



# Application of Natural Gas Compositions to Migration and Filling Models in Large Tight Gas Sand Reservoirs of the Rocky Mountain, USA

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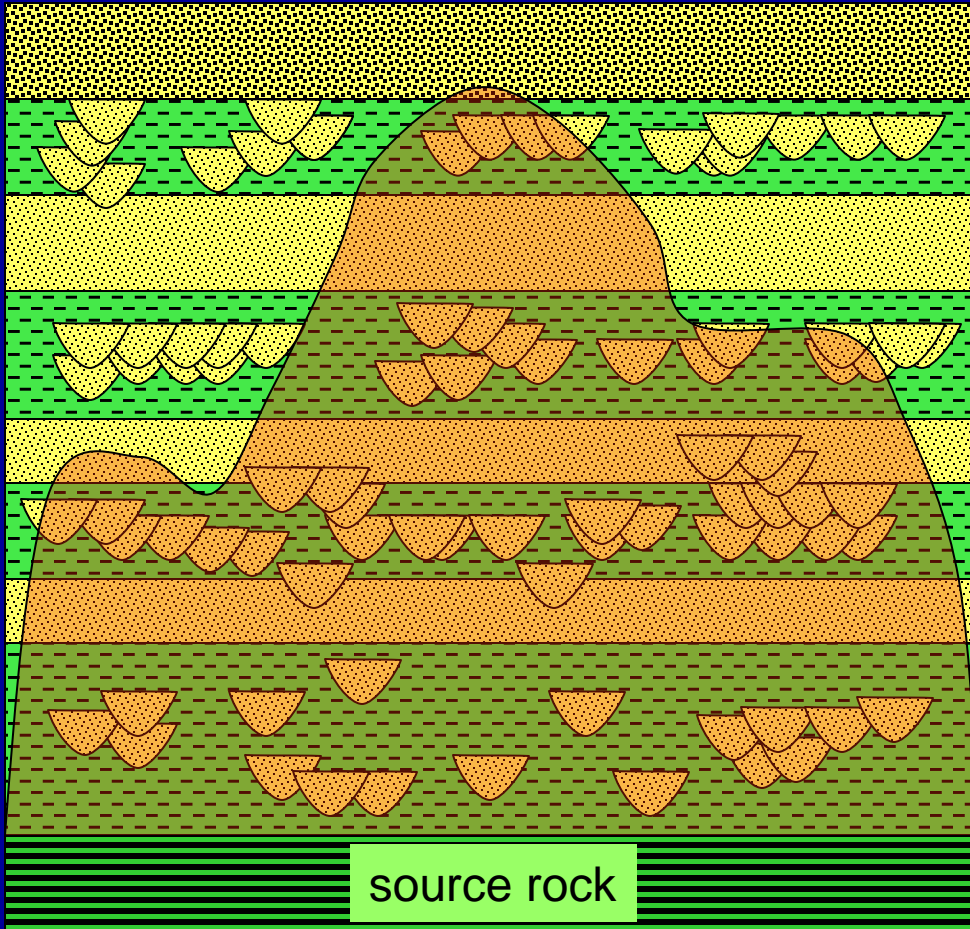
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<sup>3</sup>University of Oklahoma

<sup>4</sup>University of Manchester

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# Tight gas-sand reservoirs

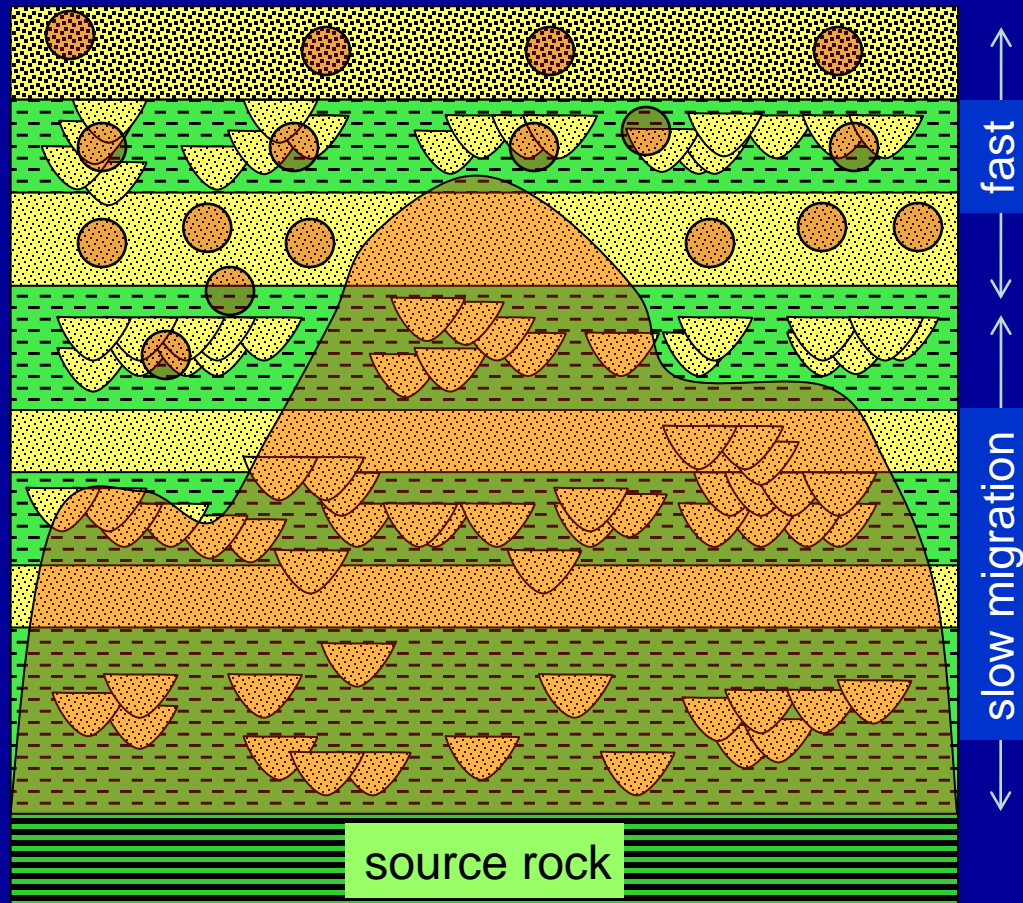


These reservoirs differ from conventional reservoir:

No clearly defined top-seal for these gas reservoirs; instead:

- 1) a top-of-gas that varies stratigraphically within a field and between nearby fields:
- 2) a fuzzy transition to unproduceable gas.
- 3) may be overpressured or underpressured

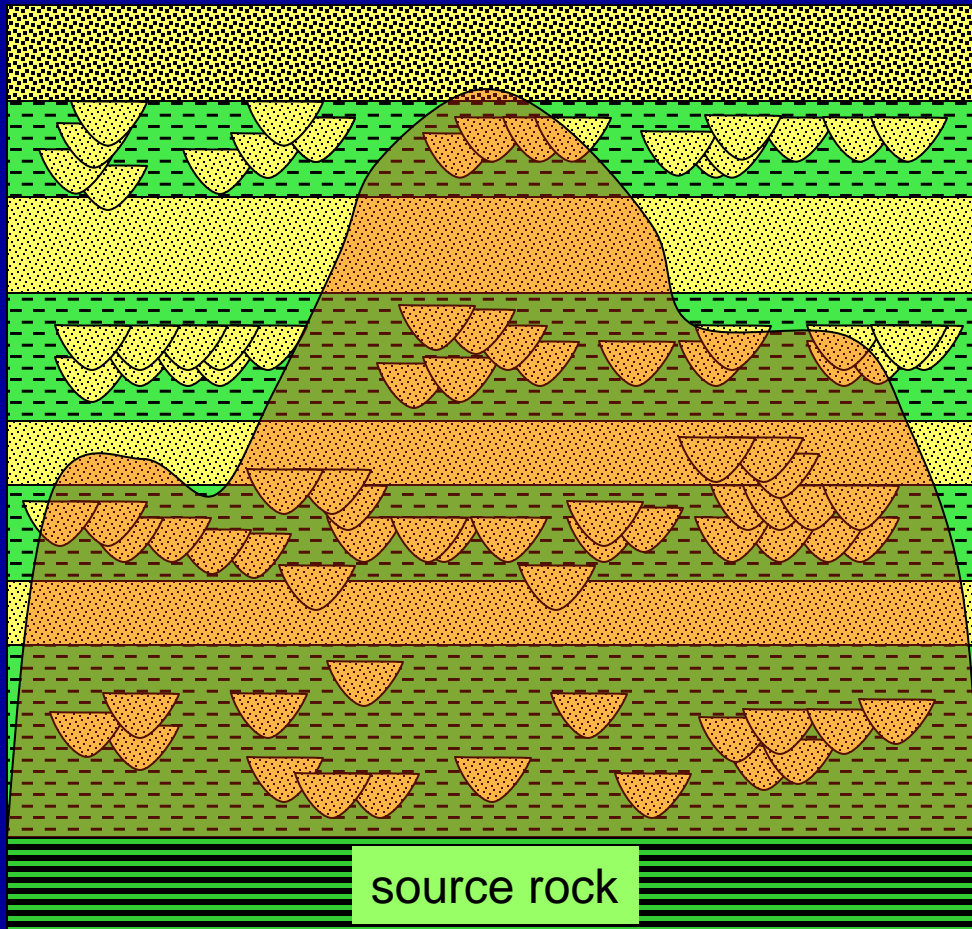
# So how does gas migrate through and fill these reservoirs?



A dynamic system, where gas concentration decreases as migration velocity increases. At steady state, mass flux is identical in and above reservoir:

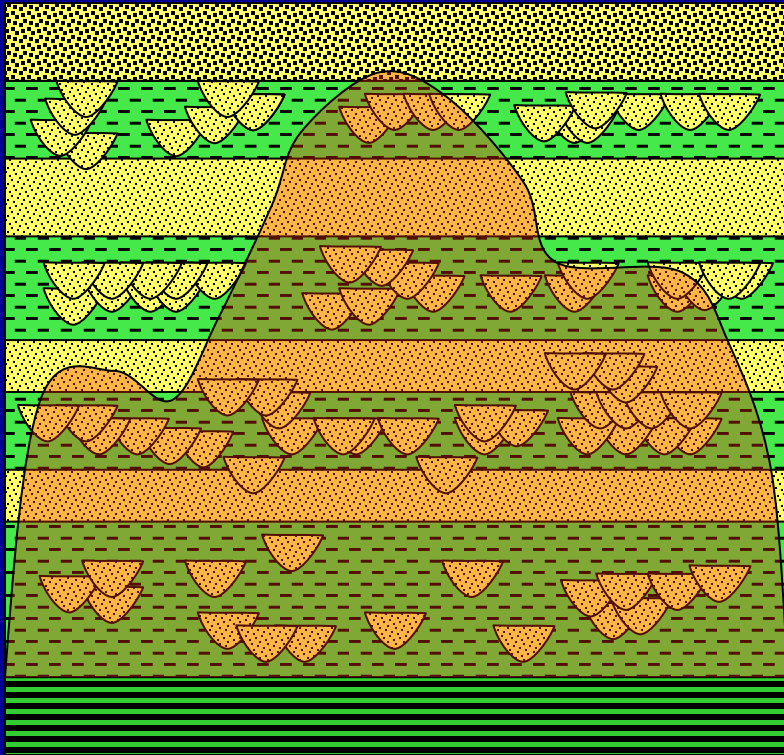
$$\text{Mass flux} = \text{concentration} * \text{velocity}$$

# So how does gas migrate through and fill these reservoirs?



What are the migration mechanisms?

- 1) Gas pressure produces hydraulic fractures that open migration pathways into overlying reservoir compartments.
- 2) Gas diffuses through seals acting as semi-permeable membranes.
- 3) Gas migrates along faults or fracture systems.



Hypothesis –

The three different mechanisms should leave different signatures in the gas composition.

By analysis of an extensive dataset, we can identify the critical mechanism(s).

- Many samples
- Complete analysis: bulk composition, trace gases (He, Ar, Xe, Ne), carbon / oxygen isotopes, radiogenic gas isotopes.

# Sample Database

## Tight Gas Resources

1. Cave Gulch
2. Madden
3. Pine Dale Anticline
4. Jonah Field
5. Moxa – LaBarge
6. Wamsutter Arch
7. Natural Buttes
8. Rulison Area
9. Wattenberg

## Fields in the study:

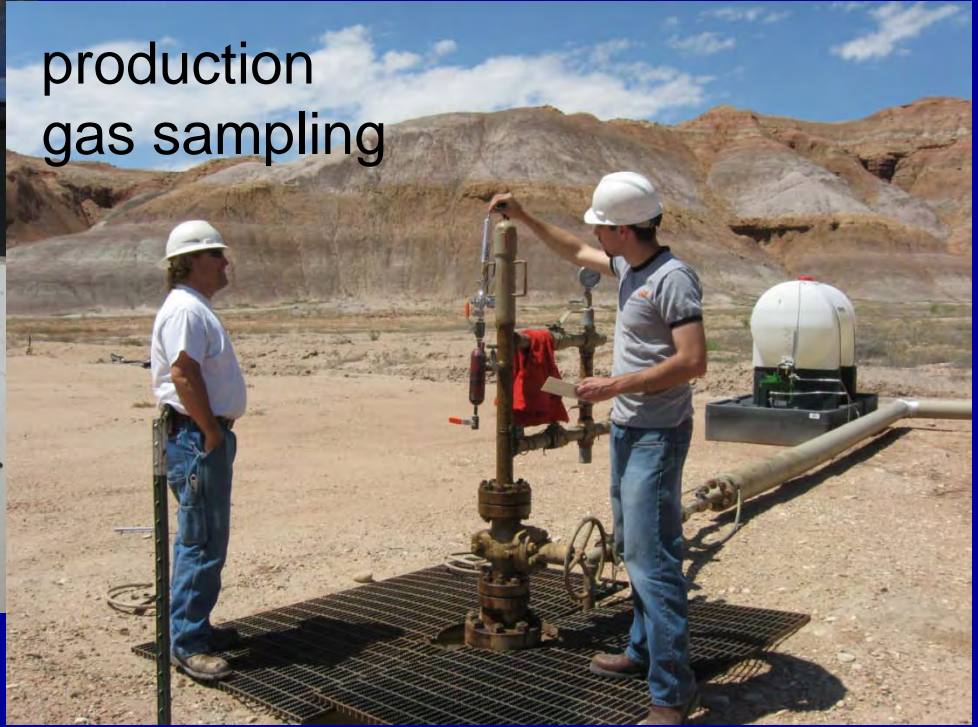
- 1) Jonah Field
- 2) Piceance: Mamm Creek – Rulison – Parachute – Grand Valley
- 3) Greater Natural Buttes

modified from Sonnenberg 2006

mud gas  
sampling



production  
gas sampling



noble gas  
sampling





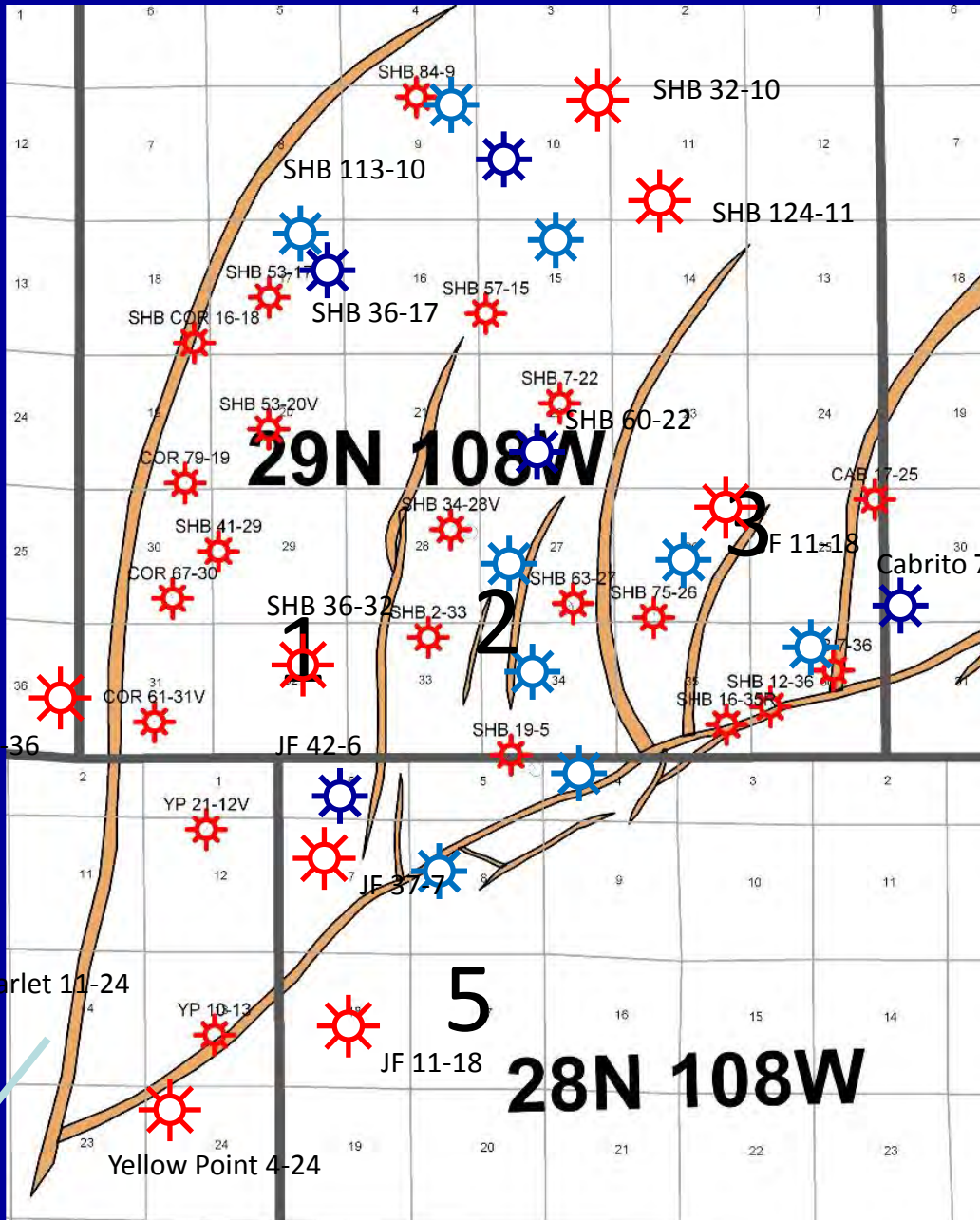
mud gas



production gas



JF 1-8

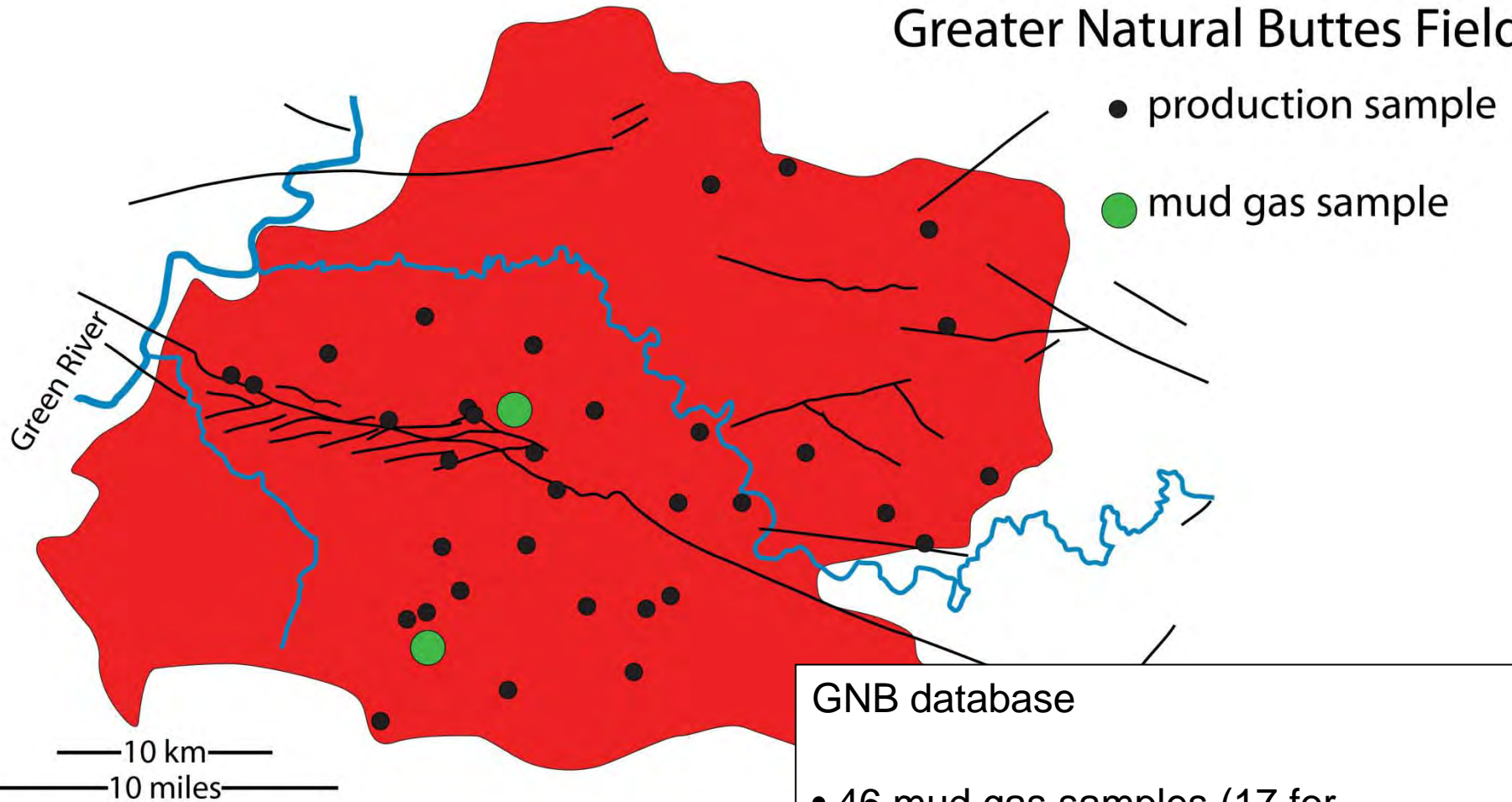


### Jonah Field, Wyoming database

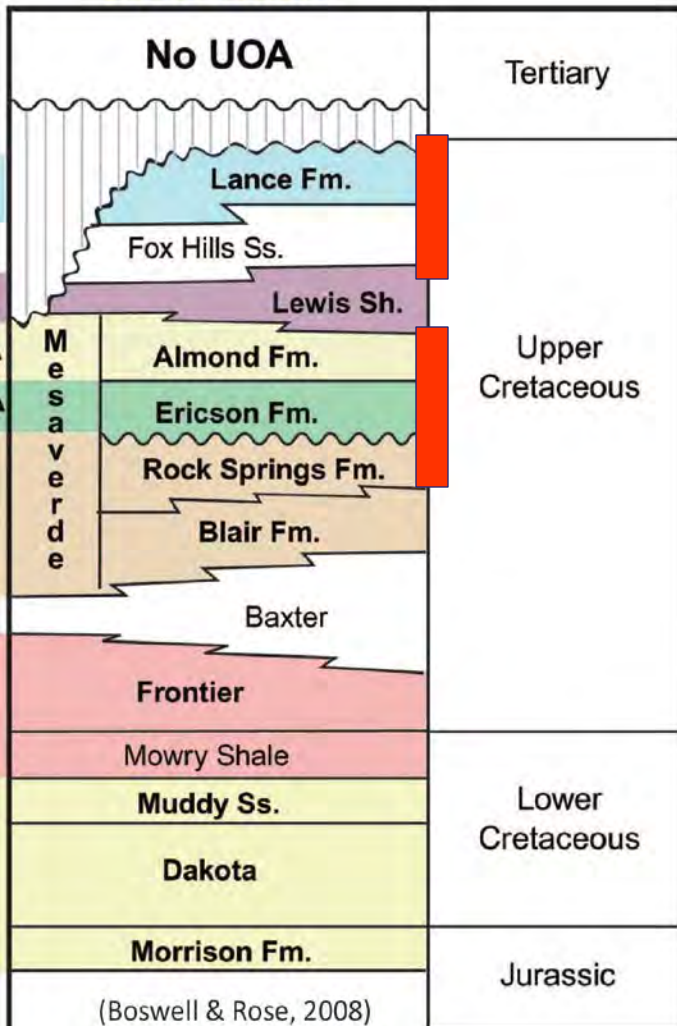
- 261 mud gas samples (100 for compound-specific isotope analysis)
- 31 production gas samples
- 18 noble gas samples
- 6 wells sampled for fluid inclusion analysis



# Greater Natural Buttes Field



# Greater Green River Basin

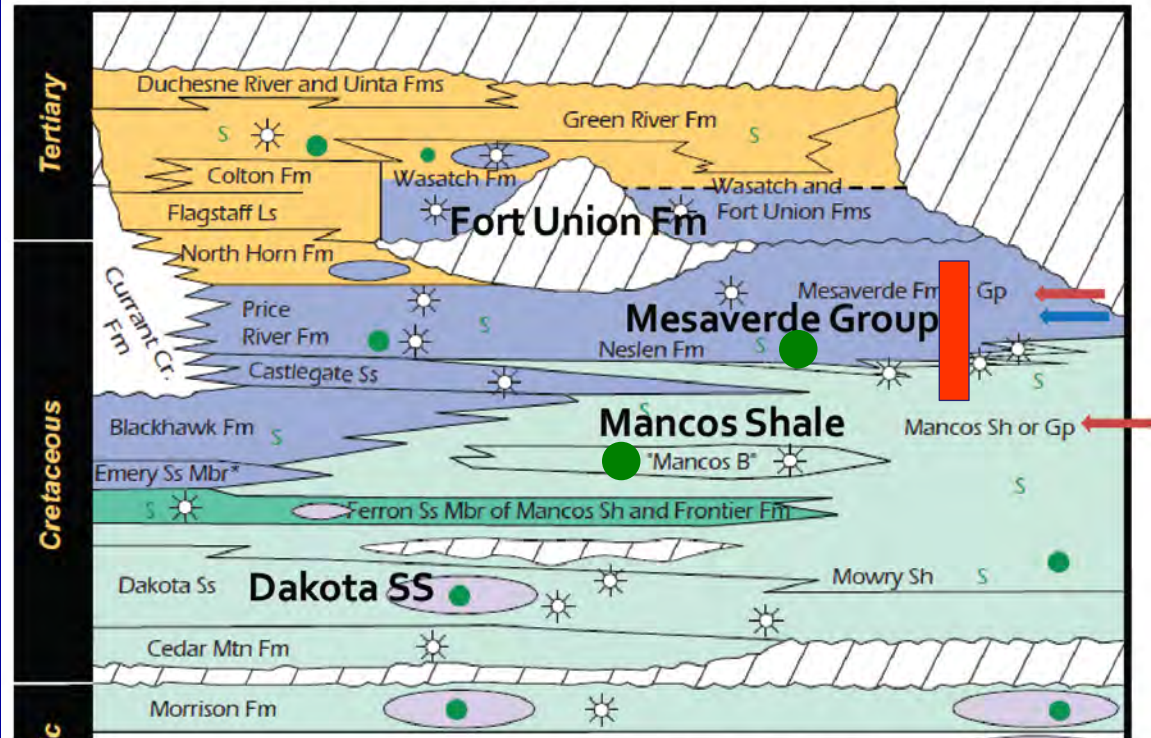


Reservoirs are fluvial sandstones interbedded with overbank siltstones and mudstones

## Uinta Basin

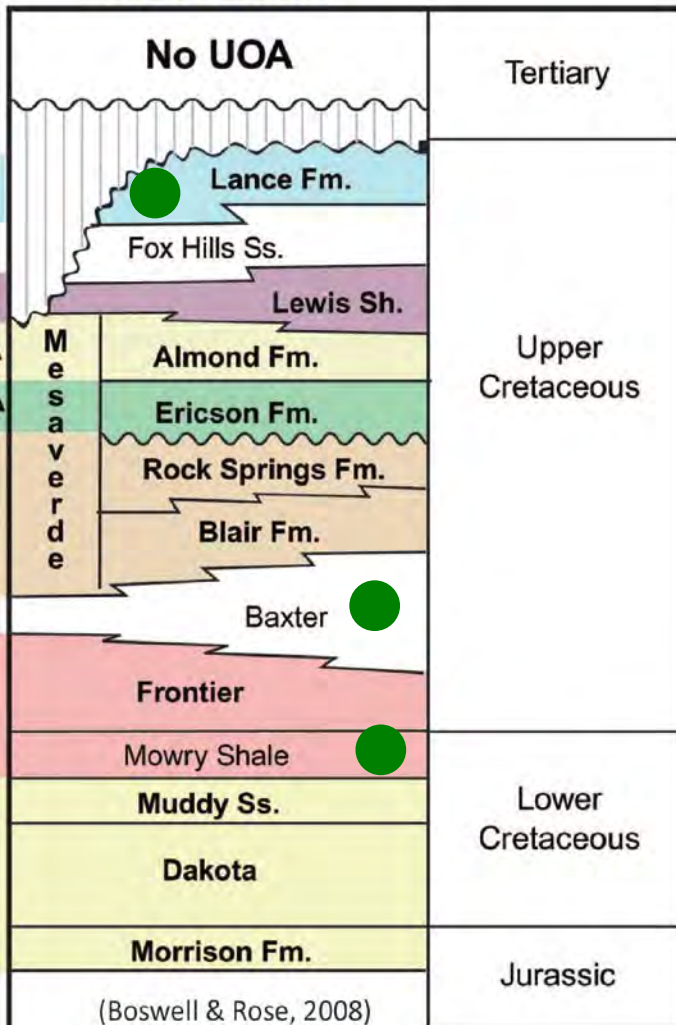
Douglas Creek arch

## Piceance Basin



(USGS Uinta-Piceance Assessment Team, DDS-69-B, 2003)

## Greater Green River Basin



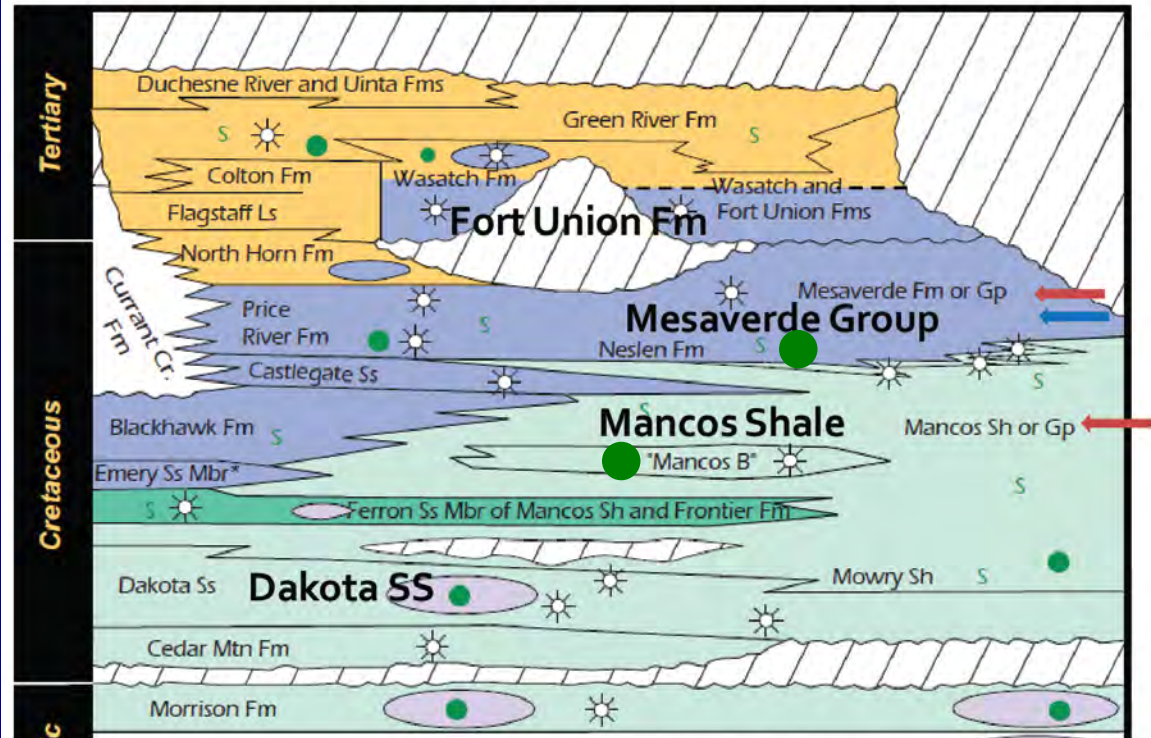
Possible gas source rocks for Jonah, GNB and the Piceance gas fields

- Type II (Mowry), Type III (Cameo Coal, Lance) or mixed Type II-III (Mancos, Baxter)

## Uinta Basin

Douglas Creek arch

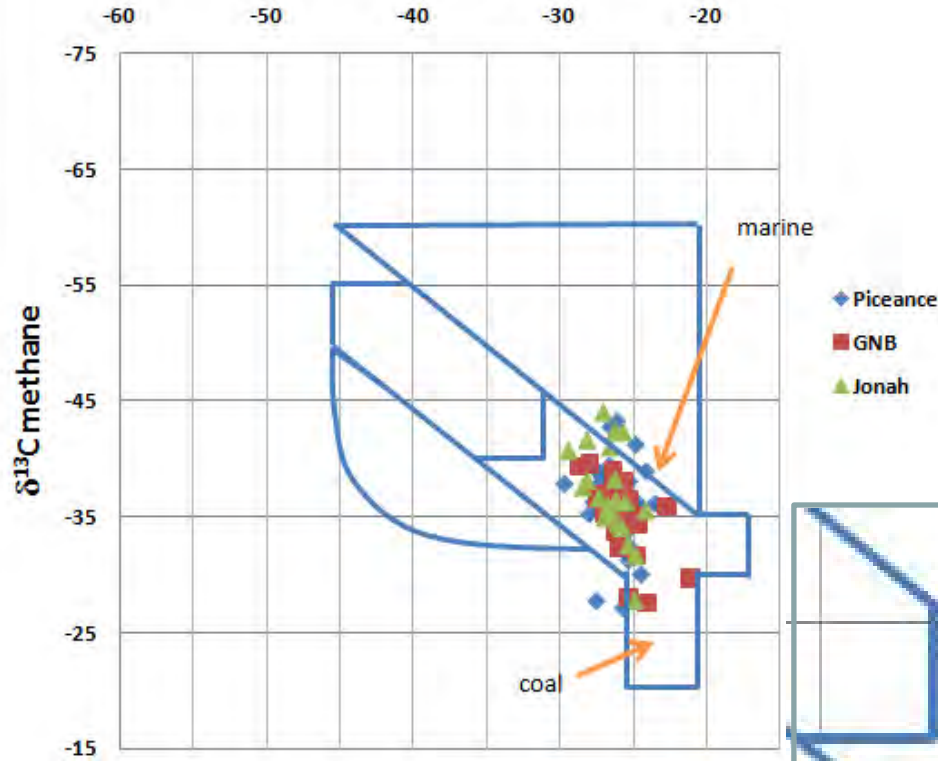
## Piceance Basin



(USGS Uinta-Piceance Assessment Team, DDS-69-B, 2003)

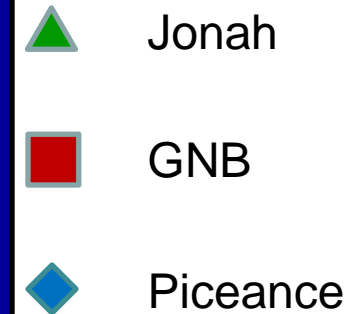
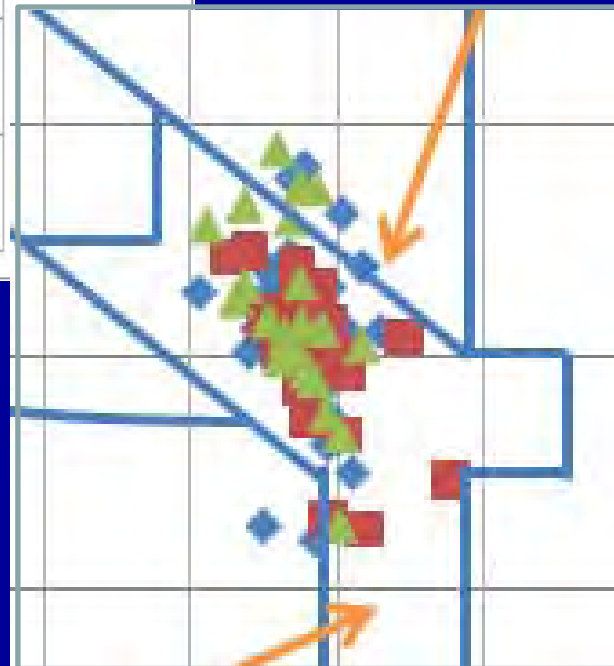
## Production Wells

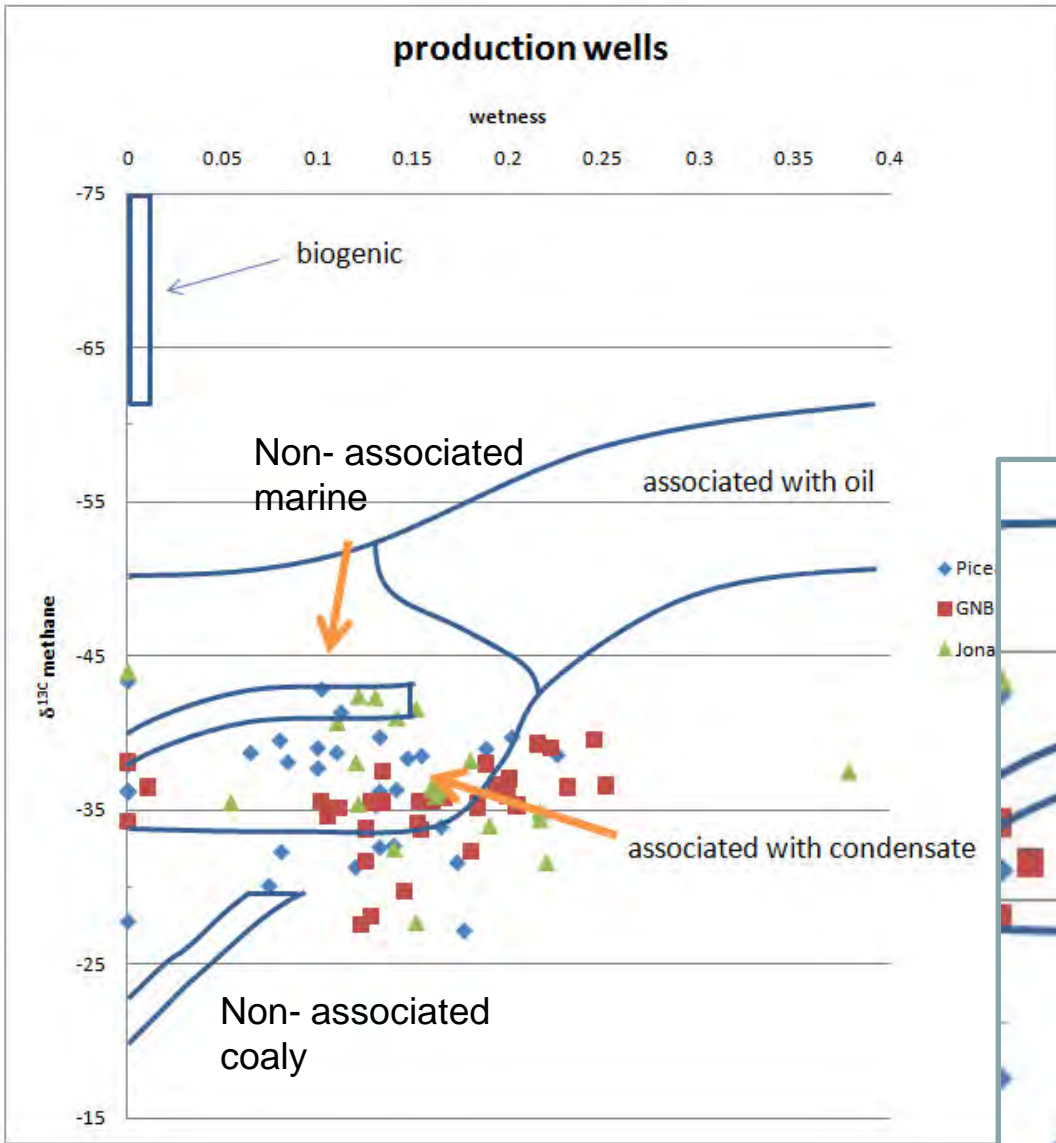
$\delta^{13}\text{C}$  ethane



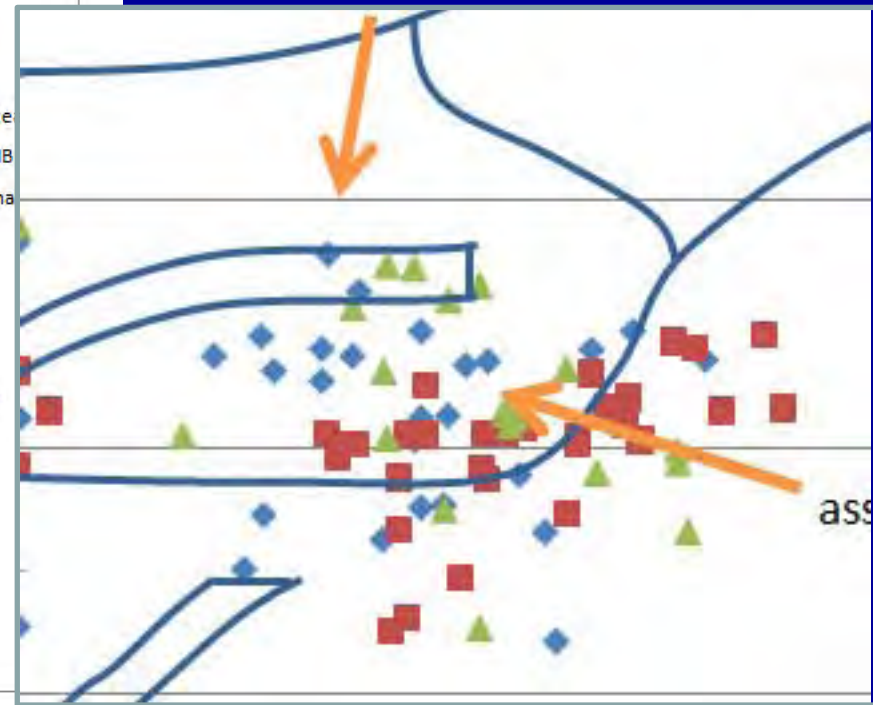
1) Gas compositions are identical.

2) Gas compositions not consistent with a coaly source rock.





1. Piceance gases slightly drier,  $\delta^{13}\text{C}$  very slightly more negative.
2. No indication of more gas from coals in the Piceance data



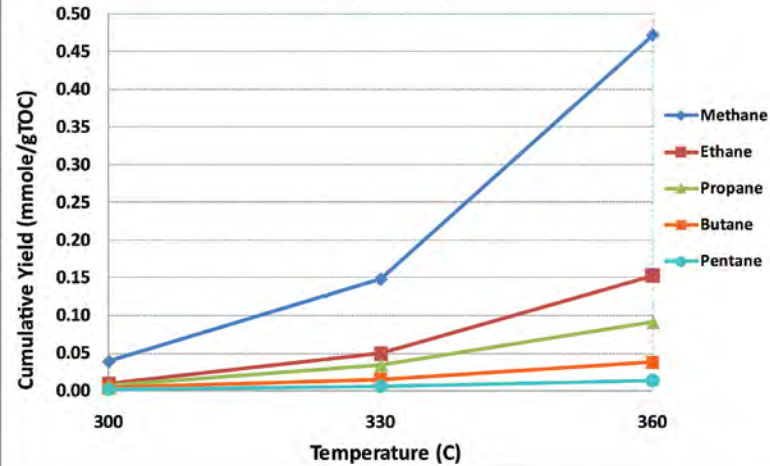
▲ Jonah    ■ GNB    ◆ Piceance

Diagram after Schoell, 1983

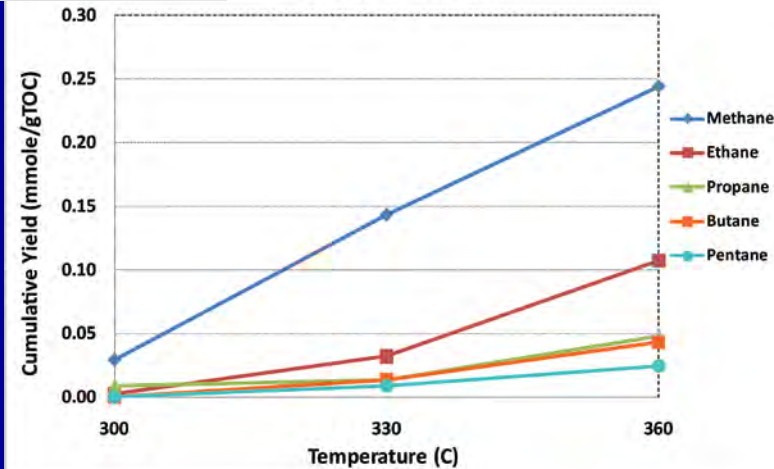
# Hydrous Pyrolysis Experiments

At high maturity ( $\sim 1.63\%$  Ro), bulk hydrocarbon compositions from different source rocks are very similar, but at intermediate maturity, Mowry generates wetter gas

Cameo Coal

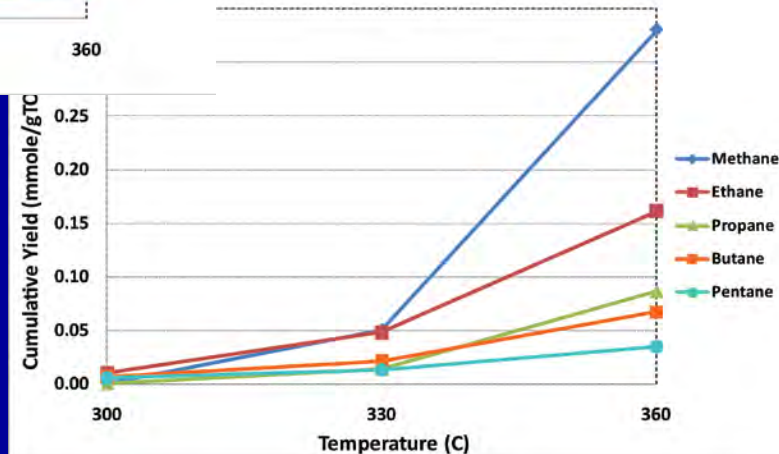


Mancos Shale



Ko, 2010

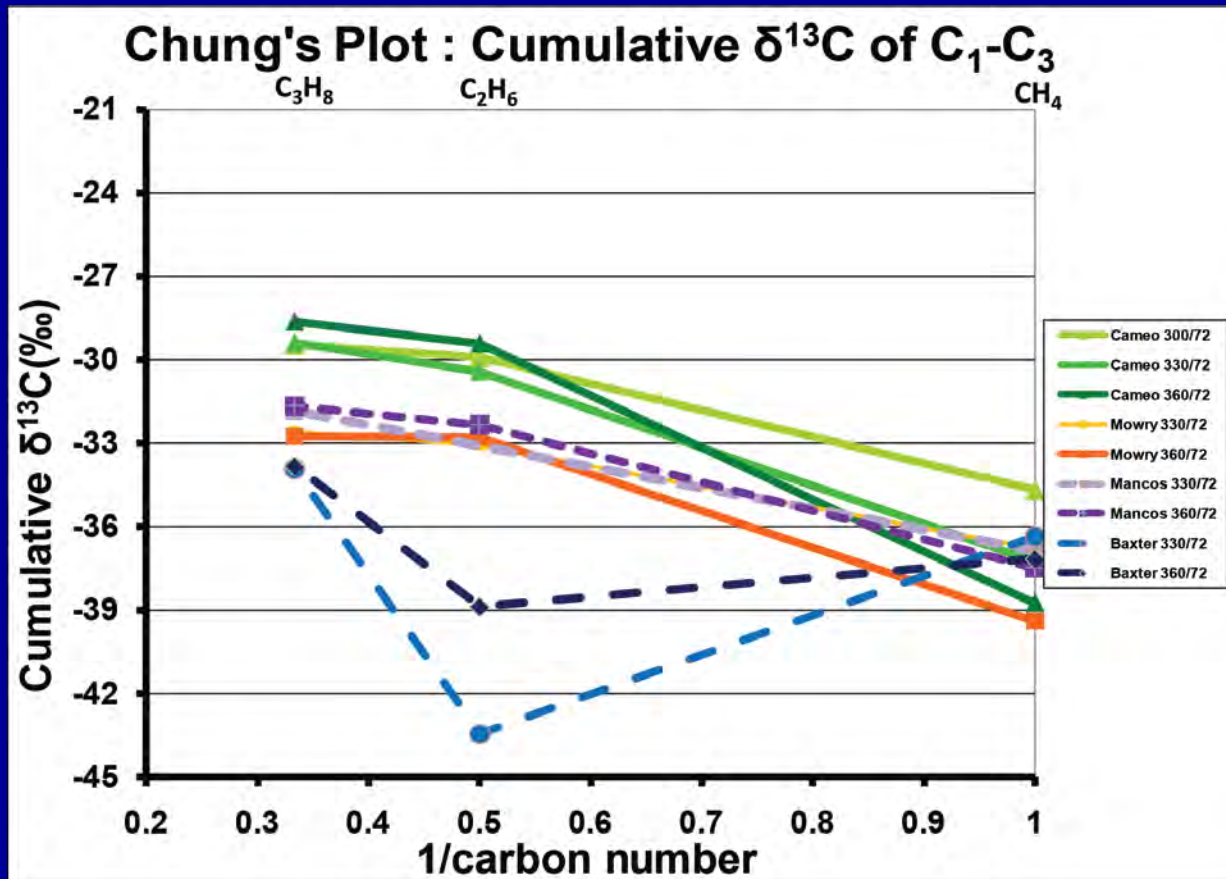
Mowry Shale



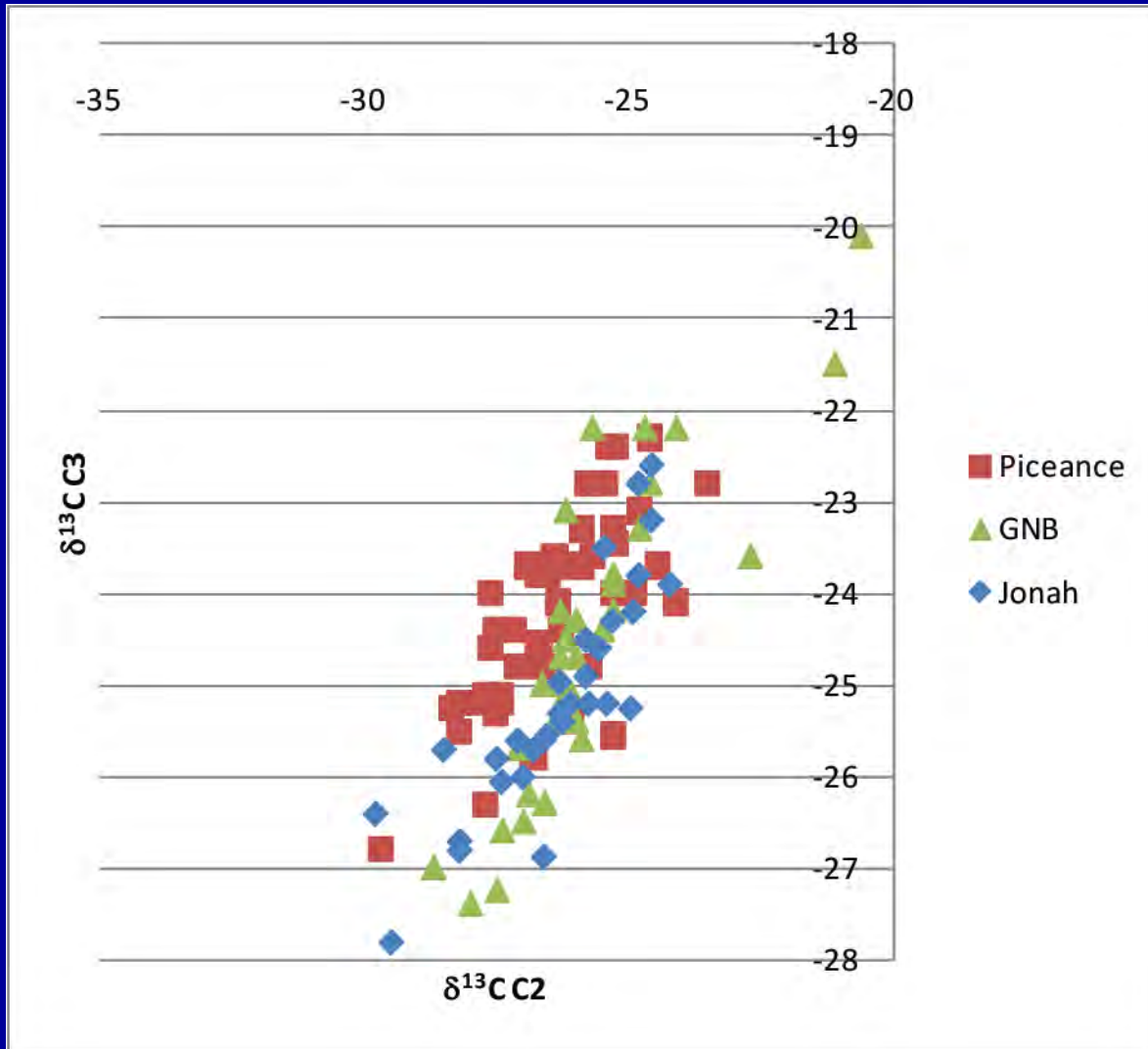
# Hydrous Pyrolysis Experiments

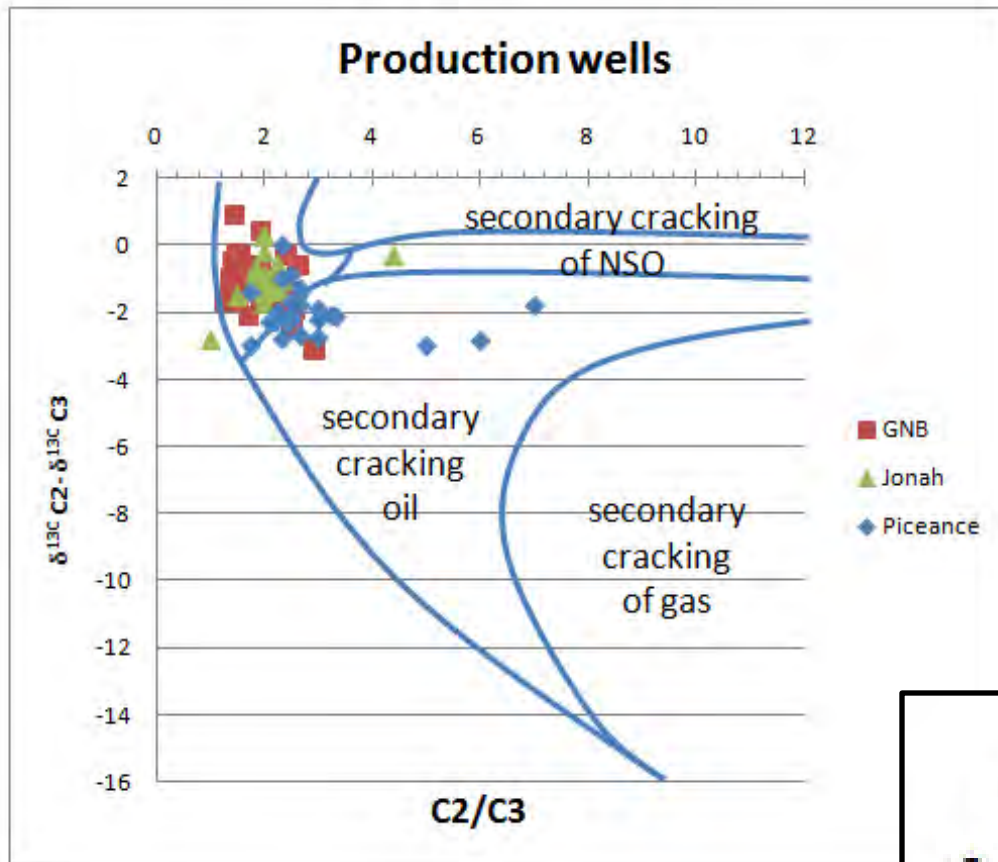
Methane compositions are very similar for all source rocks, but Cameo has heavier carbon in ethane and propane.

This may give us a tool for discriminating gas sources.



A cross-plot of  $\delta^{13}\text{C}$  ethane versus  $\delta^{13}\text{C}$  propane suggests Cameo-derived gases maybe distinguishable through combination of C1 and C3 isotopes.





Piceance gases exhibit slightly higher C2/C3, larger  $\Delta\delta^{13}\text{C C2/C3}$

Suggests more secondary cracking of oil to gas in Piceance fields

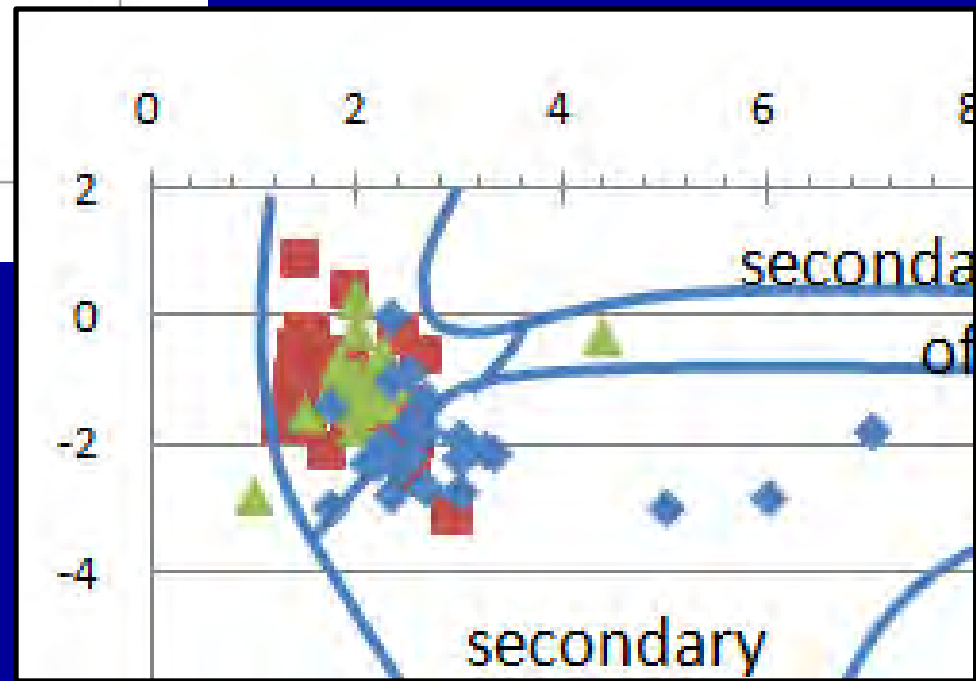
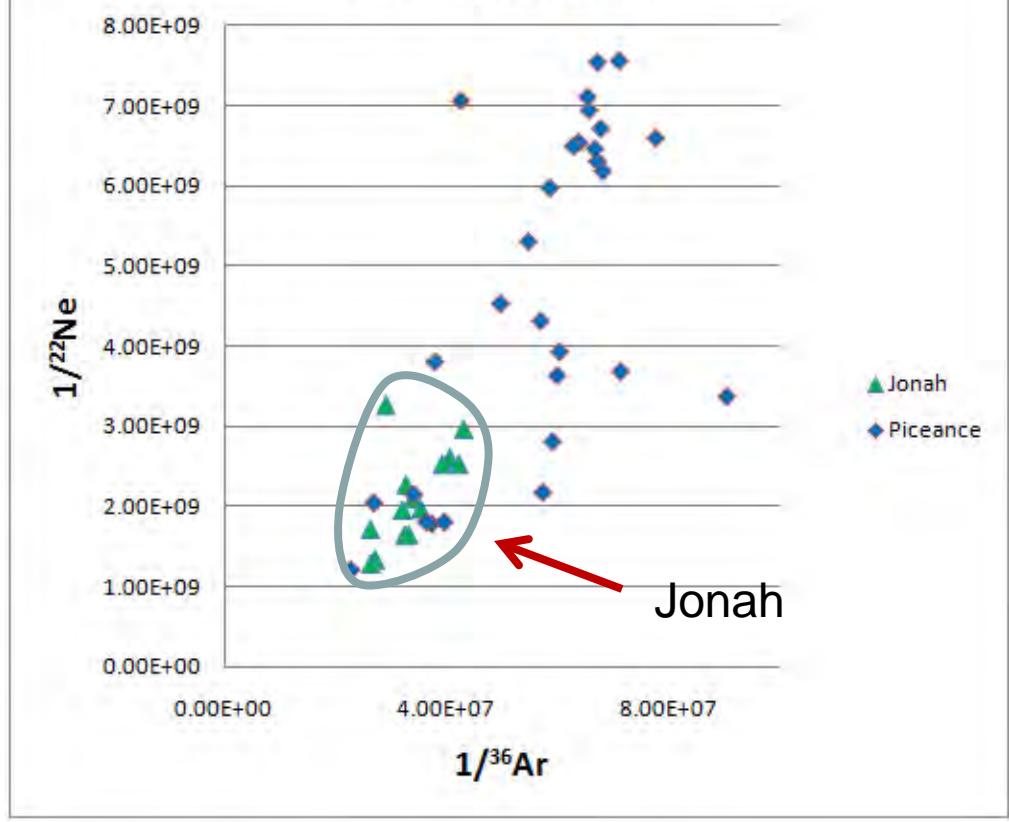


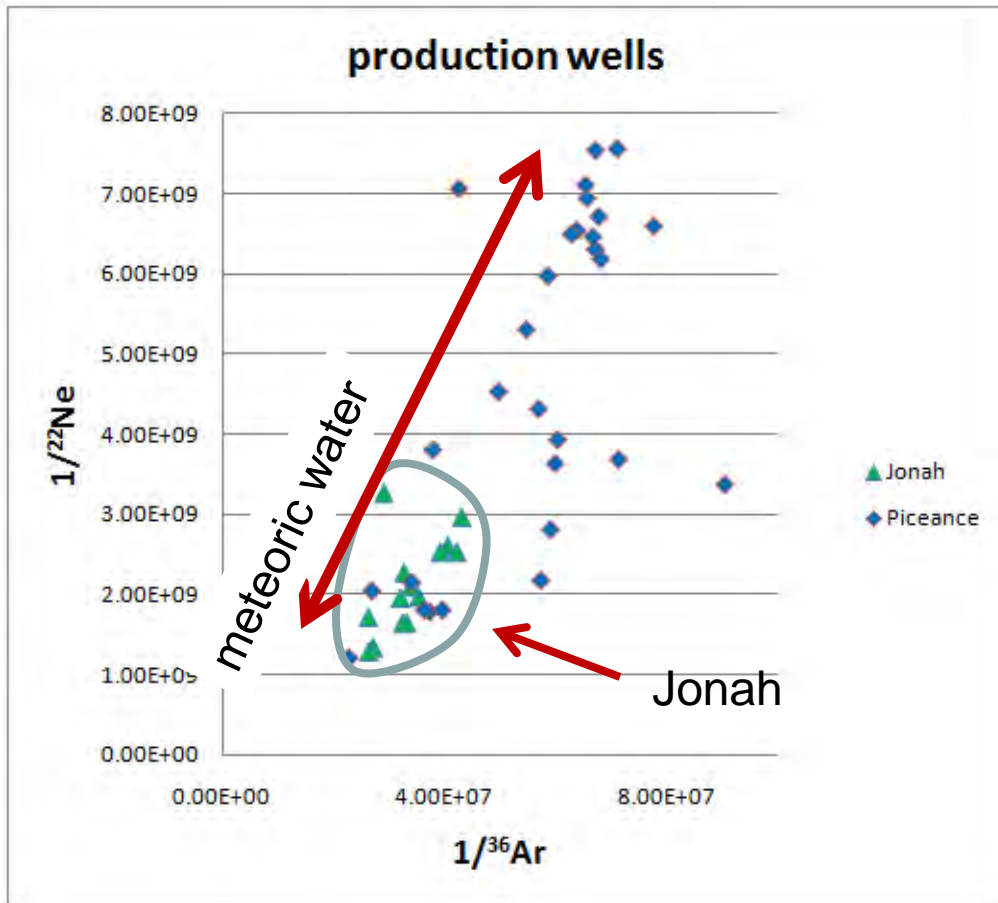
Diagram after Lorant et al., 1998

### production wells



Noble gases are non-reactive, non-hydrocarbon gases

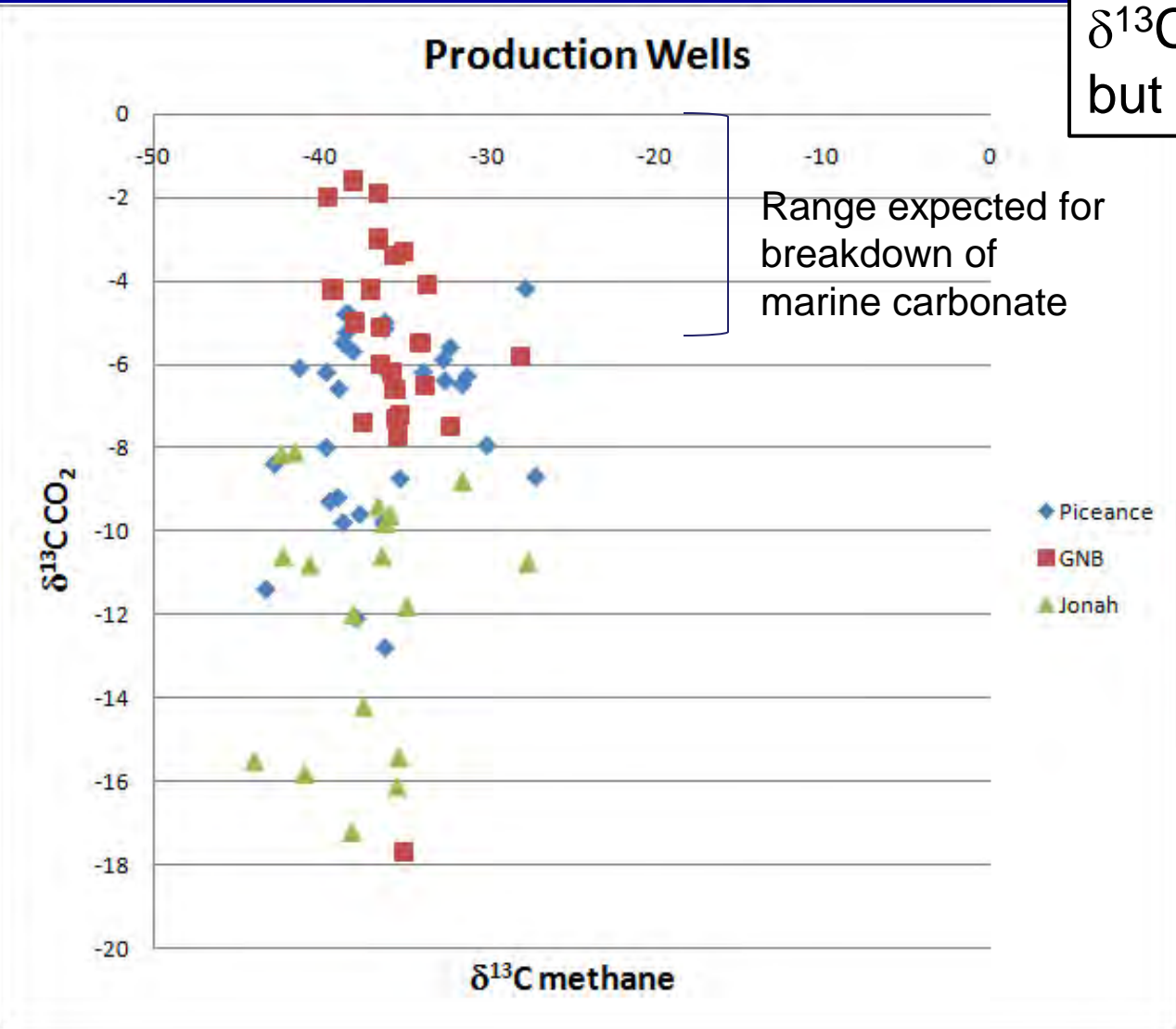
Can indicate contributions from volcanic or meteoric water sources



All Jonah gases show meteoric water contribution

Piceance gases show varying meteoric water contributions

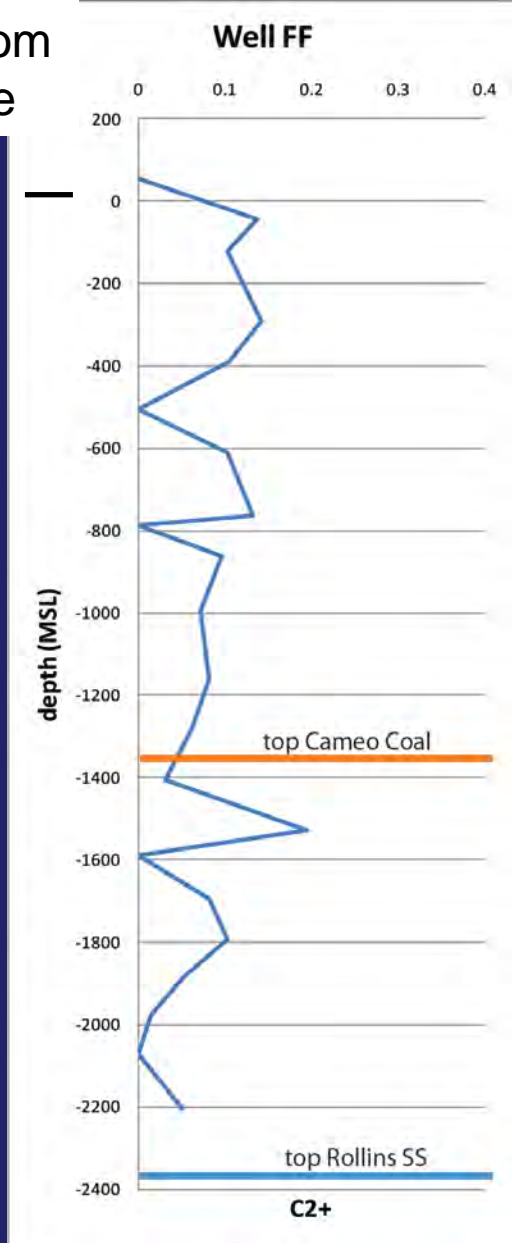
Clear differences in  $\delta^{13}\text{C CO}_2$  between fields but not in  $\delta^{13}\text{C methane}$



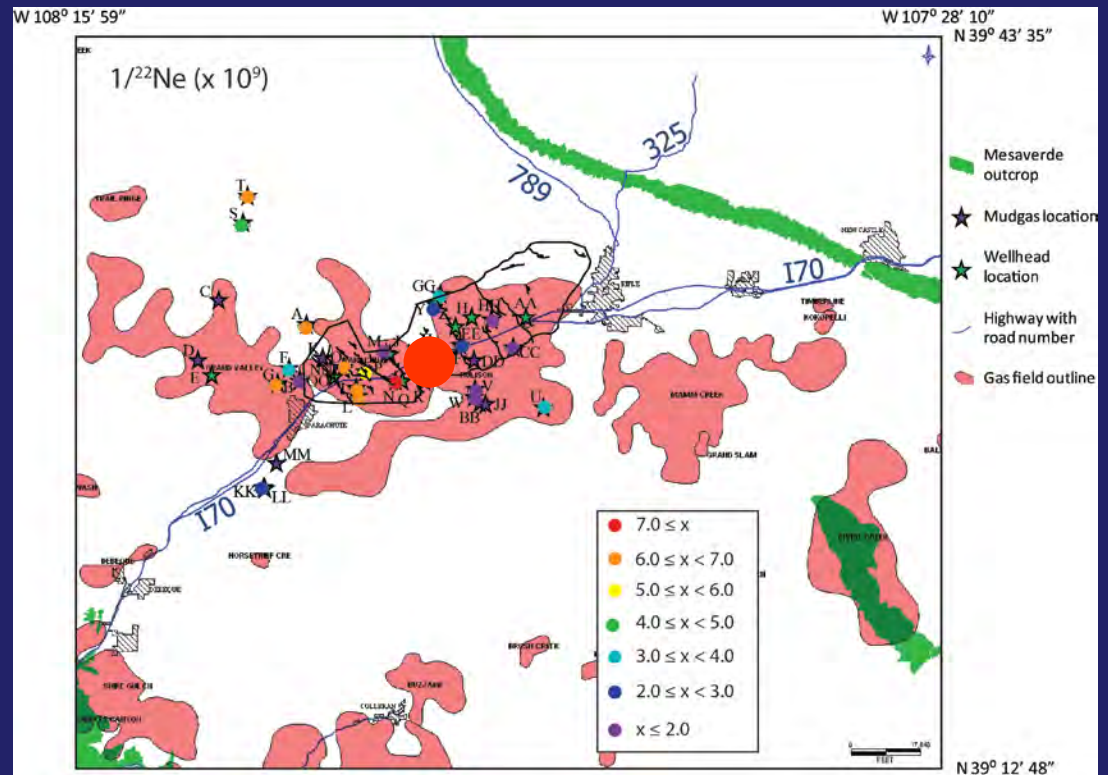


depth from surface

5500



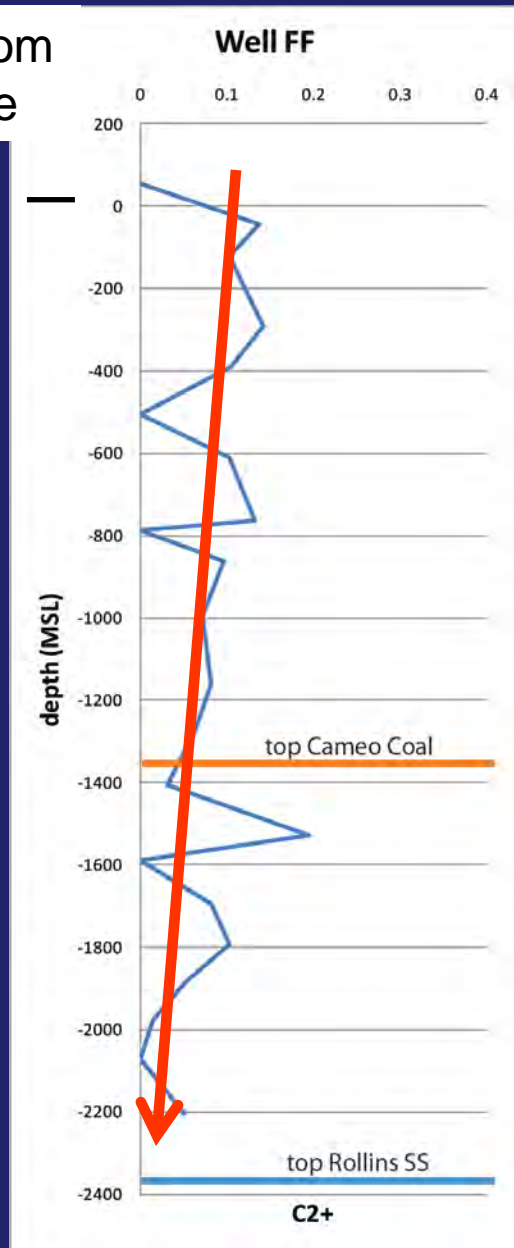
# Piceance Basin mud gas



# Piceance Basin samples

depth from  
surface

5500

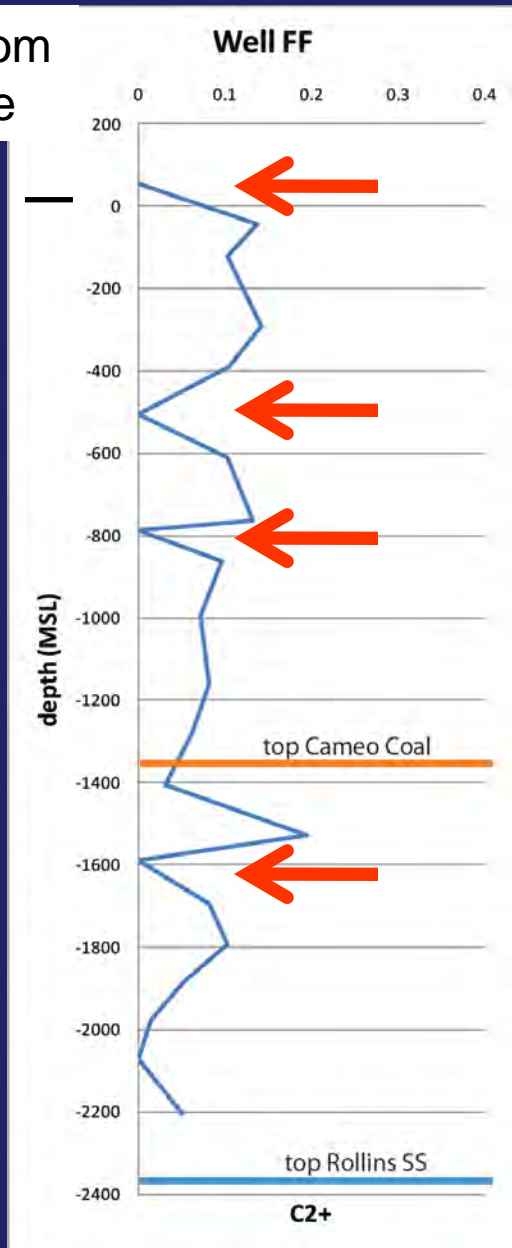


- Gases become drier with depth.
- No clear change in gas compositions associated with Cameo Coal.

# Piceance Basin samples

depth from surface

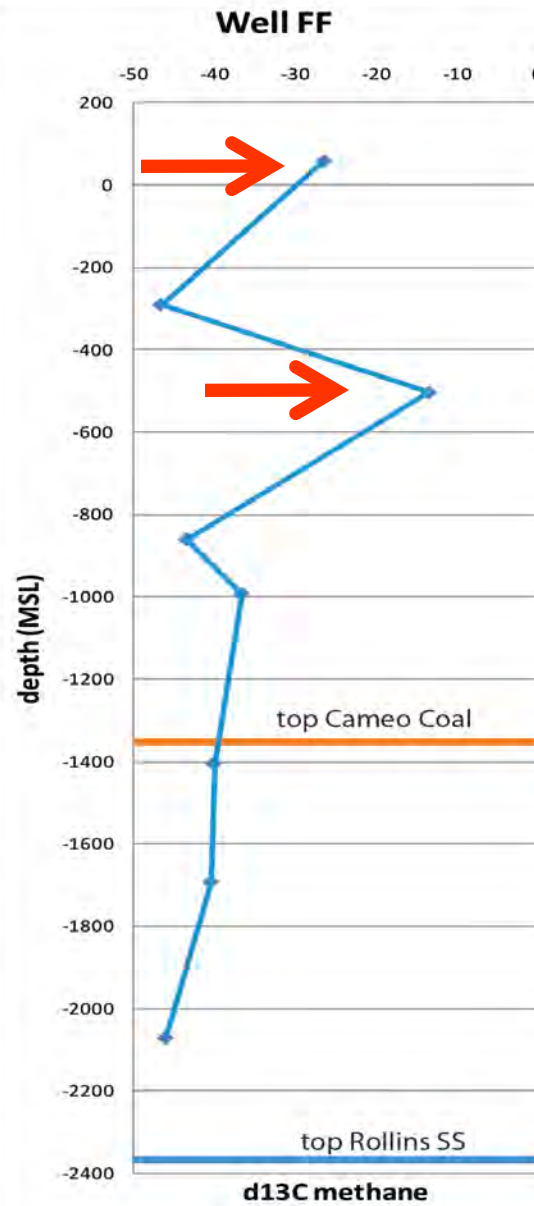
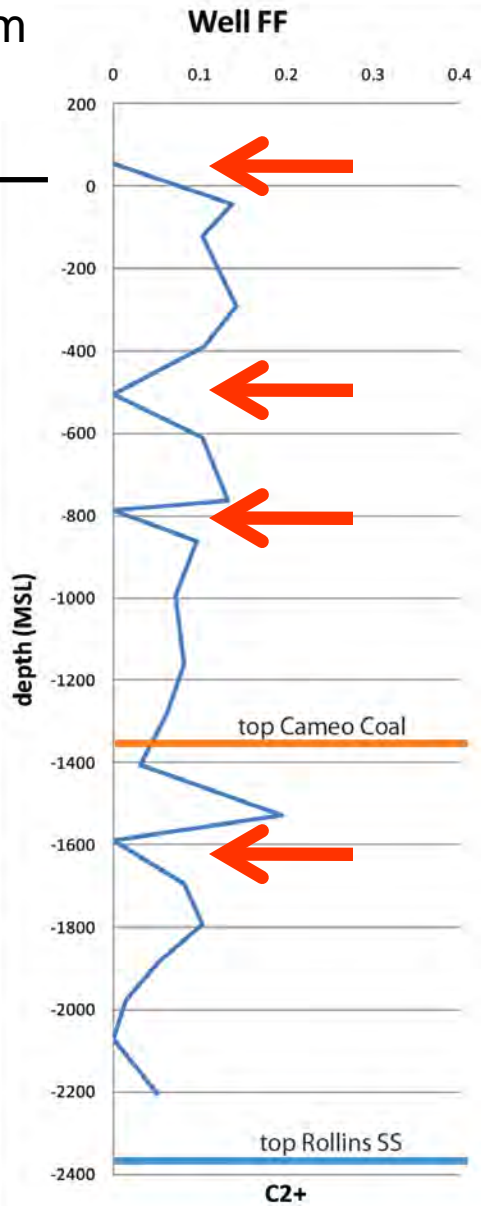
5500



- A few samples of pure methane.

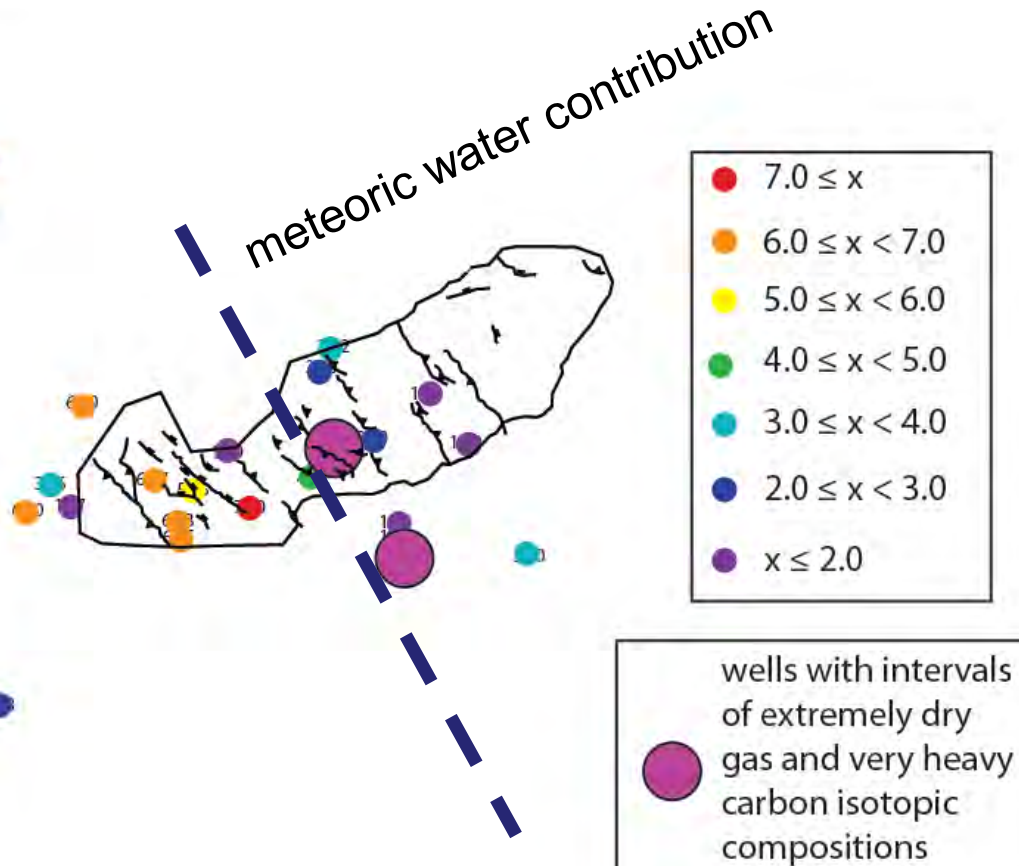
depth from surface

5500

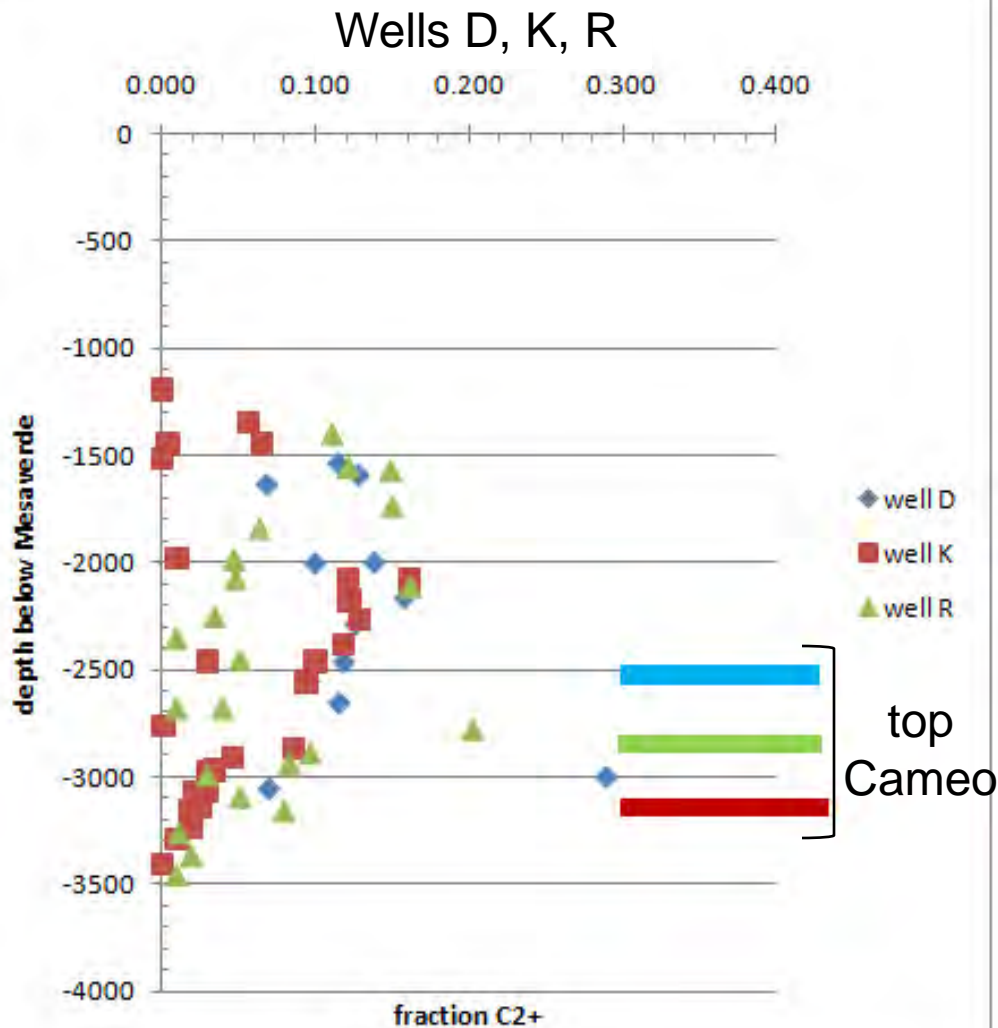


- Very pure methane samples have 'heavy' carbon isotopes
- Evidence for microbial oxidation of gases – selective destruction of wetter gases and of the lighter carbon in methane

$1/^{22}\text{Ne}$  ( $\times 10^9$ )

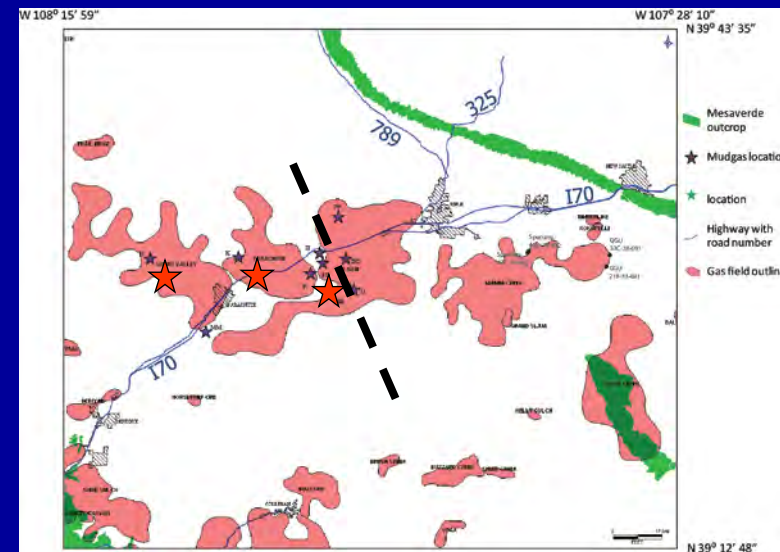


# western wells / mud gas sampling



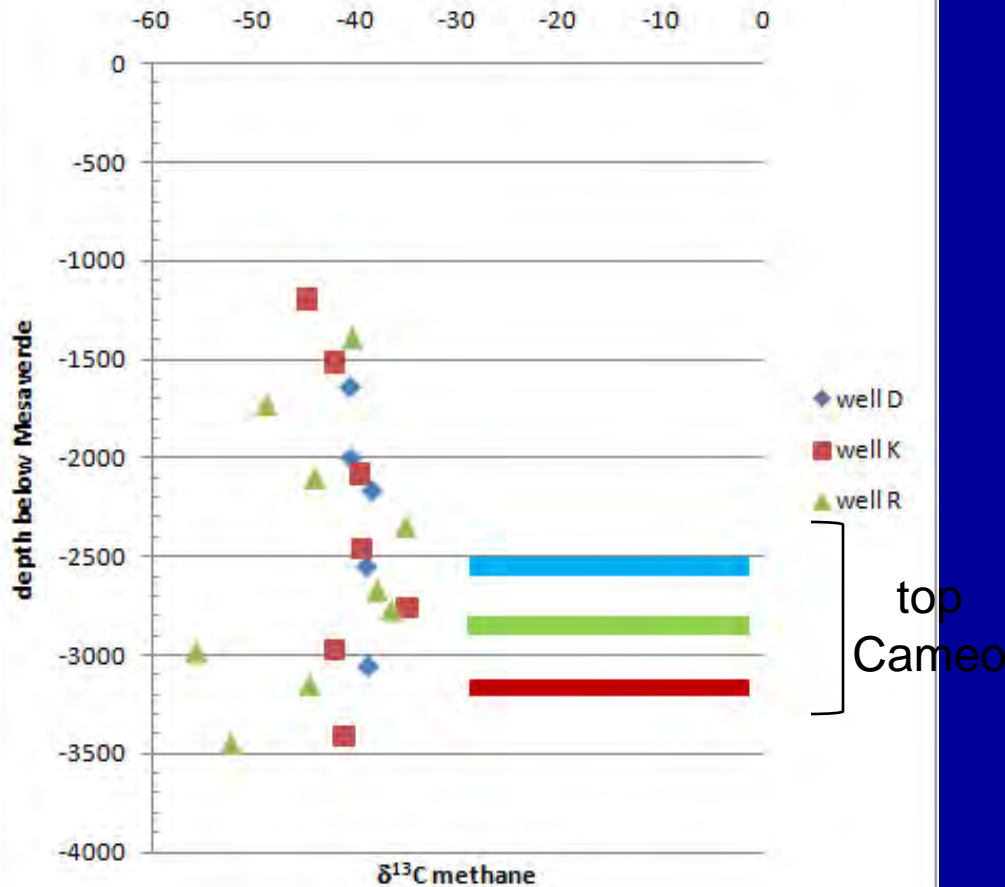
Gases at maximum C2+  
1500-2000 feet below top  
MV, 500 to 1000 feet above  
Cameo

Gases become dry below  
Cameo



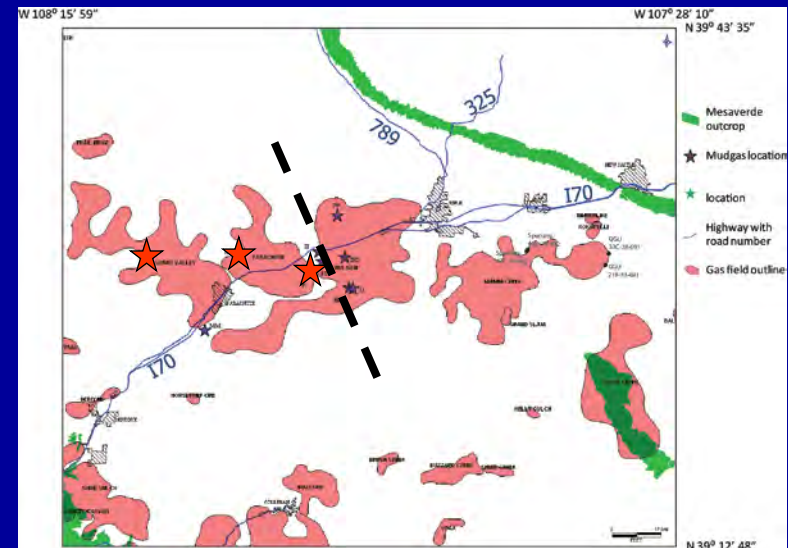
# western wells / mud gas sampling

## wells D, K, R

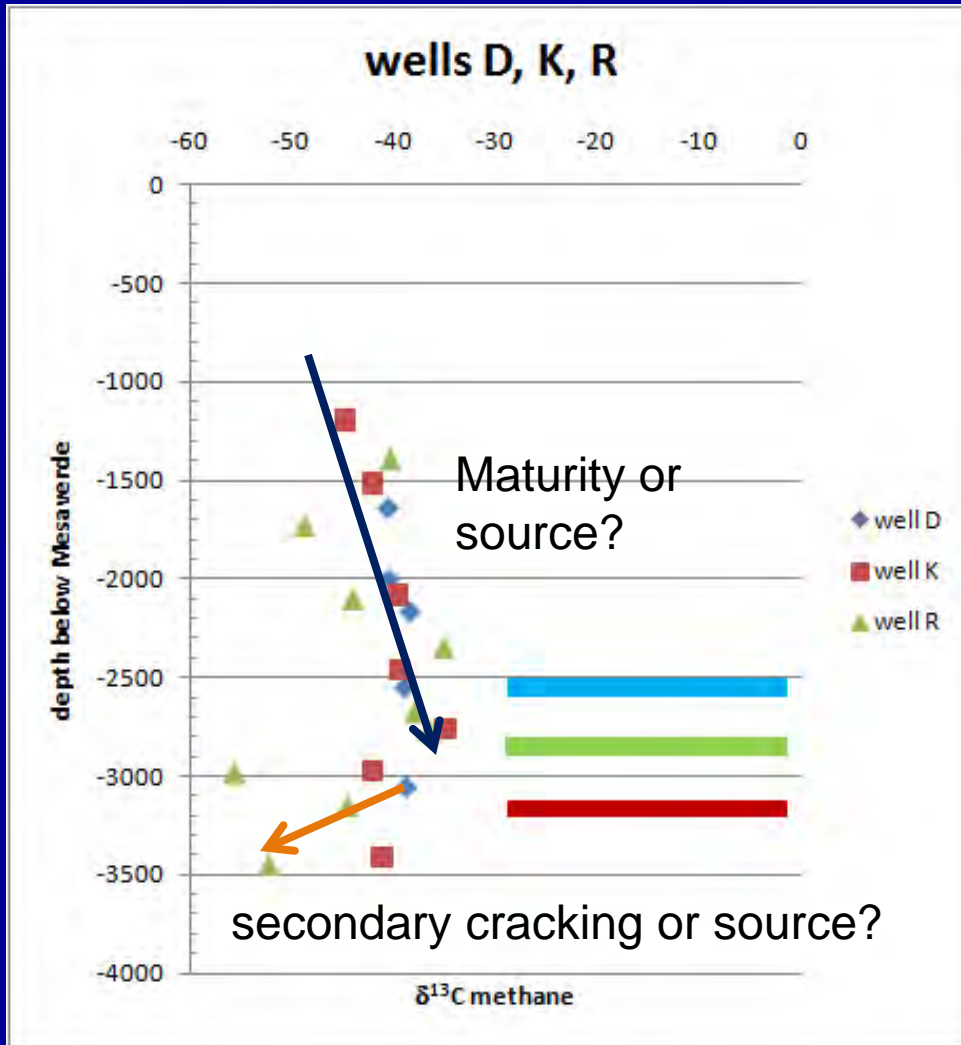


Gases at heaviest  $\delta^{13}\text{C}$  at Cameo level

Gases become start to become significantly more negative below Cameo

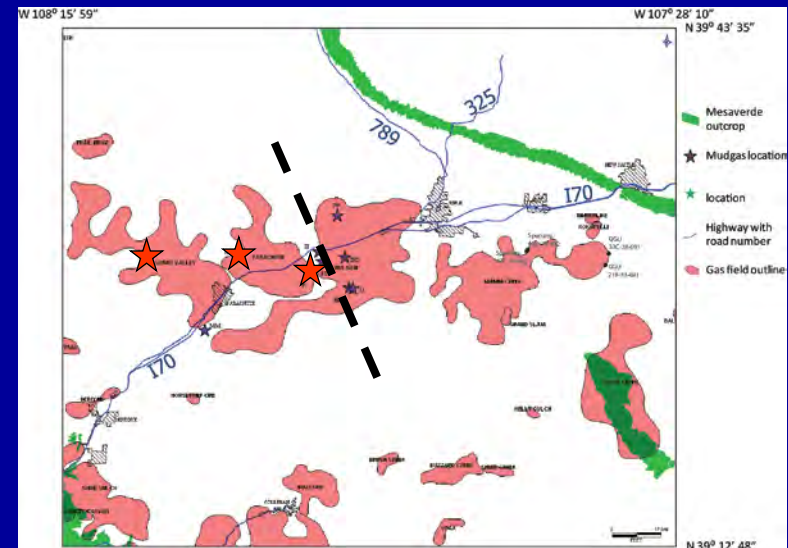


# western wells / mud gas sampling



Gases at heaviest  $\delta^{13}\text{C}$  at Cameo level

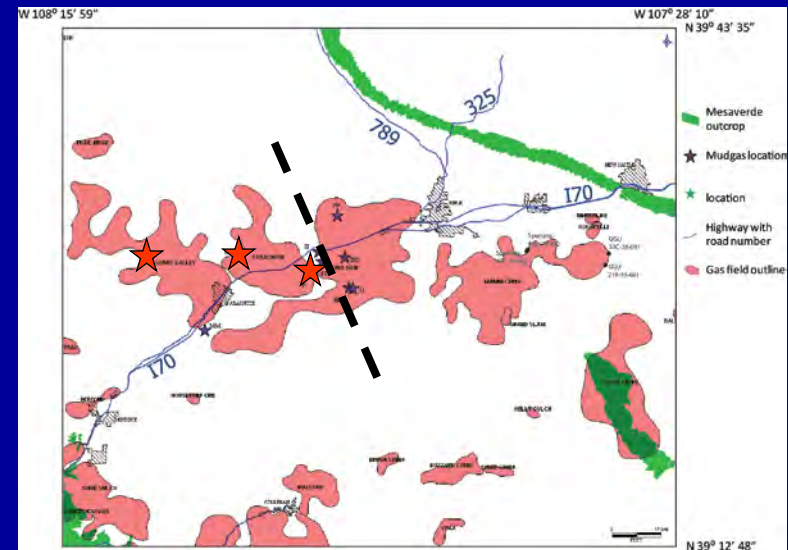
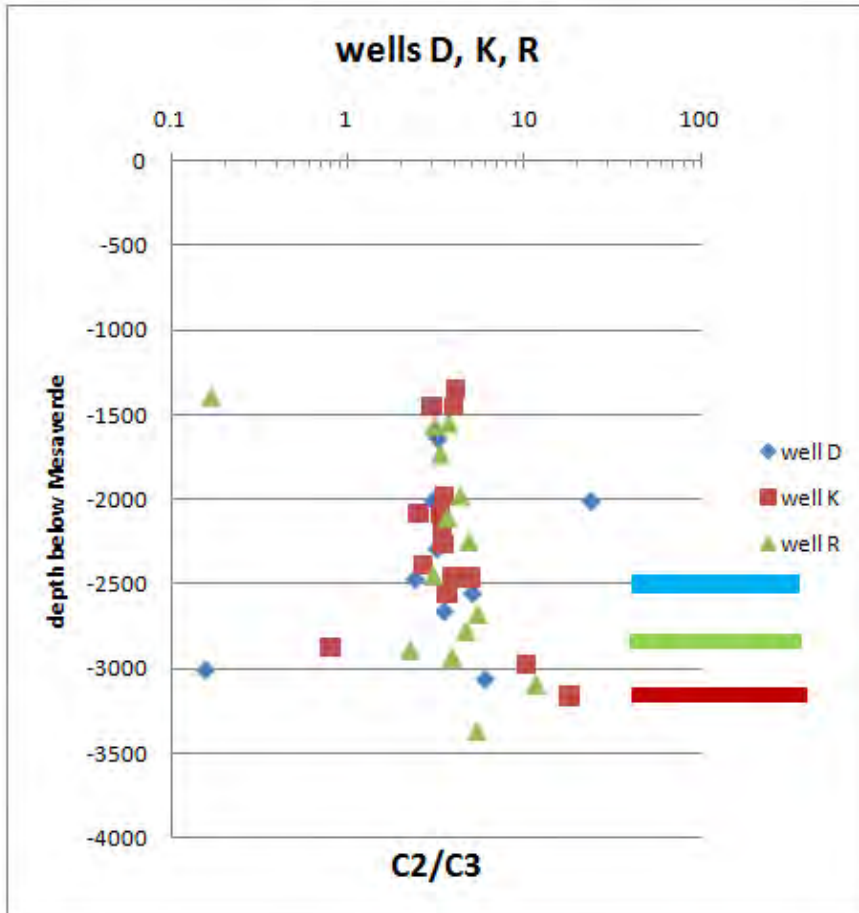
Gases become start to become significantly more negative below Cameo

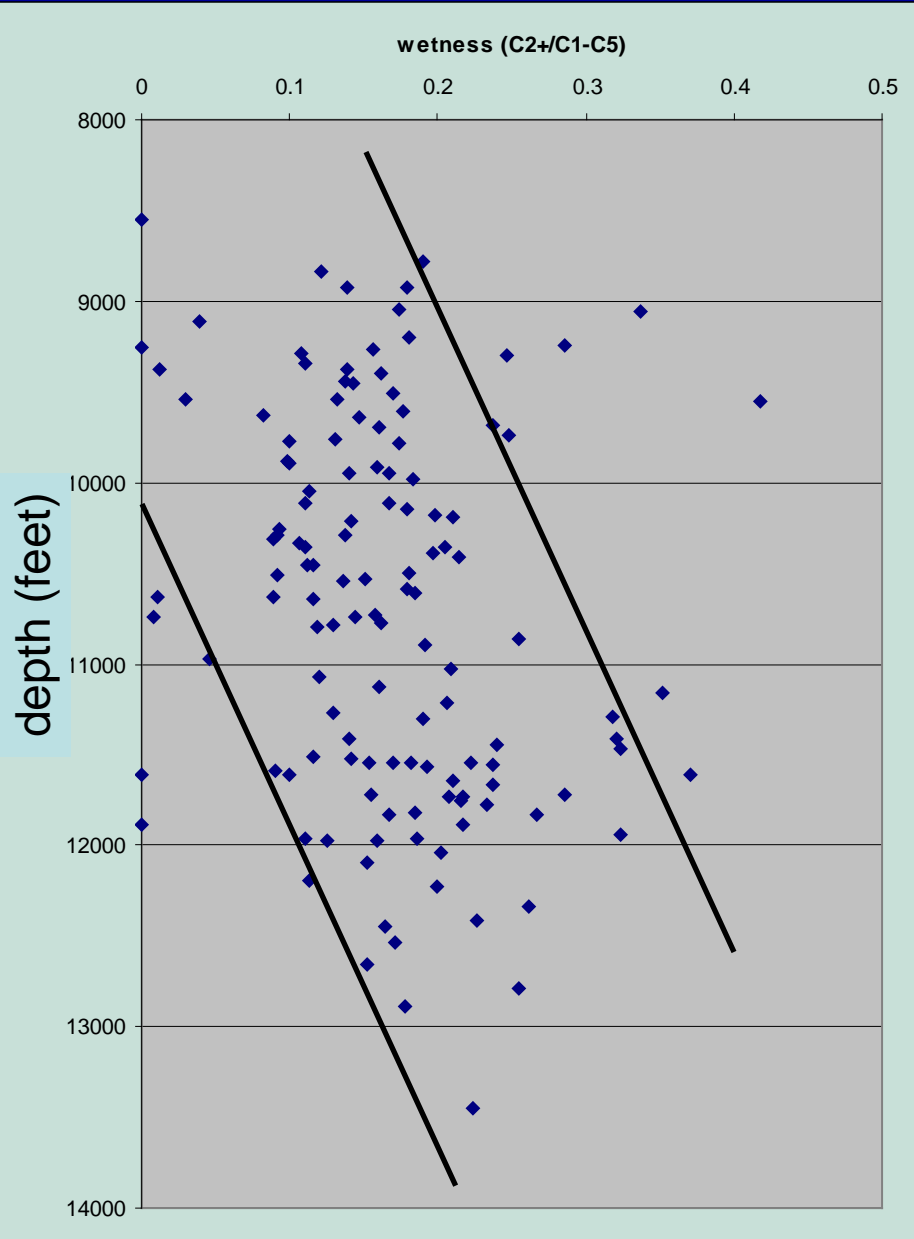


# western wells / mud gas sampling

C2/C3 increases with depth

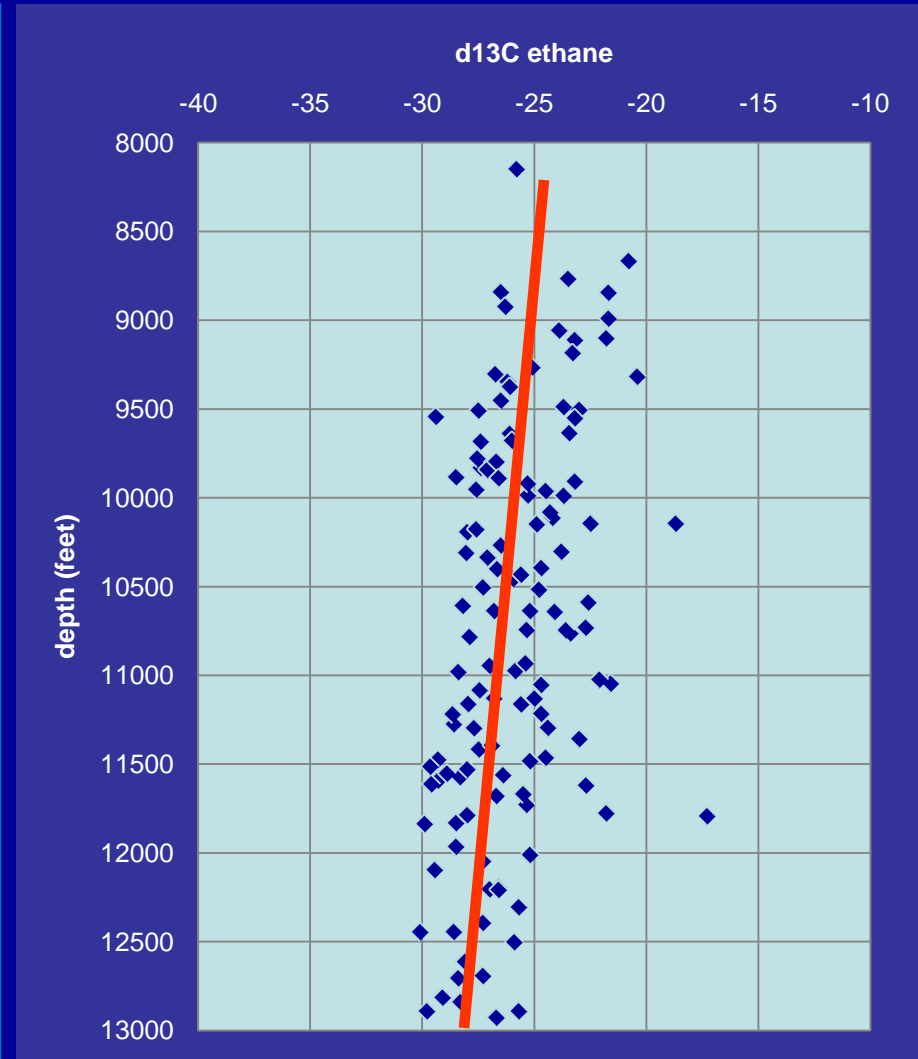
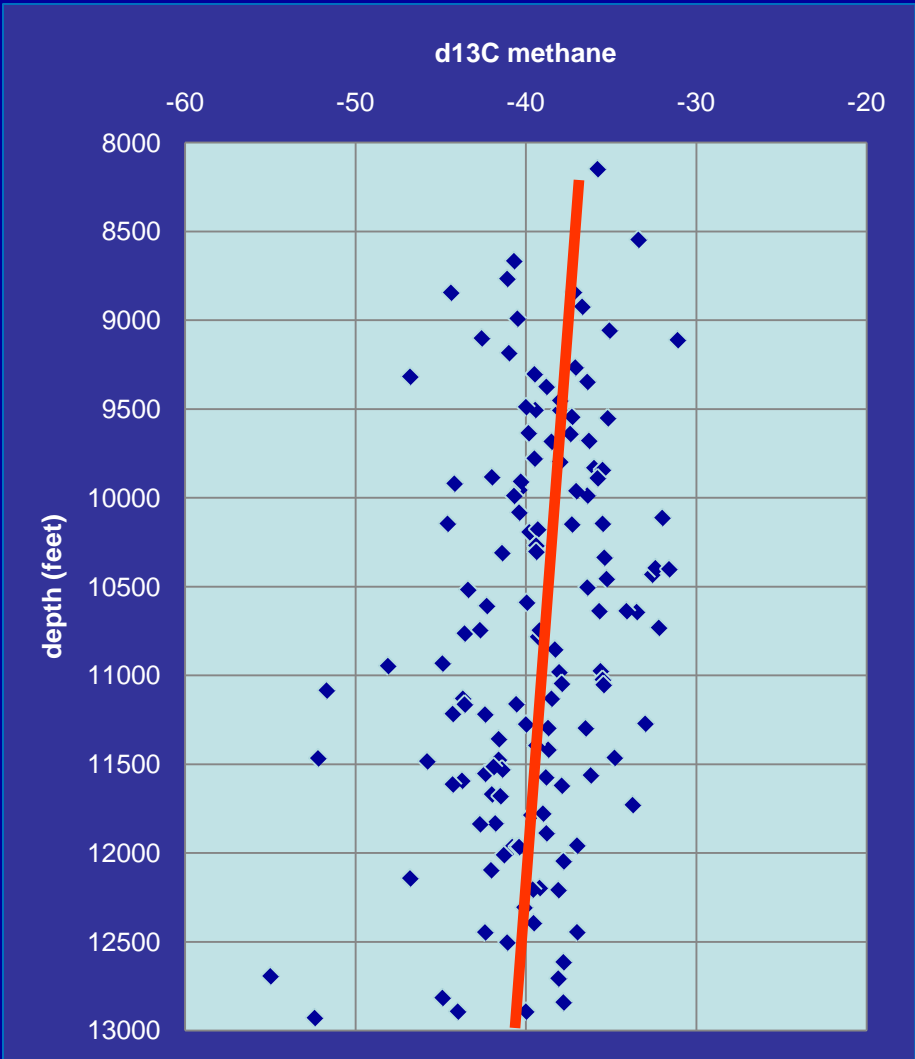
Suggests an increasing component from secondary cracking with depth



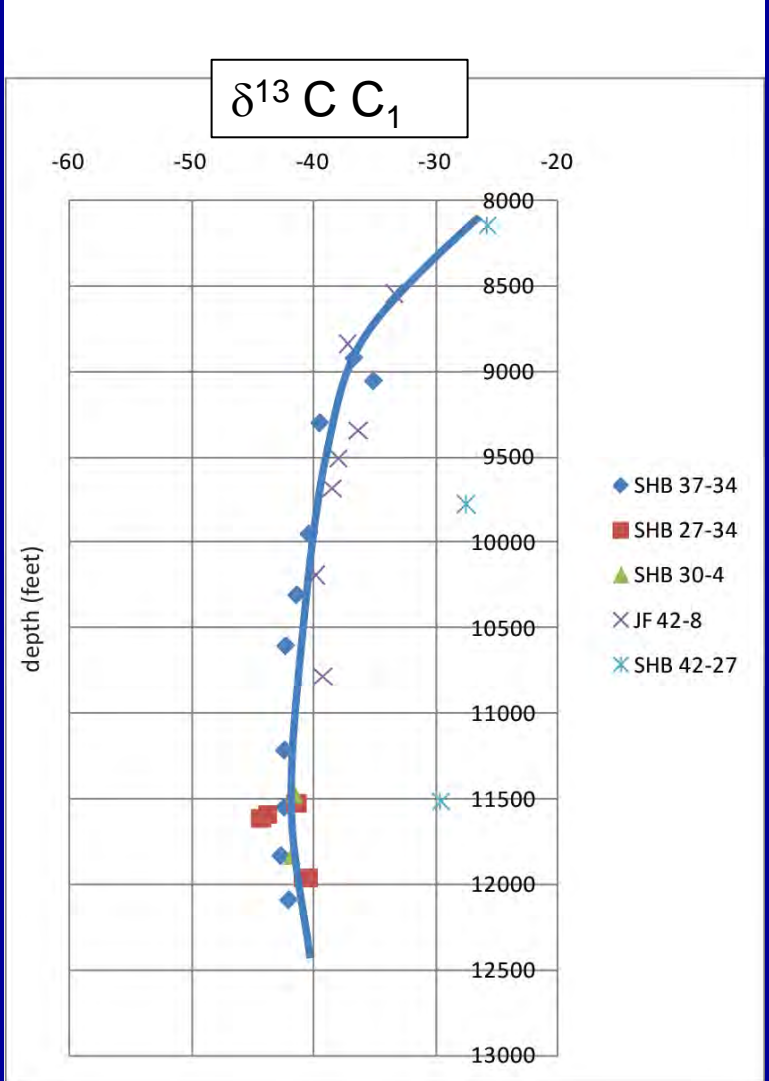
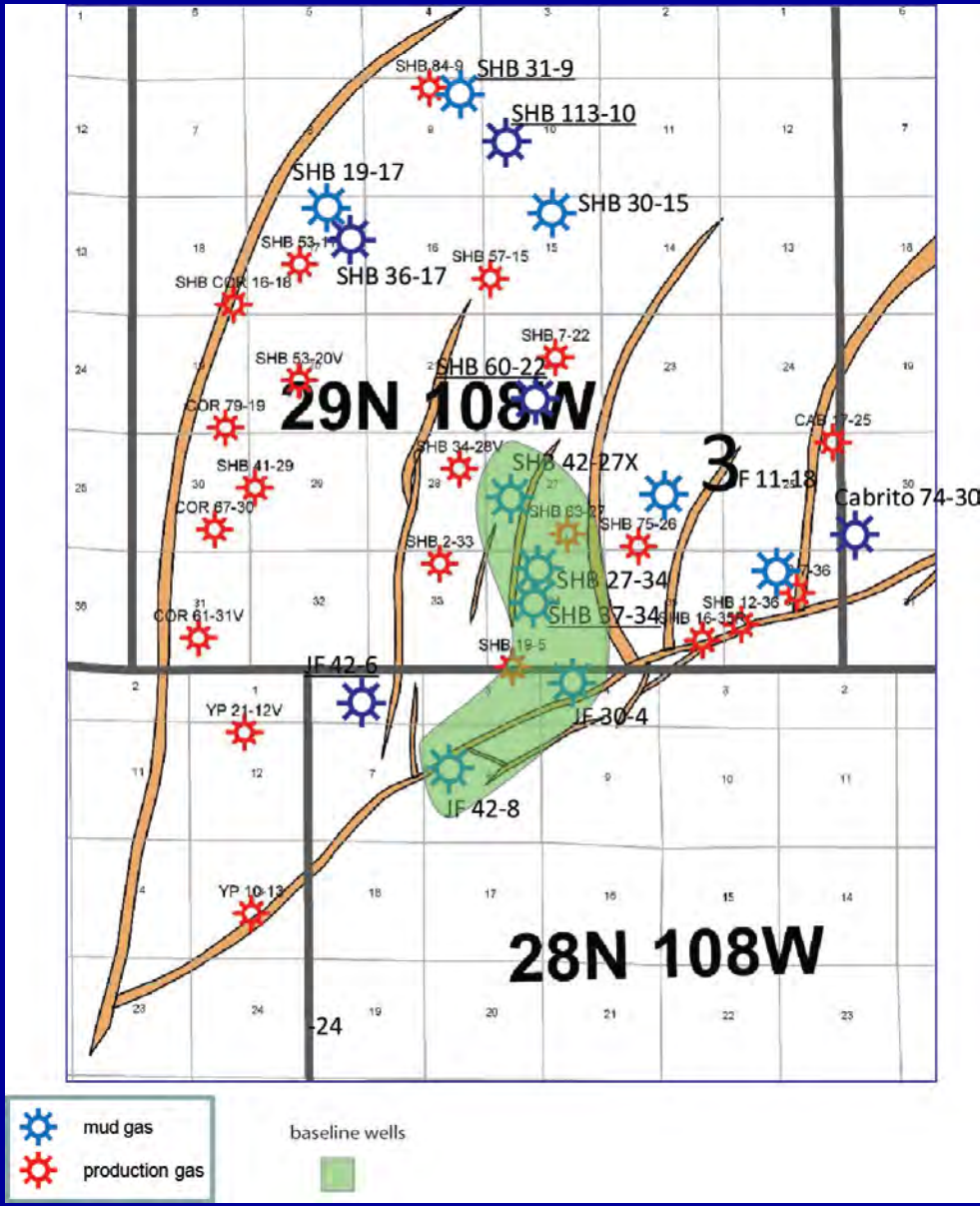


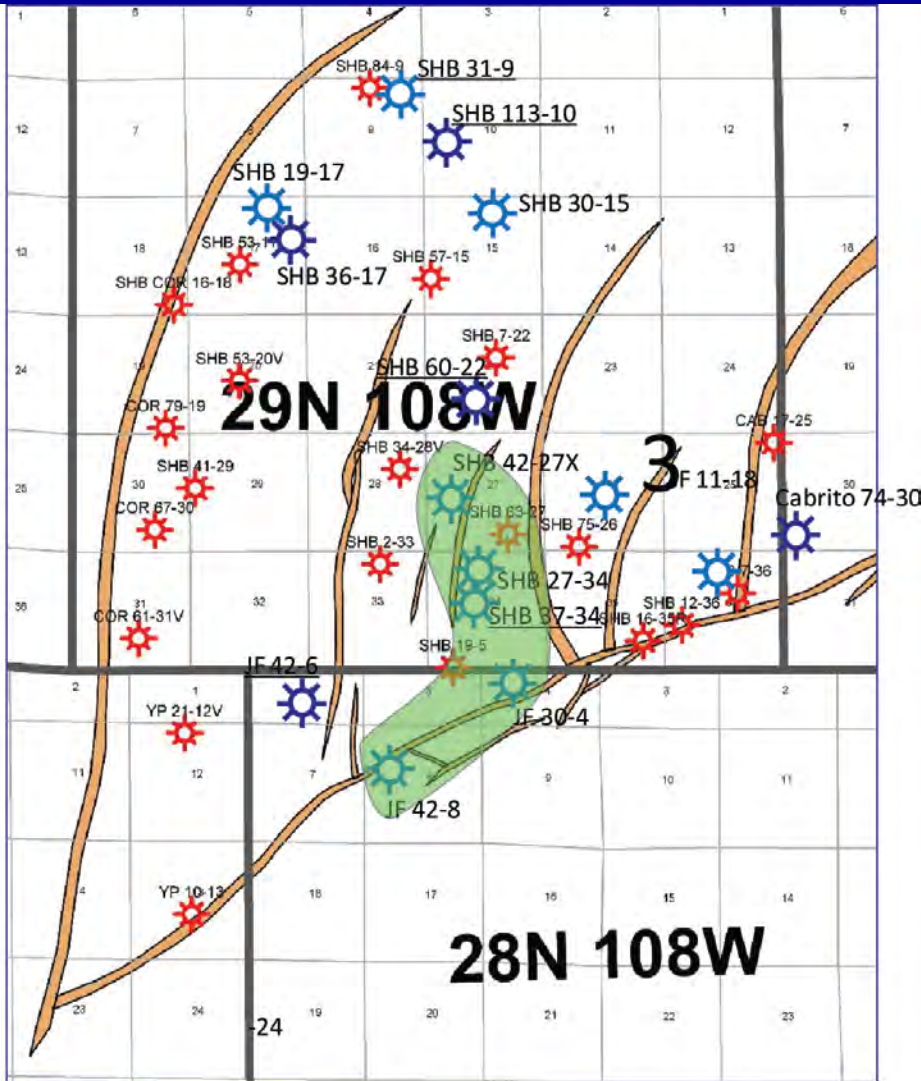
Jonah Field mud gas:

Gas compositions become systematically wetter with depth.

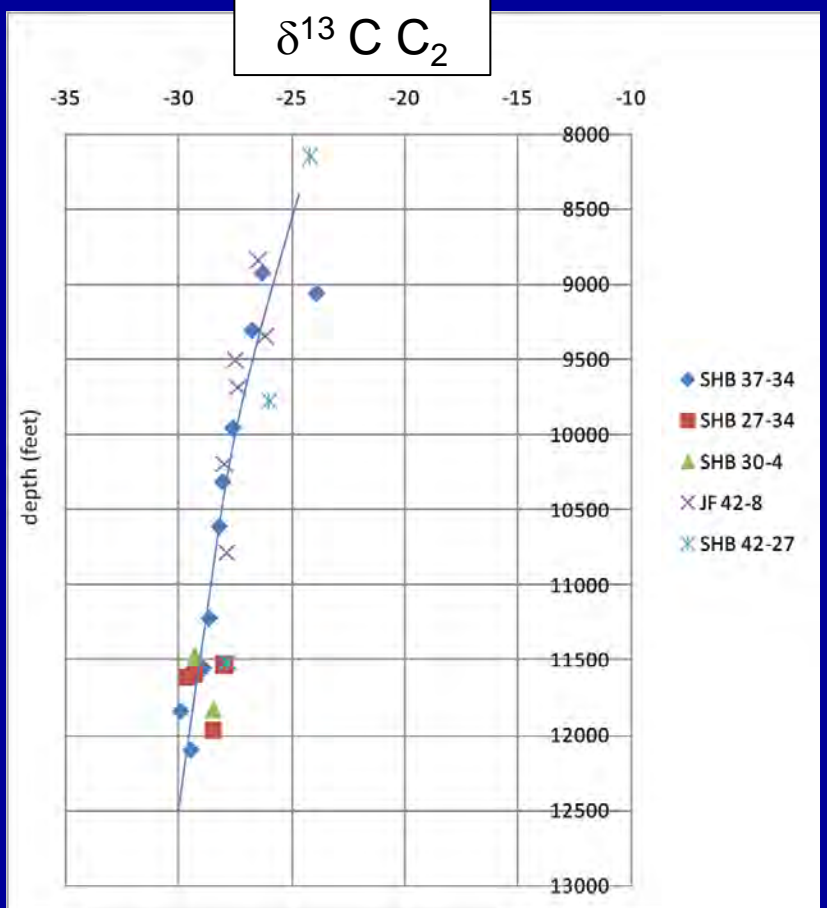


Carbon isotopic compositions become systematically lighter with depth








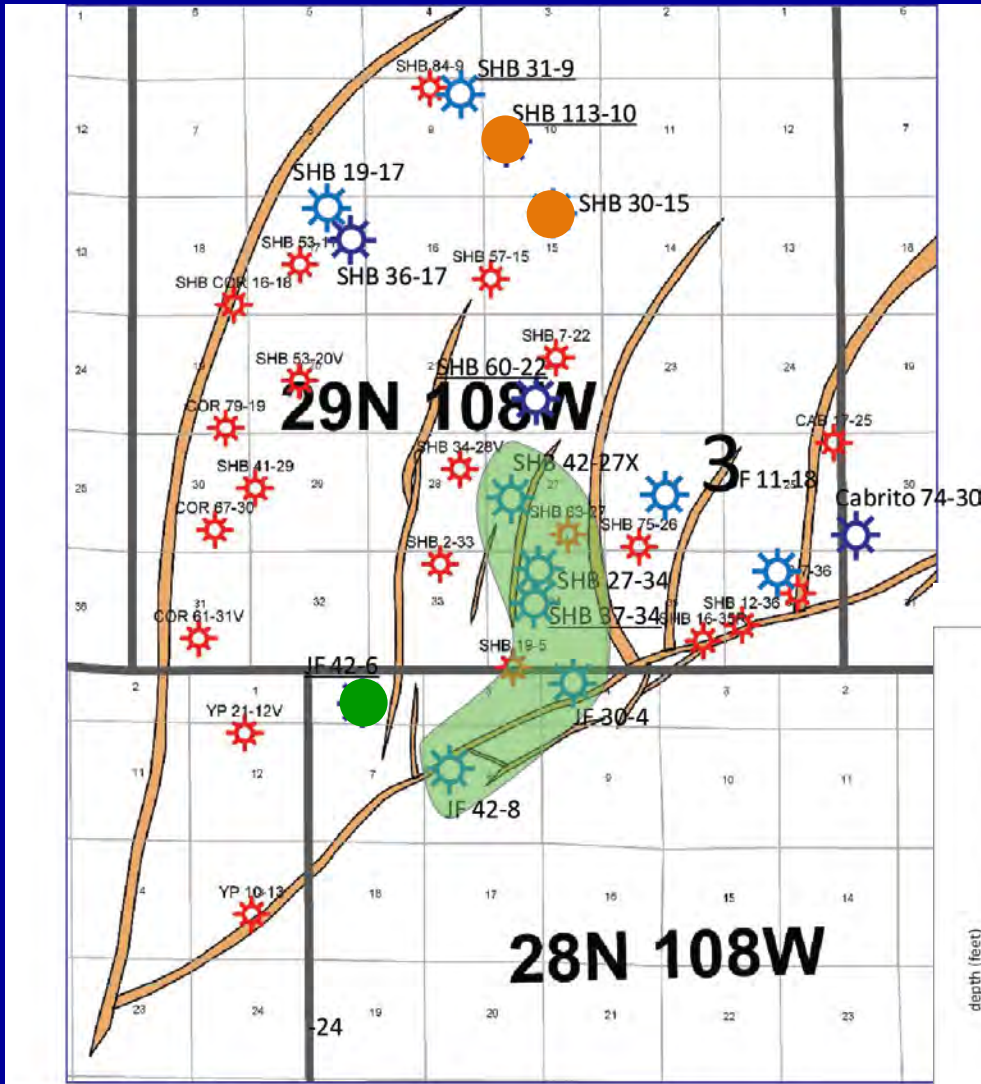





-  mud gas
-  production gas
-  baseline wells

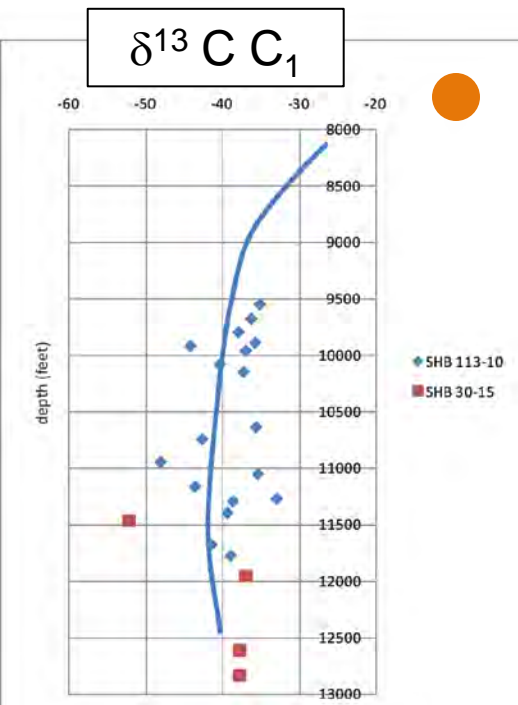
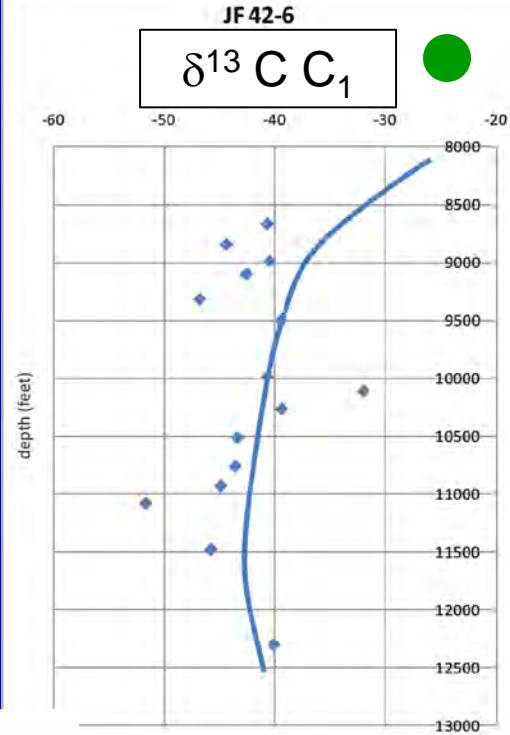


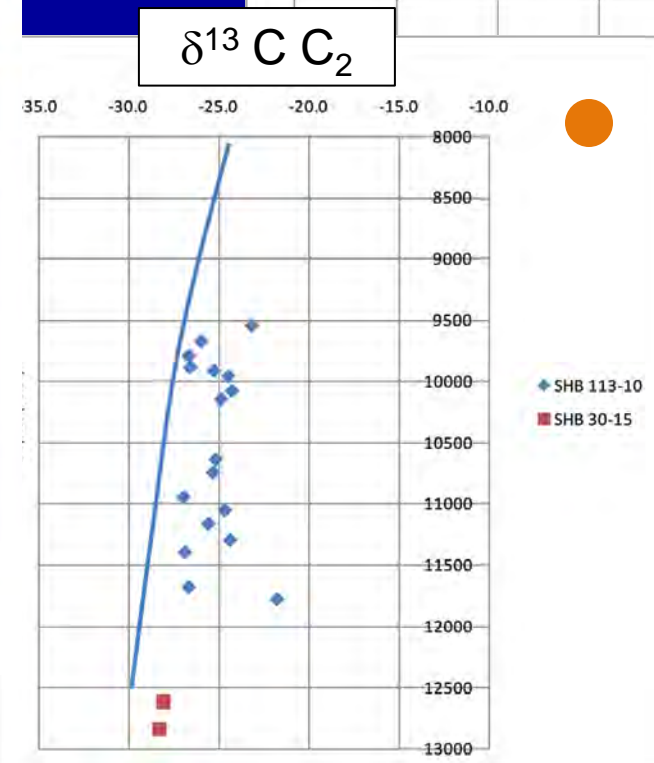
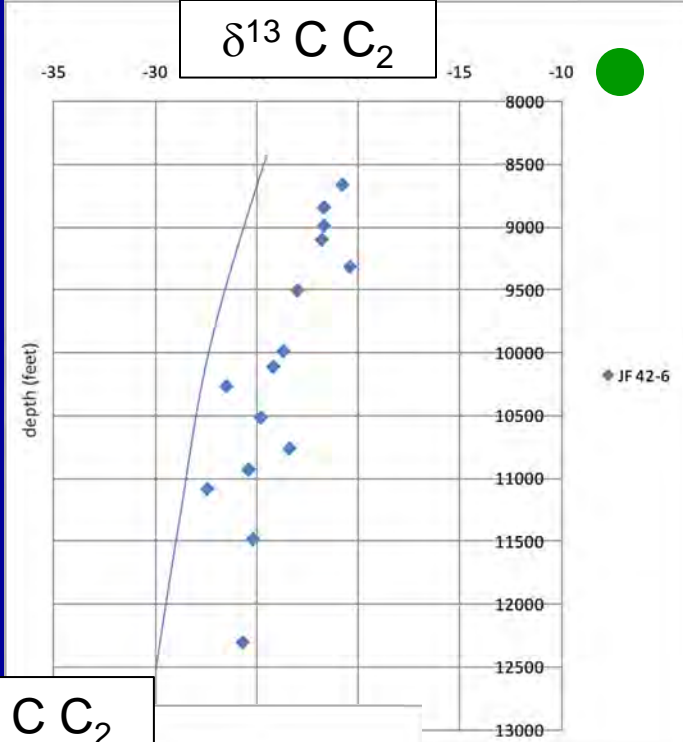
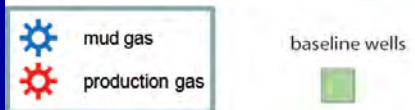
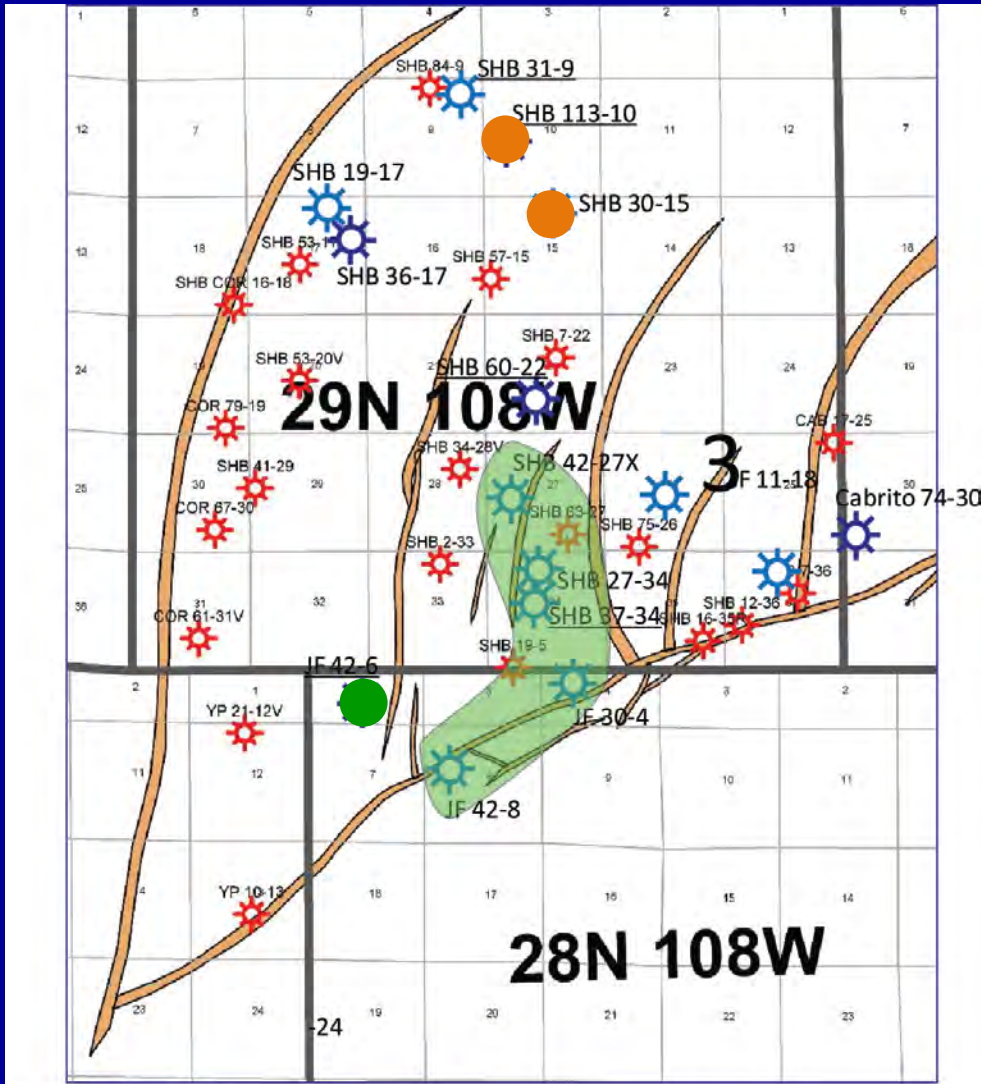
$\delta^{13}C_{C_2}$

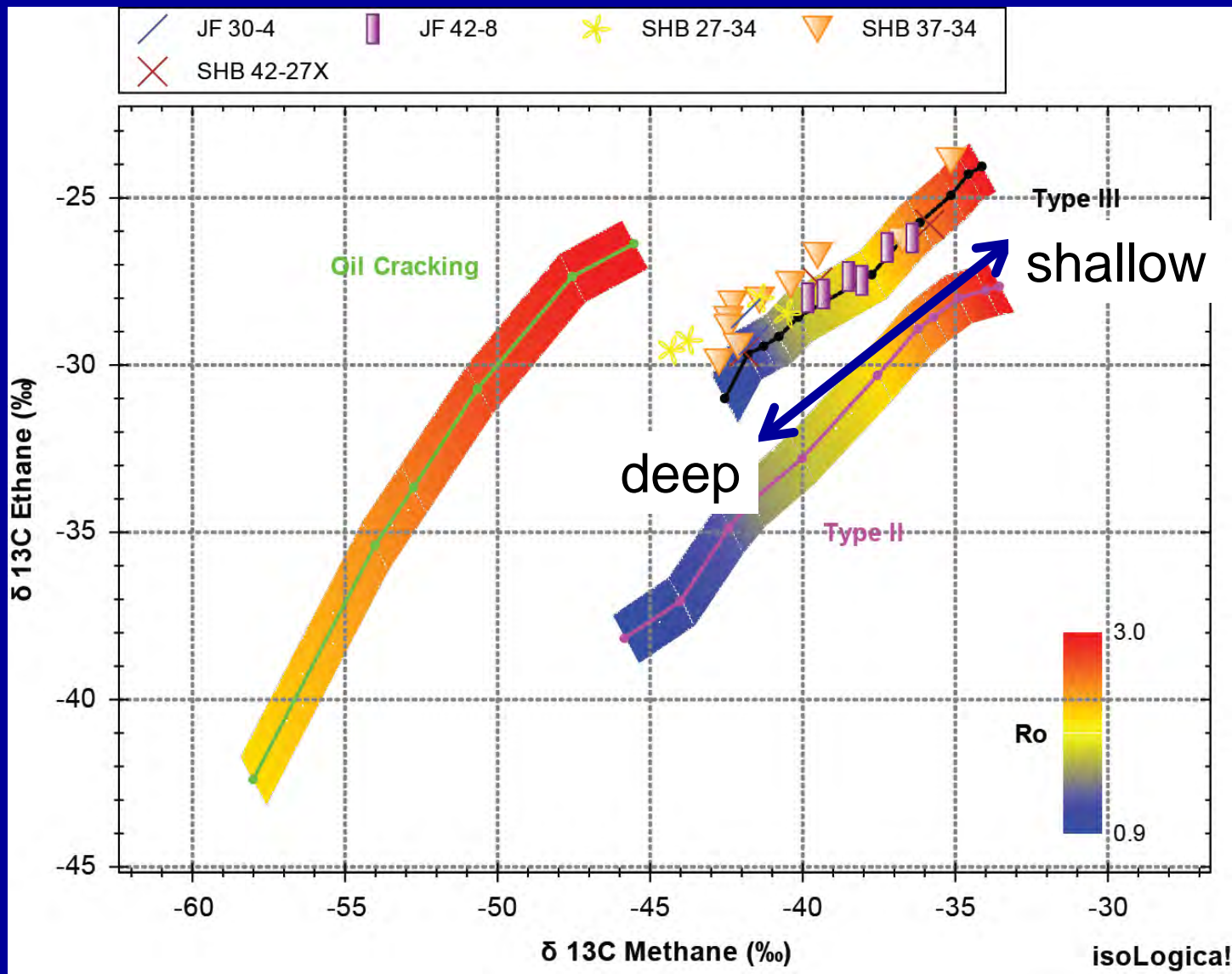
-  SHB 37-34
-  SHB 27-34
-  SHB 30-4
-  JF 42-8
-  SHB 42-27



-  mud gas
-  production gas
-  baseline wells



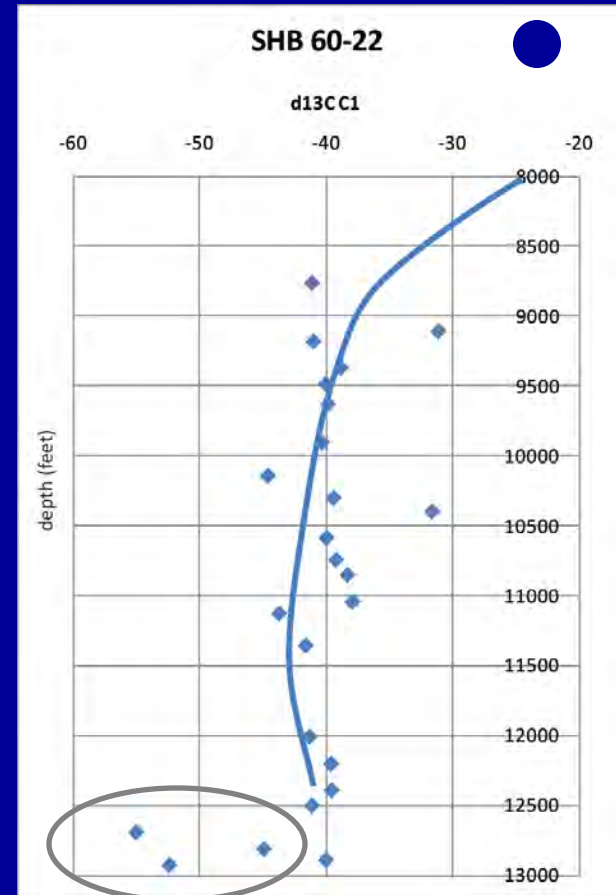
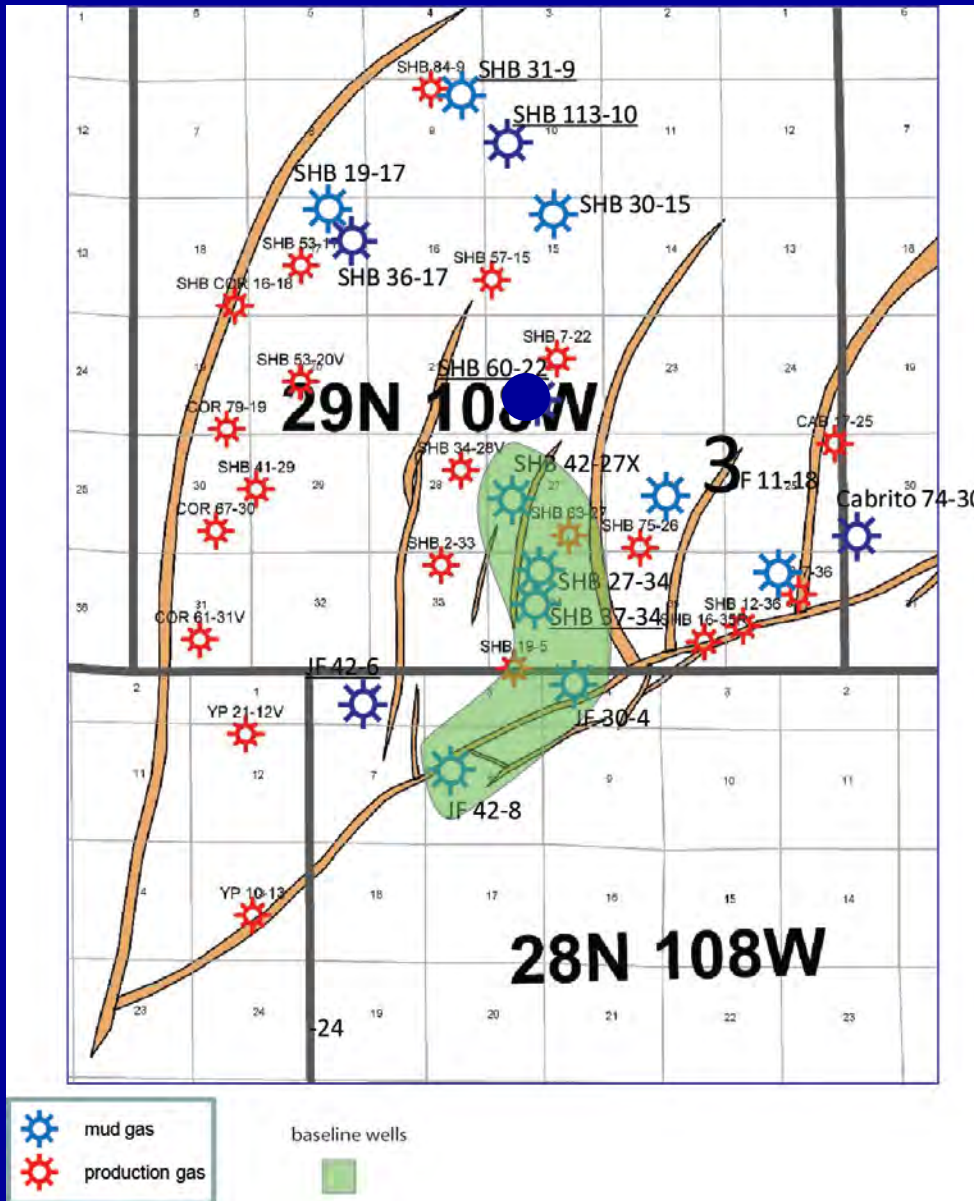






A few deep samples with very light methane

Suggest secondary cracking.





## Summary:

- Gas compositions suggest Piceance gases are derived from mixed terrestrial and marine sources, based on  $\delta^{13}\text{C}$  of ethane and propane; Jonah and Greater Natural Buttes do not have a terrestrial signature.
- Generally little indication of secondary cracking (oil to gas) except in deep Piceance and Jonah samples, based on light  $\delta^{13}\text{C}$  of methane and an increase in  $\text{C}_2/\text{C}_3$ .
- Meteoric water infiltration is significant at Jonah and in parts of Piceance system, maybe related to bleed-off of overpressure.
- Complexity for the Piceance system suggested in hydrocarbon and noble gases.



## Acknowledgements:

RPSEA (Research Partnership to Secure Energy for America)

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Fluid Inclusion Technologies and Permedia for in-kind contributions

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Field assistants: TingWei Ko, Sheven Poole, Mike Halsema and Jaron Lucero