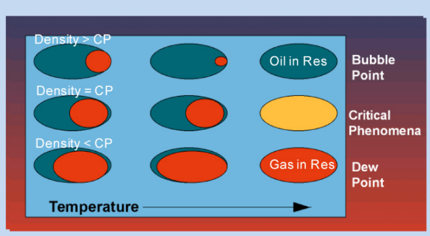
▪Measuring phase changes during heating and cooling (-196 to +200^{o}C)

▪Deducing temperature, API gravity, and salinity

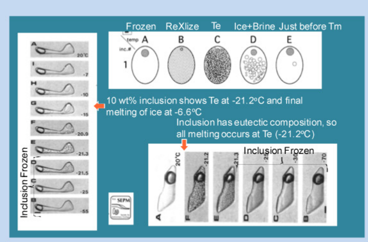
Oil/Condensate Inclusion Abundance: Migration vs. Paleo-accumulation



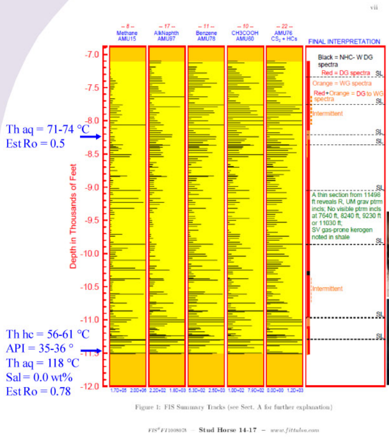
Homogenization Behavior of Petroleum Inclusions

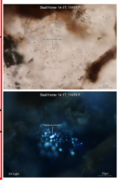


Melting Behavior; NaCl-H_2O FI



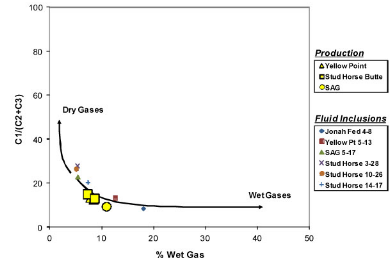
Jonah Field

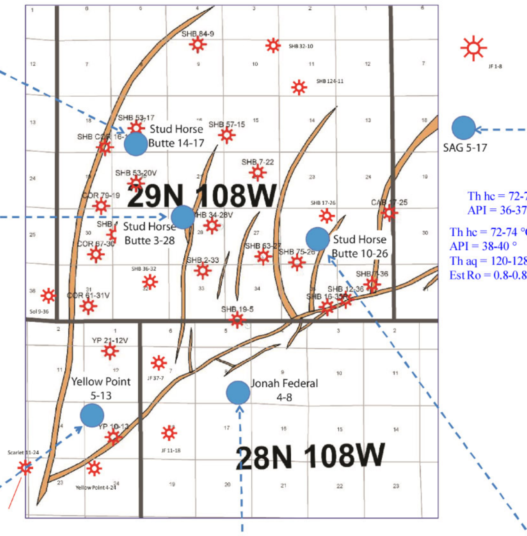


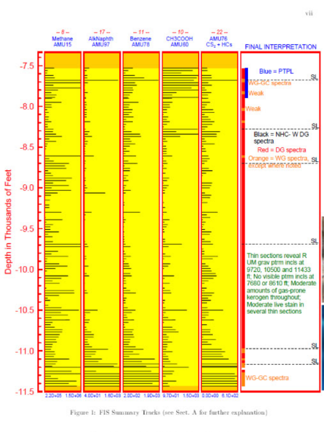


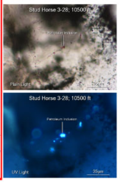
Study Wells	Fluid Inclusions Stratigraphy		
	# of samples analyzed	Top Depth, ft	Bot. Depth, ft
Jonah Fed 4-8	258	7030	10200
Yellow Pt 5-13	181	6430	10570
SAG 5-17	266	8000	14520
Stud Horse 3-28	130	7530	11433
Stud Horse 10-26	140	7630	11784
Stud Horse 14-17	158	7100	11509

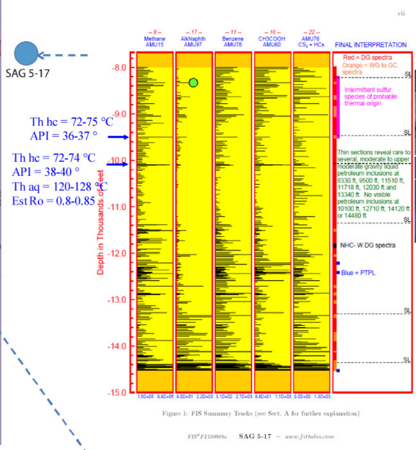
Comparison of FI Gas with Produced Gas

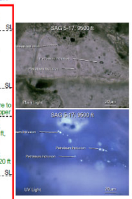


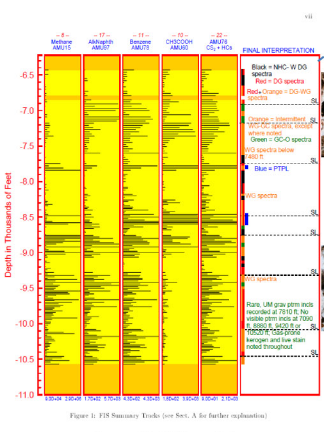


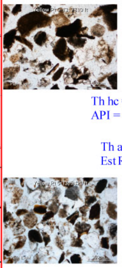


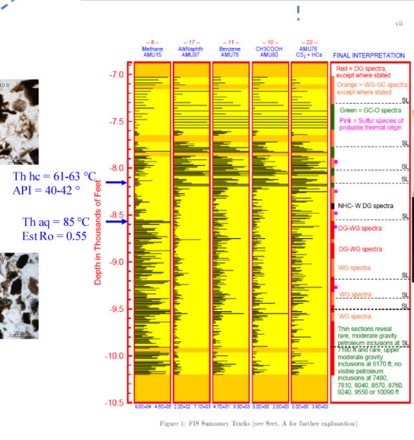


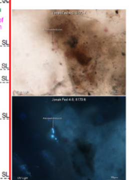


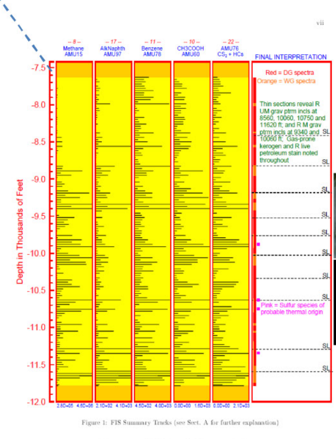


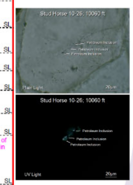






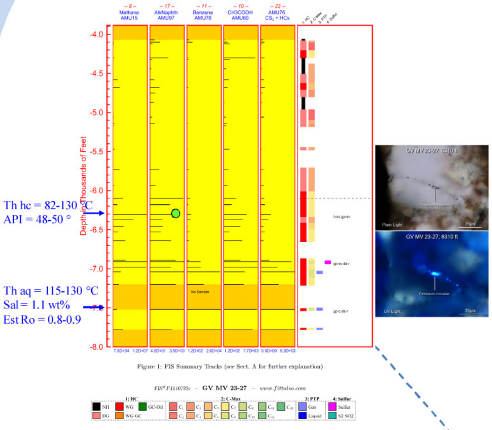


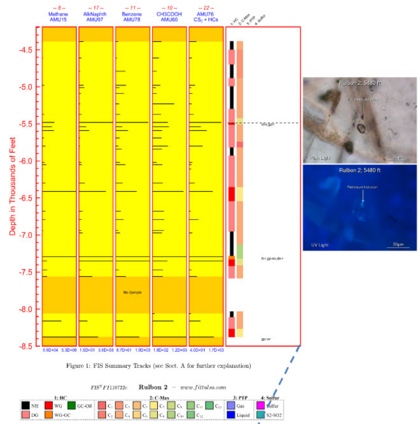


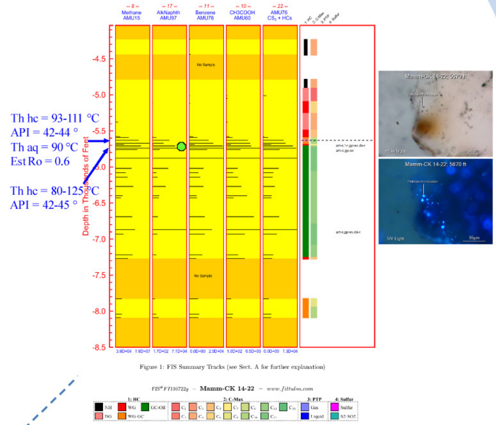


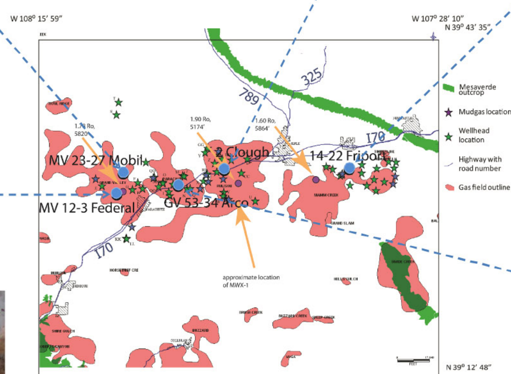
1. Bulk volatiles are more variable compositionally than produced fluid with both wetter and dried examples – reflects variable change in history.
2. Limited data suggest wetter bulk composition for southerly wells proximal to the southern boundary fault. A number of possible explanations are available, including fault influence on liquid migration direction of migration and SR distribution and/or expulsion timing.
3. No evidence of paleo-oil columns or rich gas-condensate columns.
4. Two minor liquid migrations events in area: Moderate gravity oil (35-37) and upper moderate gravity light oil (38-42).
5. Both liquids are undersaturated with respect to gas, and therefore predate gas emplacement.
6. Minimum emplacement temperatures 60-75°C.
7. Limited Th (aq) data consentient with regional Ro trends (0.5-0.55 at approximately 8,000 ft; approximately 0.8 at 10,000-11,000 ft).
8. Low salinity (fresh water) is consistent with original deposition environment and shows no evidence of influx from deeper evolved basin fluids.

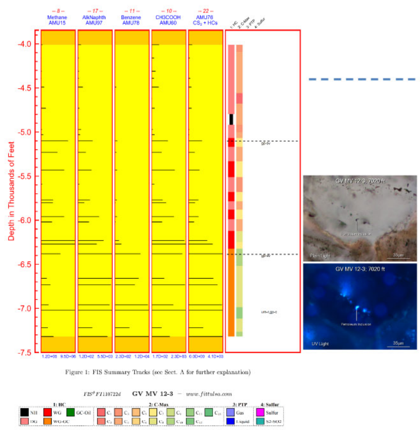
Piceance: Mamm Creek – Rulison – Parachute – Grand Valley

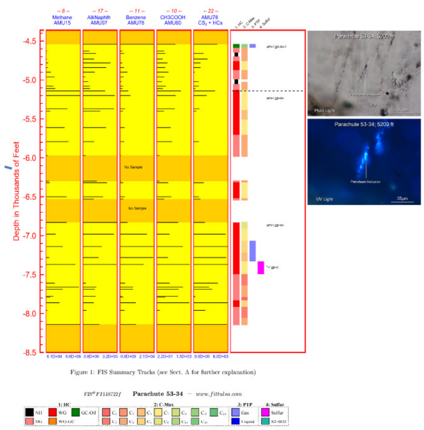












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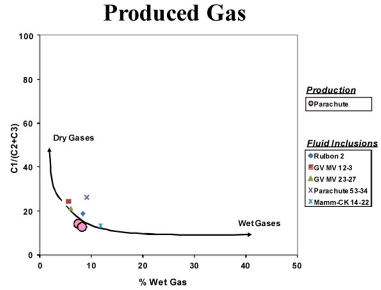

Study Wells	Fluid Inclusions Stratigraphy		
	# of samples analyzed	Top Depth, ft	Bot. Depth, ft
Rulbon 2	30	4390	8375
GV MV 12-3	27	4010	7320
GV MV 23-27	30	4070	7780
Parachute 53-34	36	4540	8140
Mamm-CK 14-22	30	4230	8090

1. Bulk volatiles are slightly more variable than produced gas, but more consistent than Jonah's results. This may indicate less variability in bulk regional change.
2. Trend toward wetter bulk composition to the East, consistent with production data, but provide better evidence for a continuous trend of decreasing wetness to the West. Similar potential explanations for Jonah.
3. Paleo-columns of light oil to rich gas condensate noted in both the East and West (Mamm CK 14-22 and GV MV 23-27), in spite of trend in wetness. These occur at approximately the same stratigraphic level.
4. Upper moderate to high gravity liquids indicated (48-50° in GV MV 23-27; 42-45° in Mamm CK 14-22).
5. Th (hc) on both liquid and gas phase show some evidence of coexisting liquid and has as discrete phases.
6. Likely emplacement of paleo-columns at 80-90°C, 0.5-0.6 Ro_{eq} are clearly migrated from a deeper source.
7. Preliminary limited Th (aq) data suggest higher geothermal gradient or more uplift, as compared to Jonah. (0.6 Ro at 5,500-6,000 ft; 0.8-0.9 Ro at 7,500 ft).
8. Low salinities (fresh to brackish) indicates no evidence of deep, evolved fluids.

ACKNOWLEGEMENTS

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