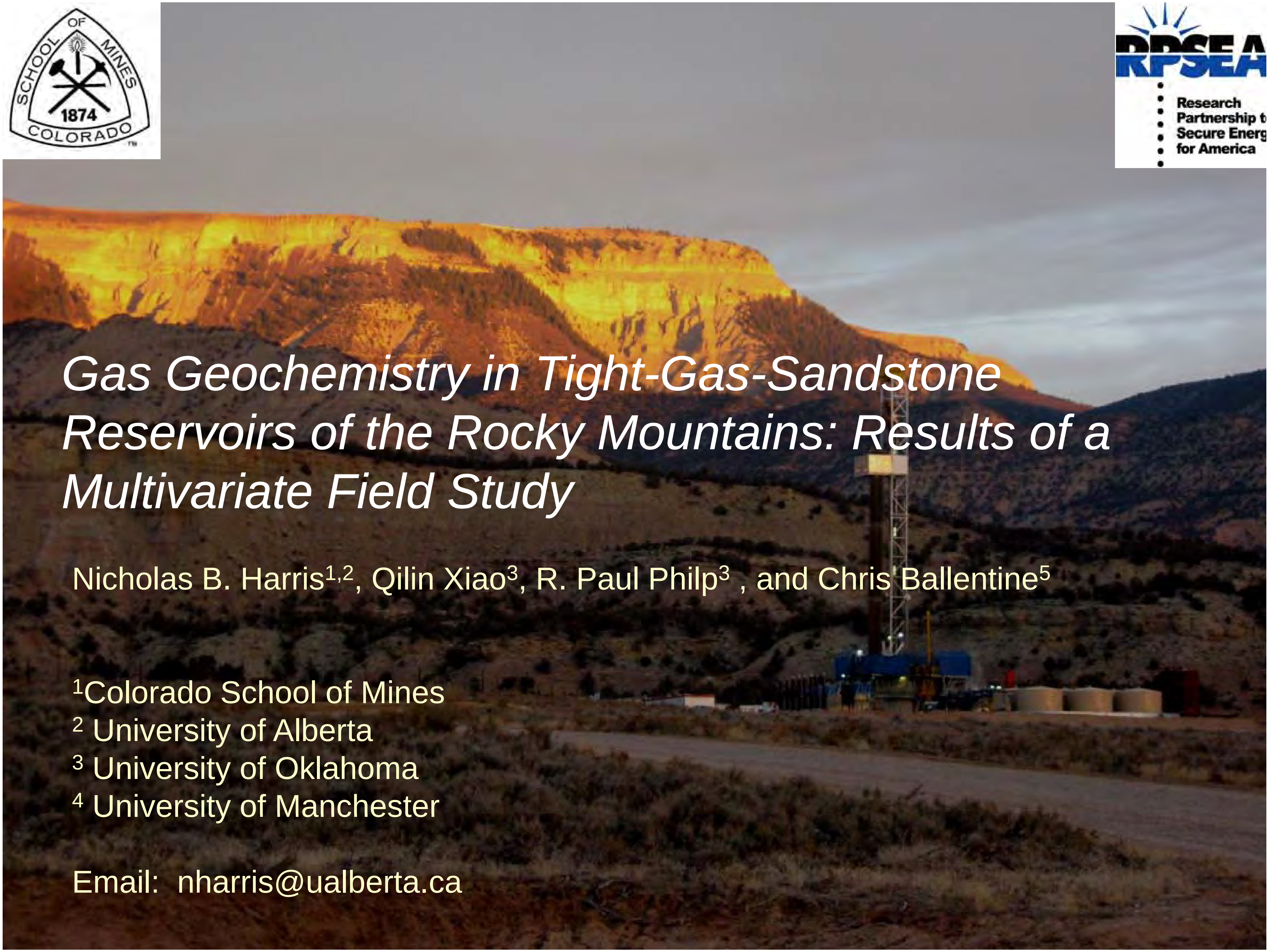

Gas Geochemistry in Tight-Gas-Sandstone Reservoirs of the Rocky Mountains: Results of a Multivariate Field Study

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[2] University of Alberta
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[4] University of Manchester

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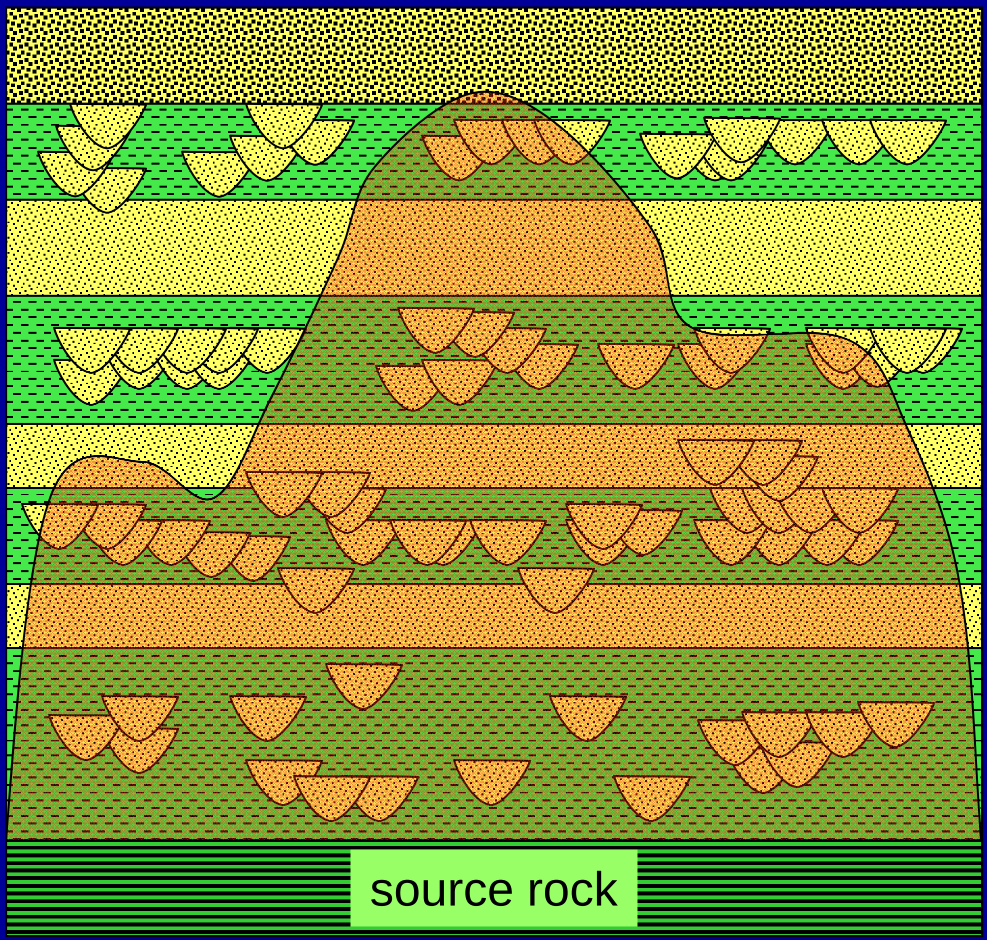
Tight gas-sand reservoirs



These reservoirs differ from conventional reservoir:

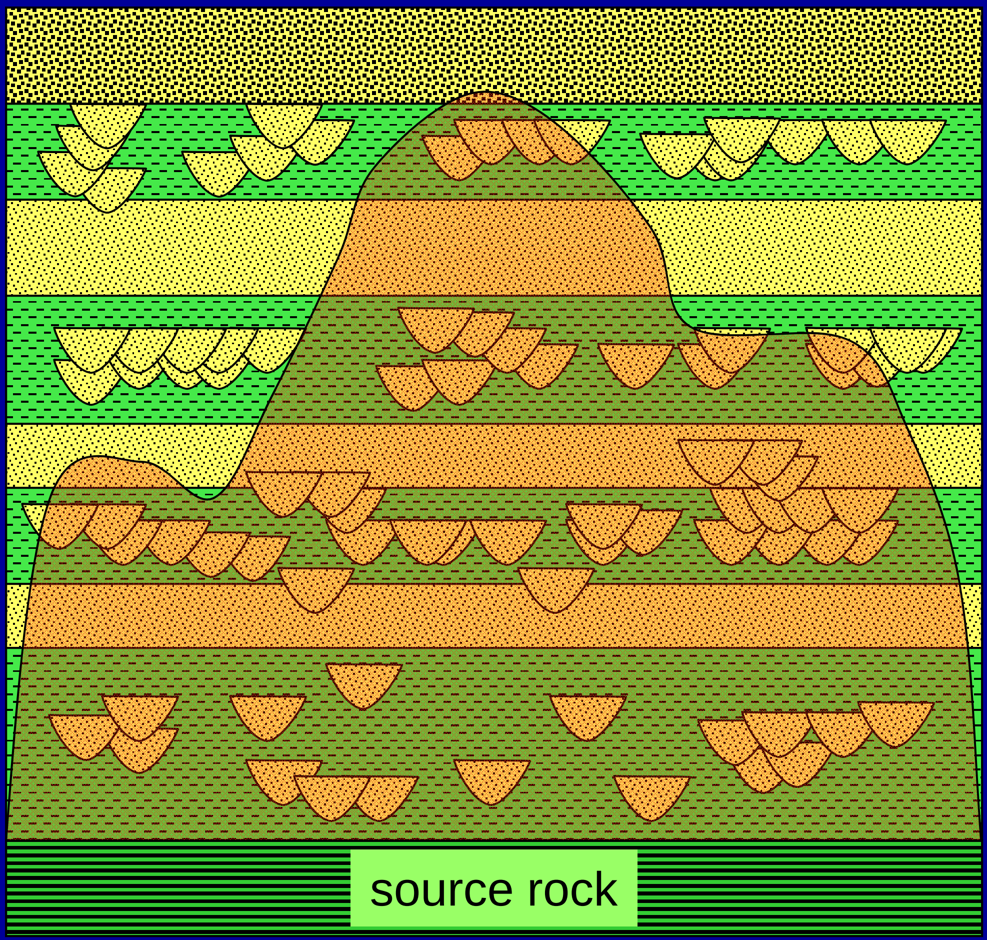
No clearly defined top-seal for these gas reservoirs; instead:

1) a top-of-gas that varies stratigraphically within a field and between nearby fields:

2) a fuzzy transition to unproduceable gas.

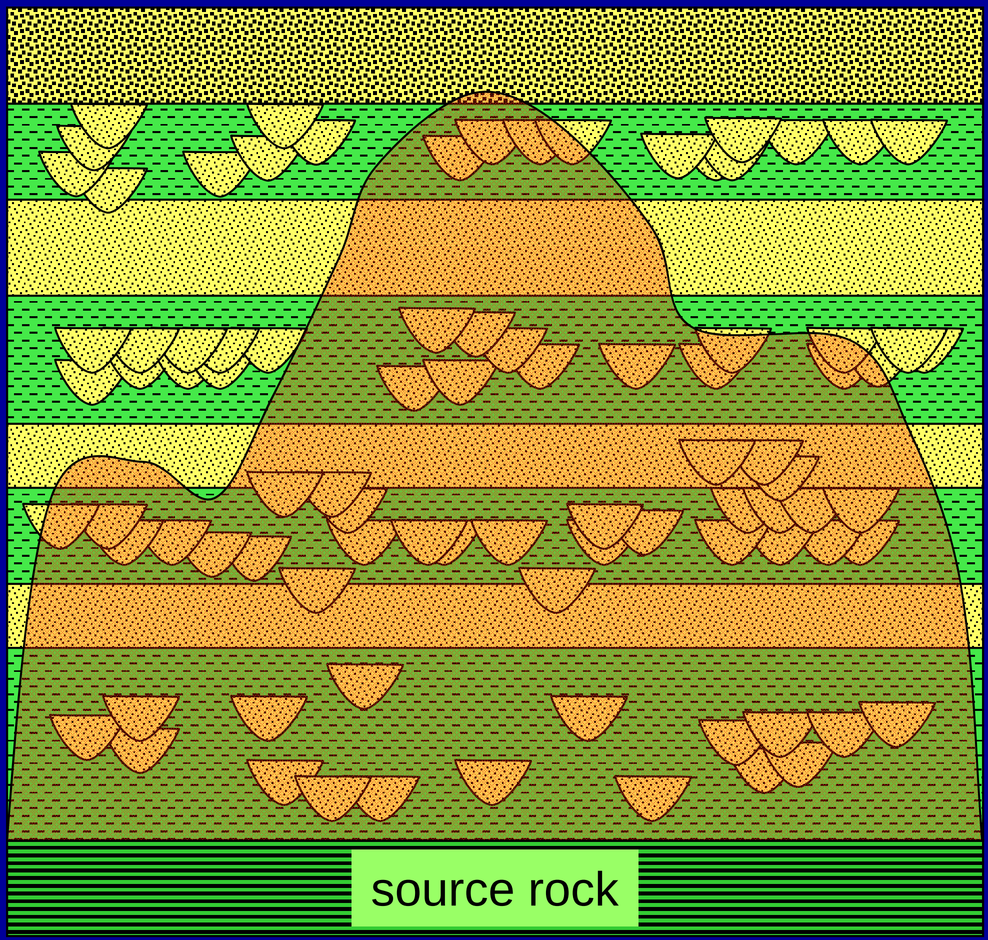
3) may be overpressured or underpressured

So how does gas migrate through and fill these reservoirs?



Is gas trapped, or are we seeing a dynamic system?

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.

Hypothesis –

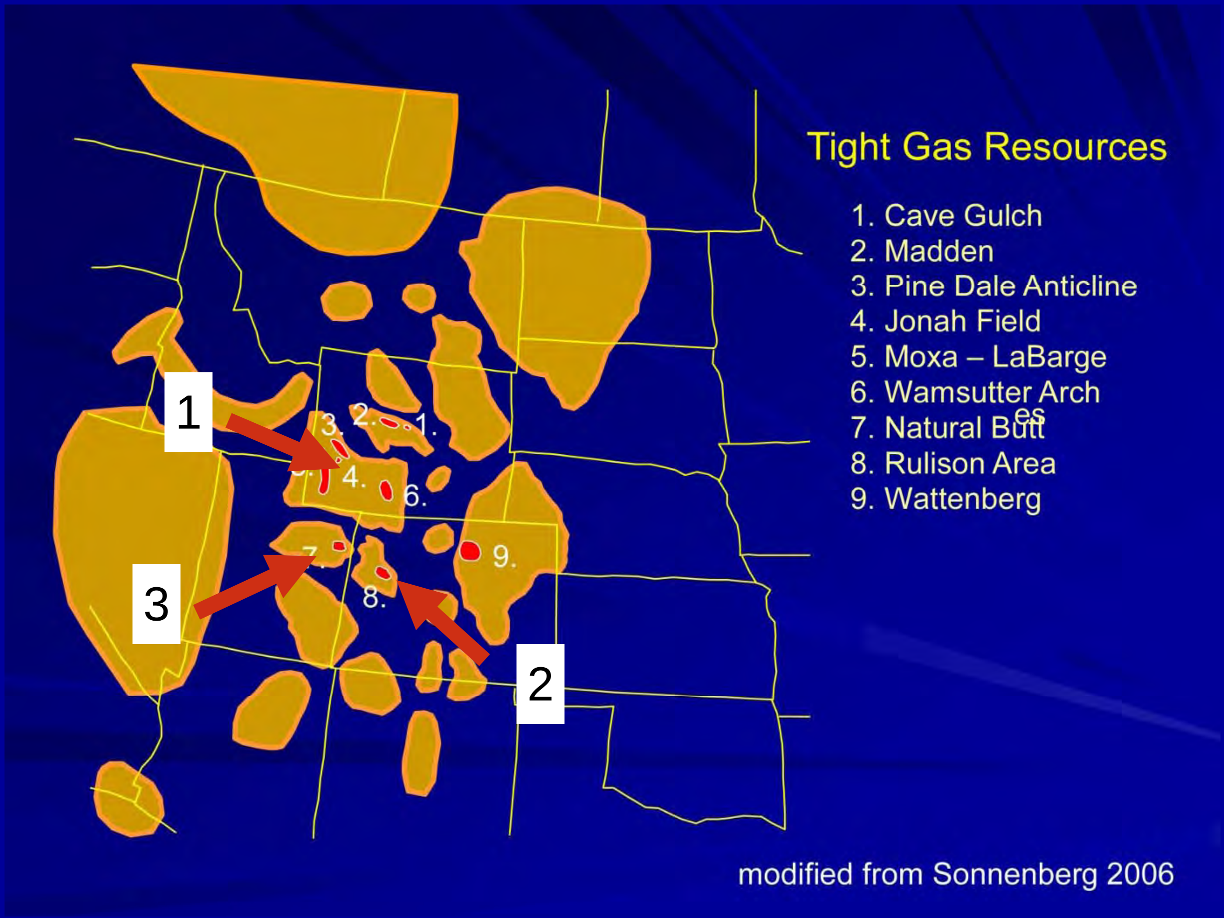
The three different mechanisms should leave different signatures in the gas composition.

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



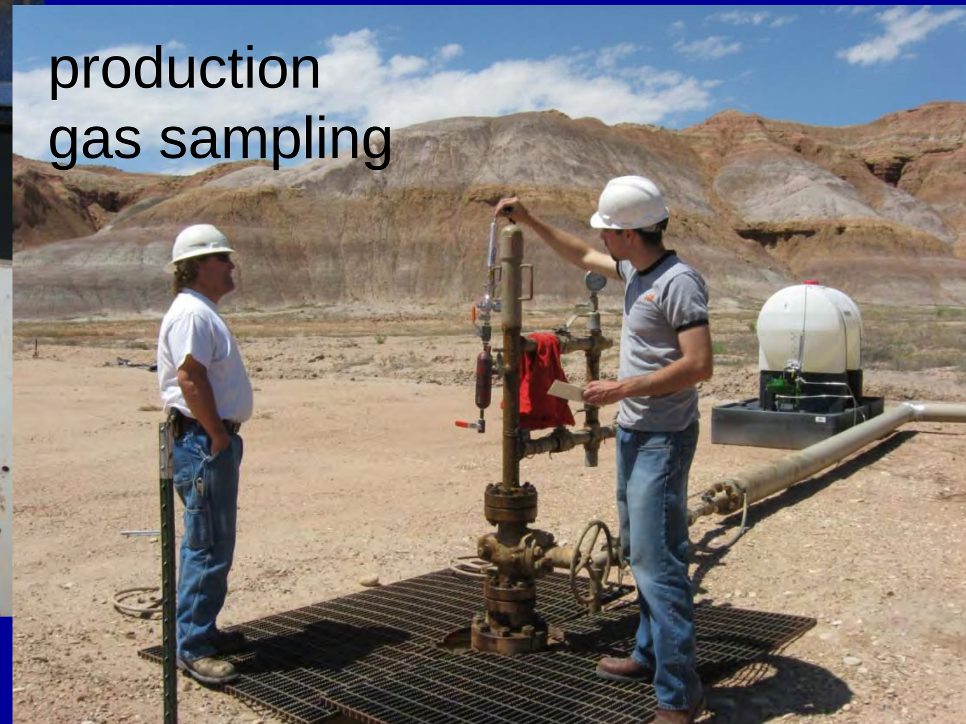
Fields in the study:

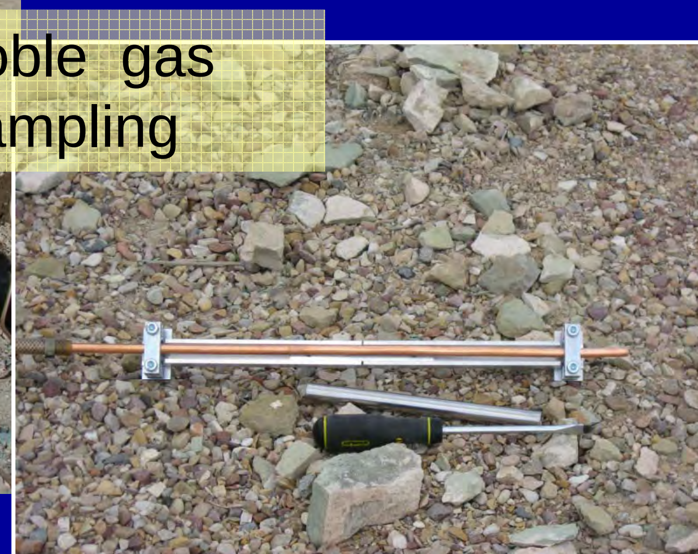
1) Jonah Field

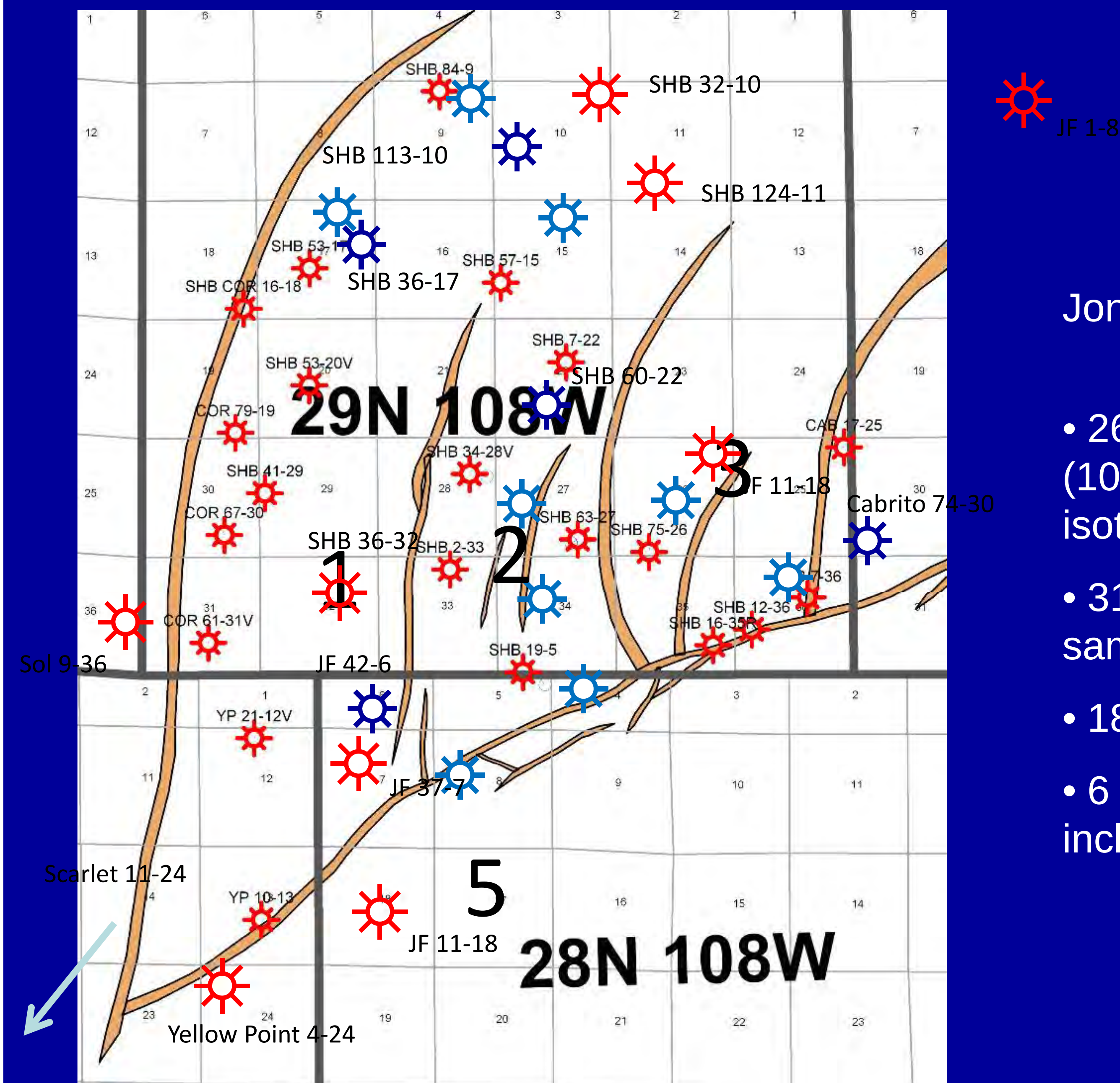
2) Piceance: Mamm Creek – Rulison – Parachute – Grand Valley

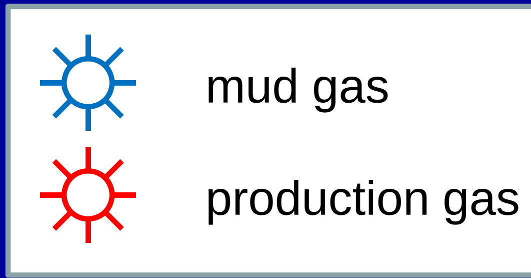
3) Greater Natural Buttes


mud gas
sampling


production
gas sampling

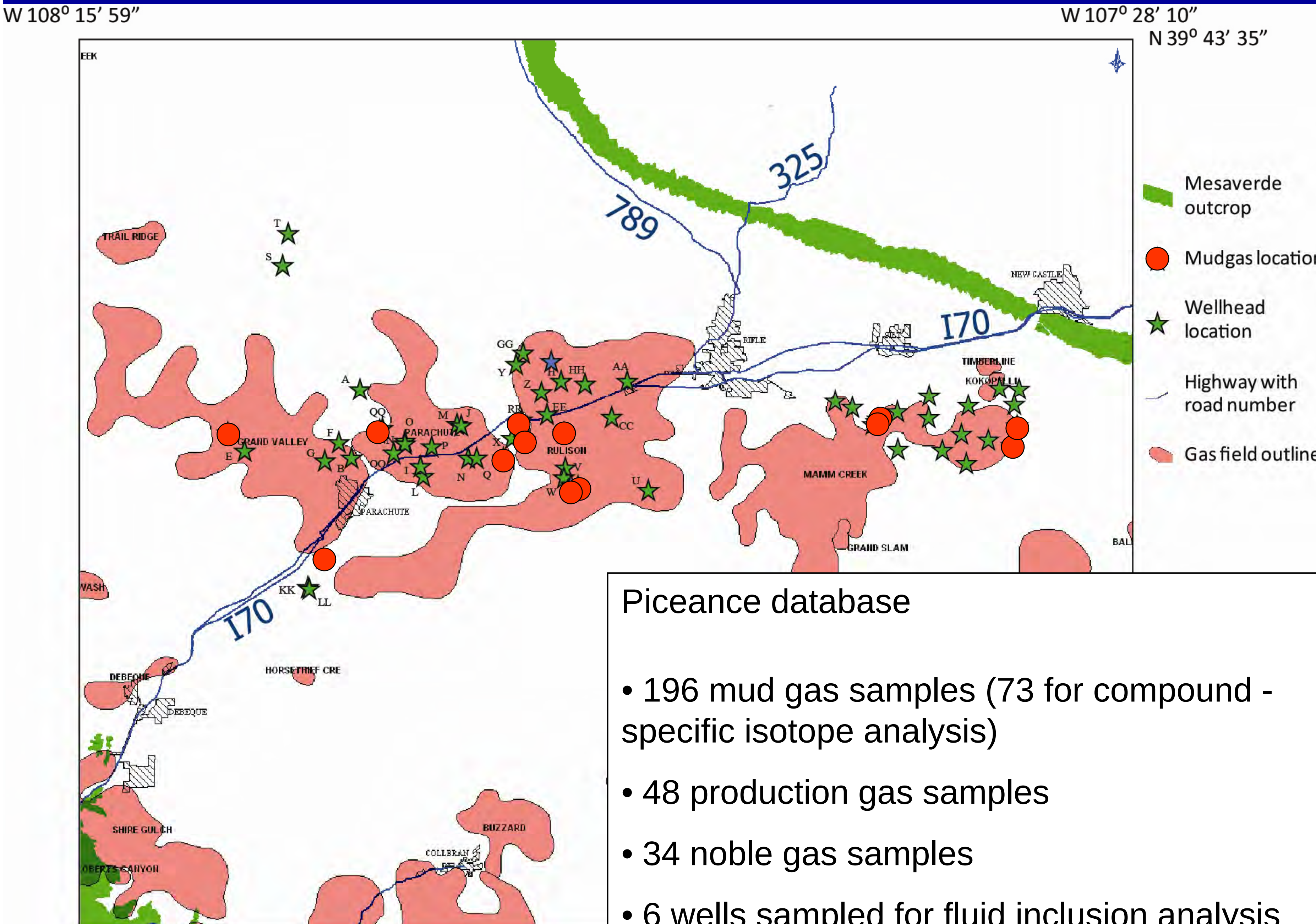

noble gas
sampling





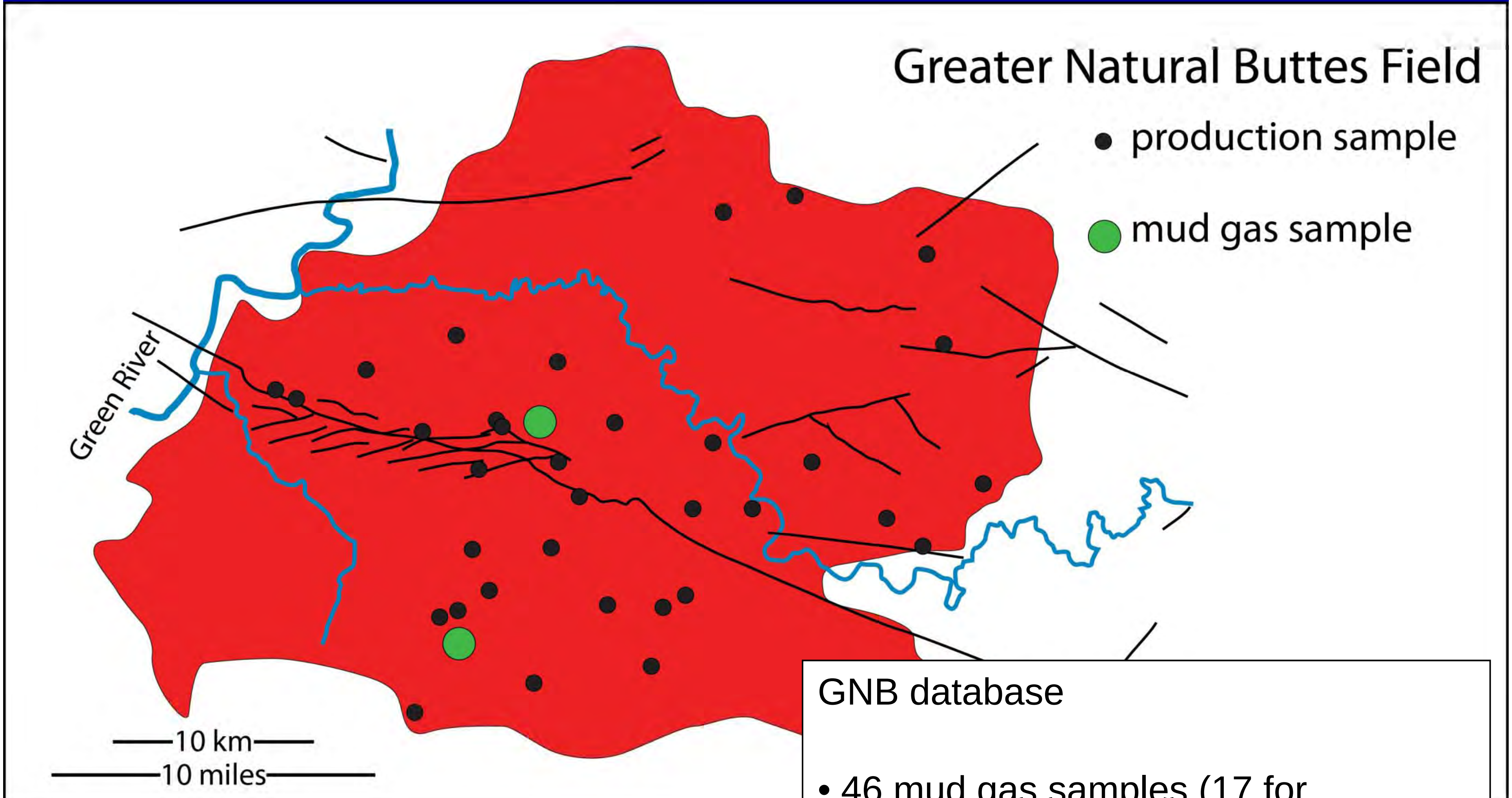
Jonah Field database

- 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



Piceance database

- 196 mud gas samples (73 for compound - specific isotope analysis)
- 48 production gas samples
- 34 noble gas samples
- 6 wells sampled for fluid inclusion analysis

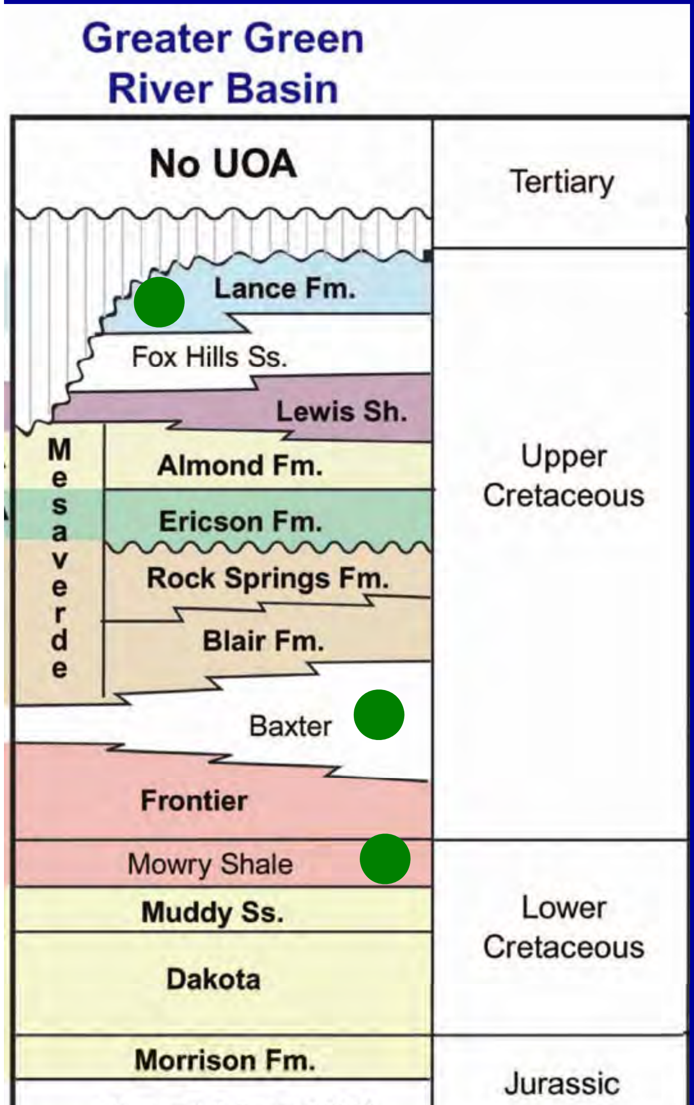


GNB database

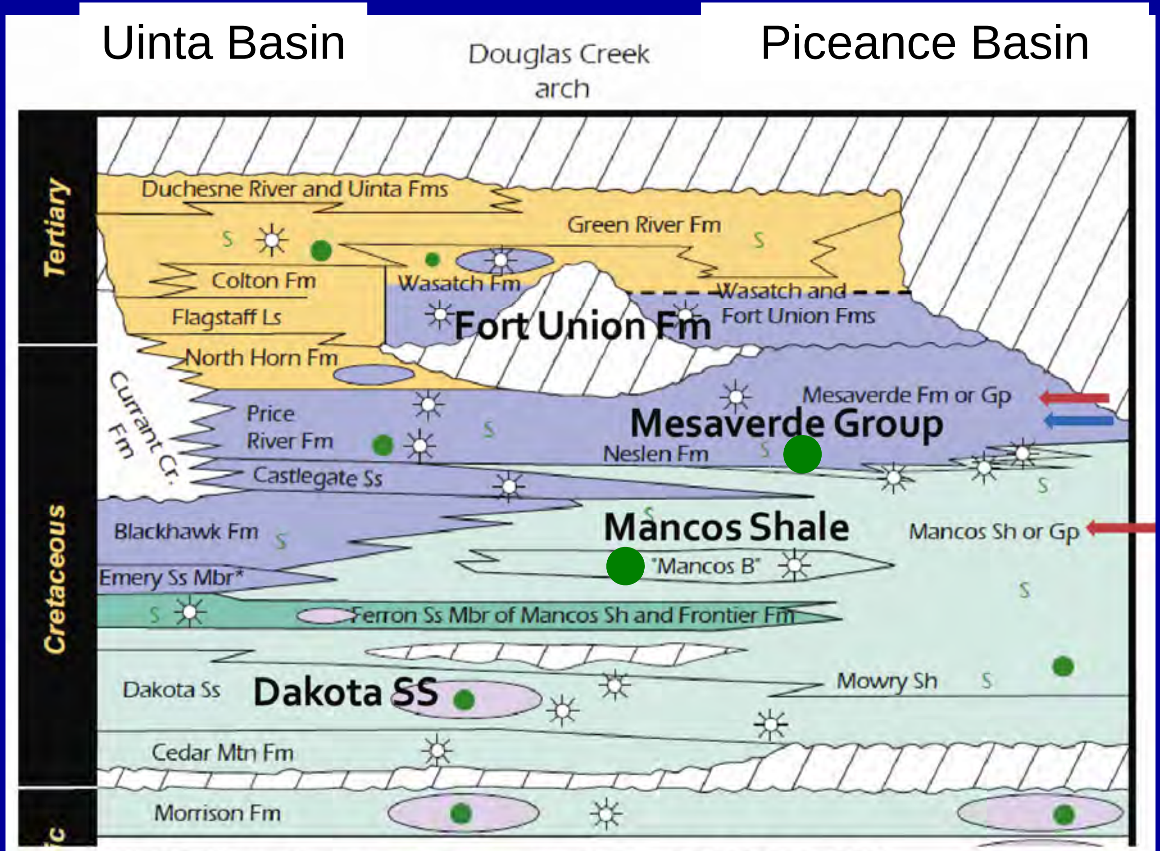
- 46 mud gas samples (17 for compound-specific isotope analysis)
- 34 production gas samples
- 16 noble gas samples

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

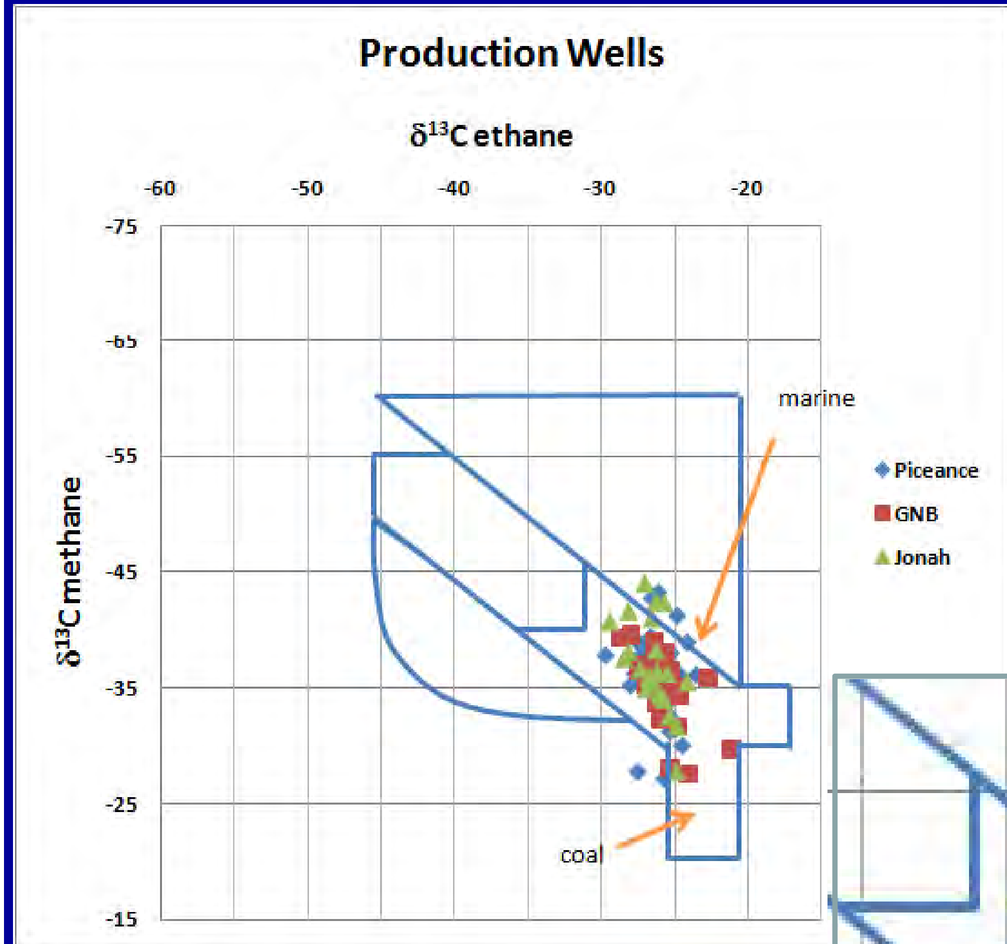
- Type II (Mowry), Type III (Cameo Coal, Lance) or mixed Type II-III (Mancos, Baxter)



(Boswell & Rose, 2008)



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



1) Gas compositions are identical.

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

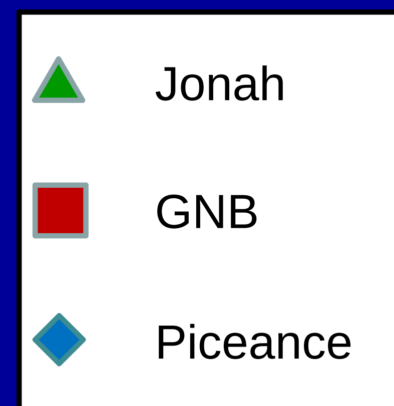
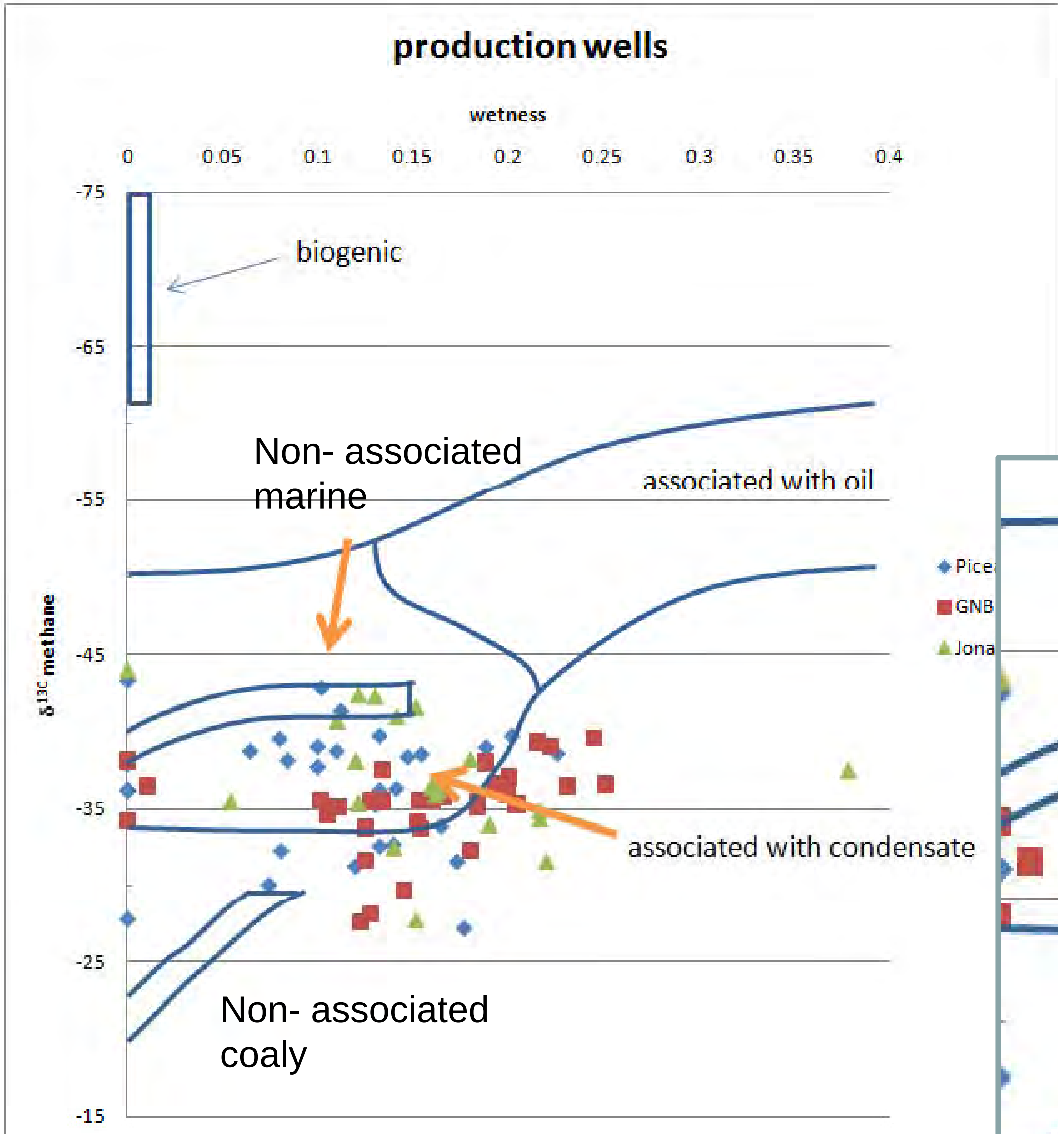
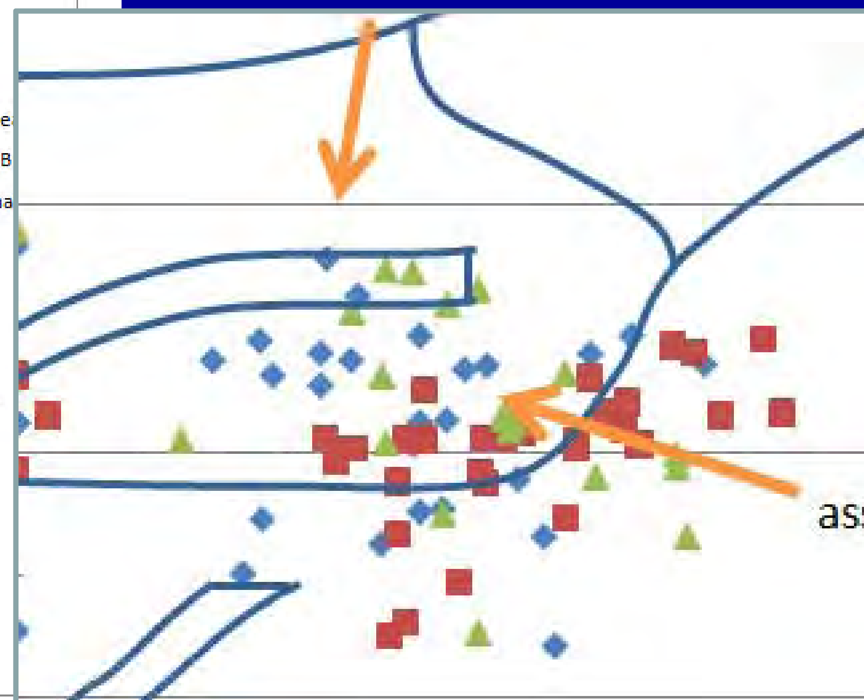


Diagram after Schoell, 1983

1. Piceance gases slightly drier, $\delta^{13}C$ very slightly more negative.

2. No indication of more gas from coals in the Piceance data



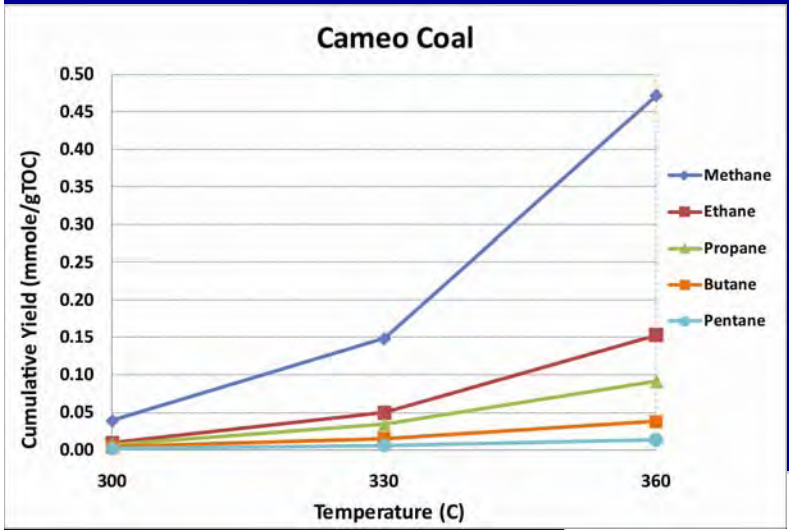


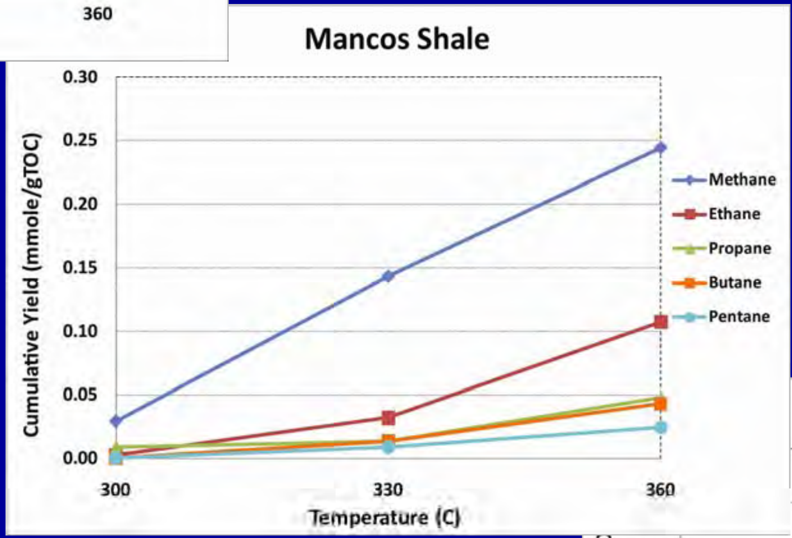
Jonah GNB Piceance

Diagram after Schoell, 1983

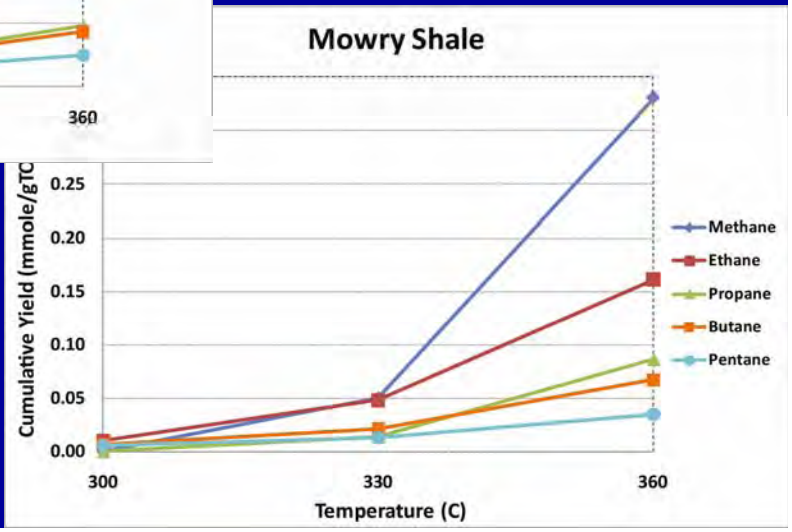
Hydrous Pyrolysis Experiments

At high maturity (~1.63% Rio), bulk hydrocarbon compositions from different source rocks are very similar



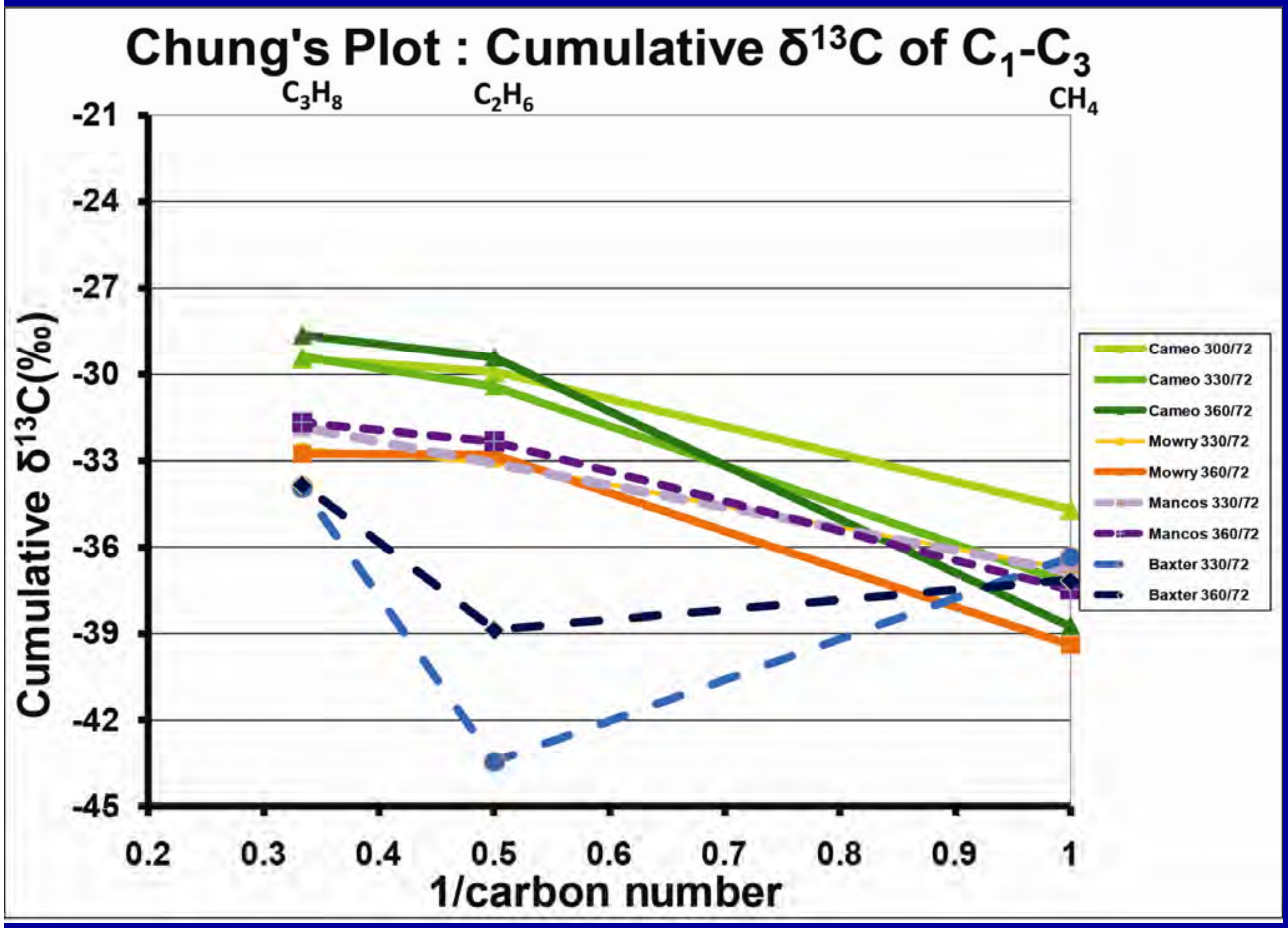


Ko, 2010

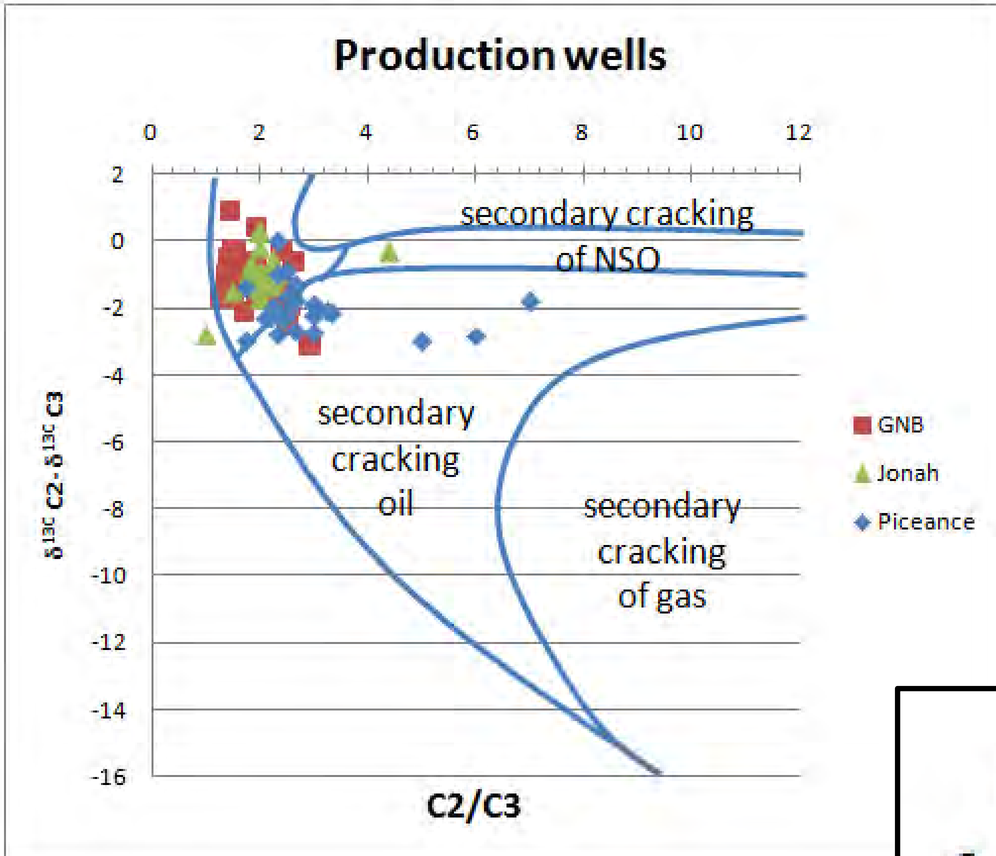


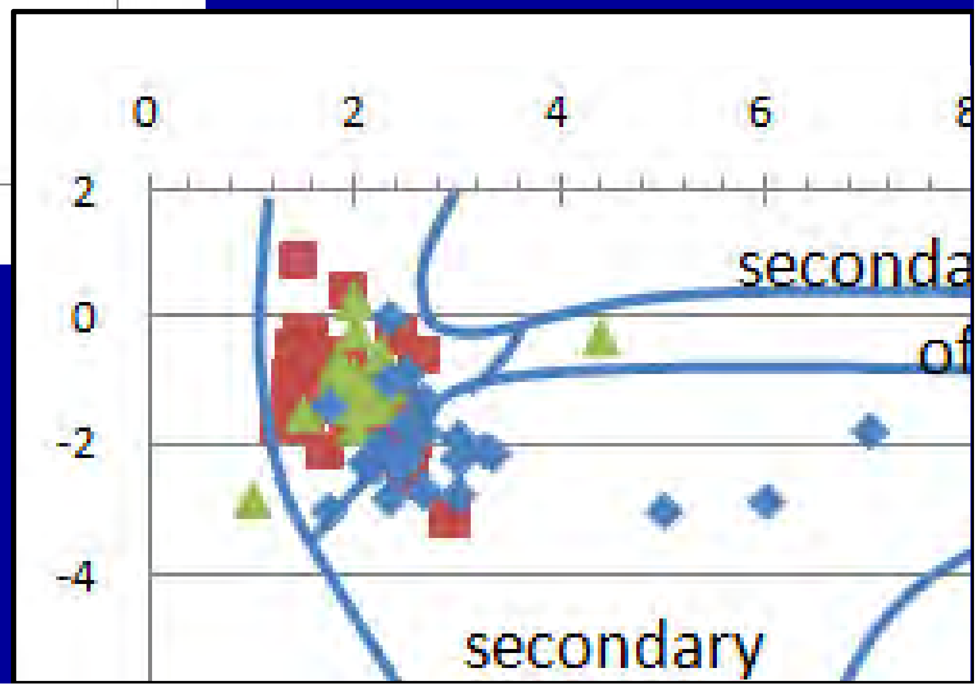
Hydrous Pyrolysis Experiments

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



Ko, 2010

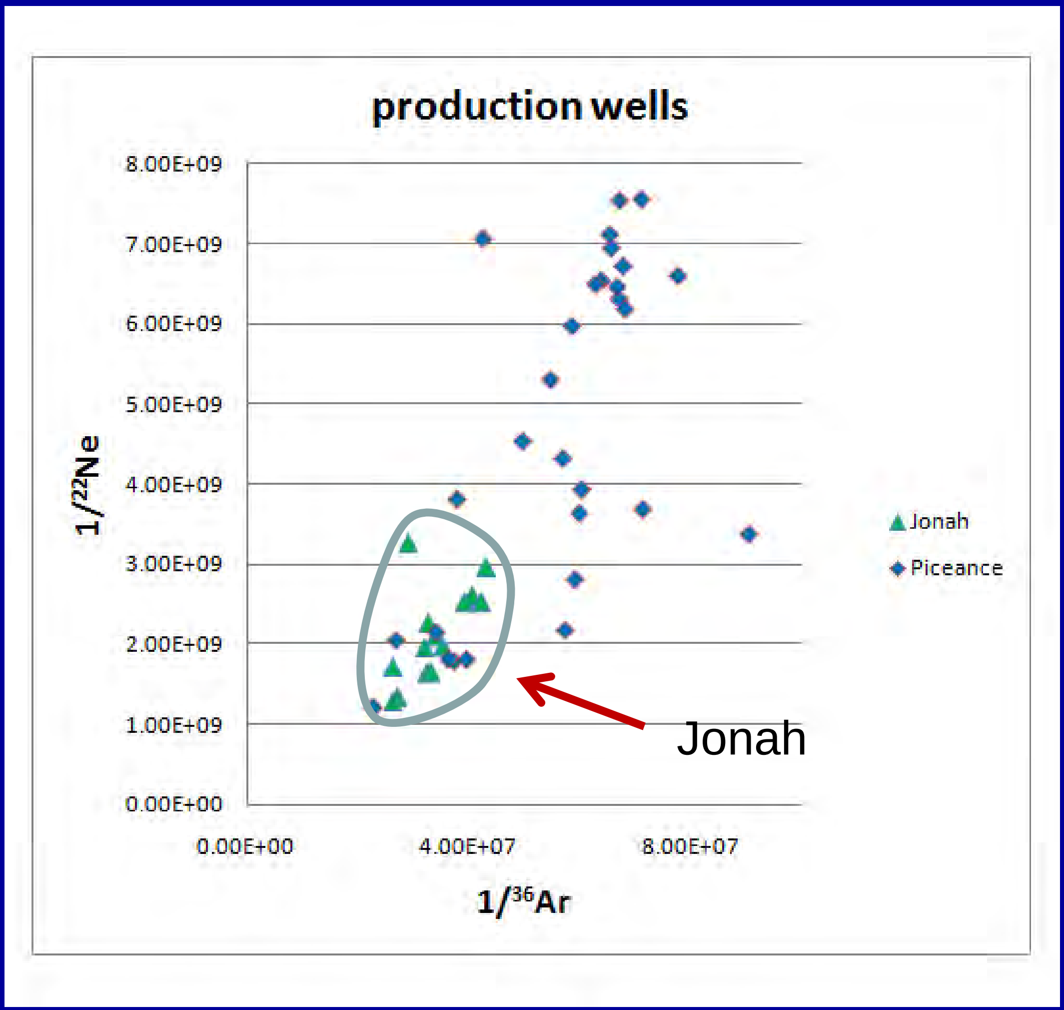




Piceance gases exhibit slightly higher C2/C3, larger $\Delta\delta^{13}C$ C2/C3

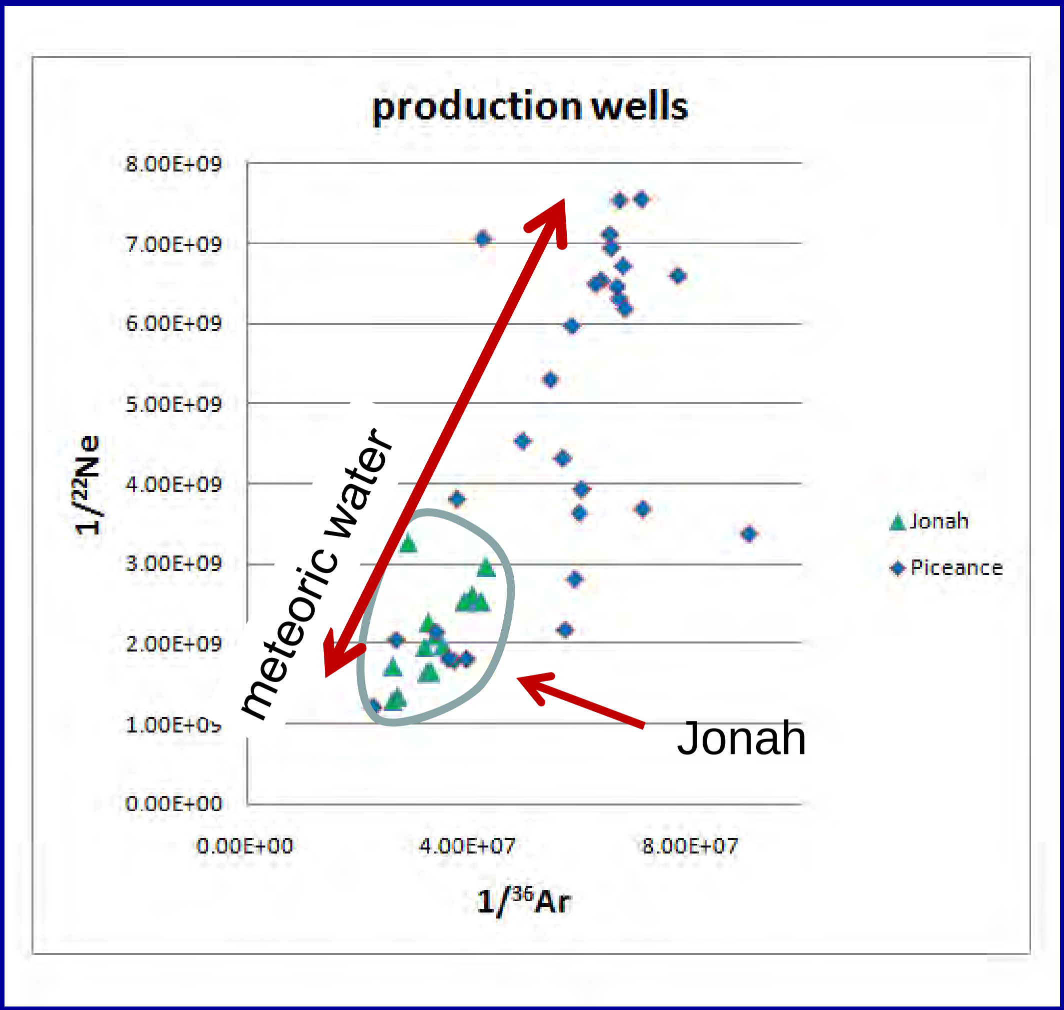
Suggests more secondary cracking of oil to gas in Piceance fields

Diagram after Lorant et al., 1998



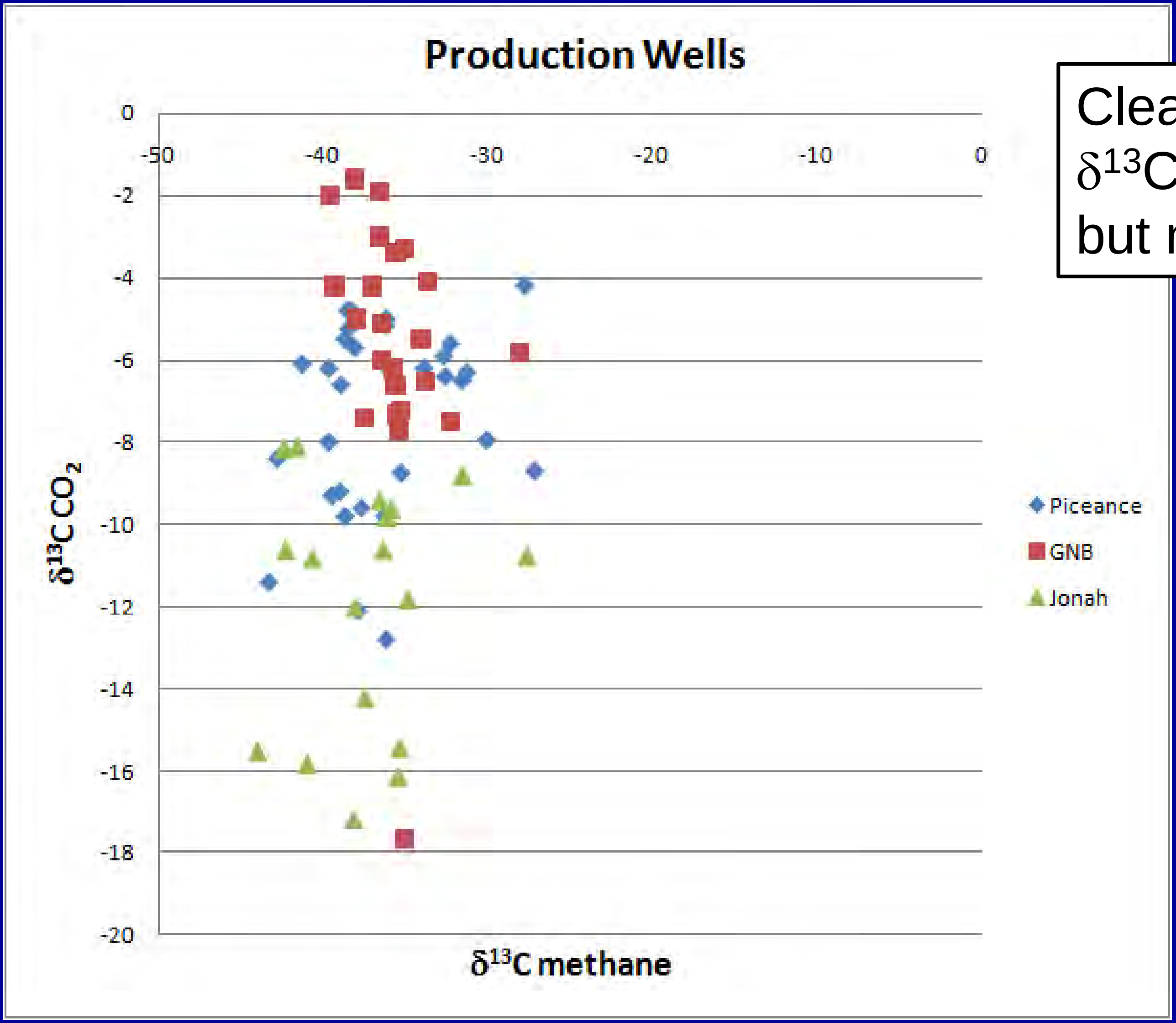
Noble gases are non-reactive, non-hydrocarbon gases

Can indicate contributions from volcanic or meteoric water sources

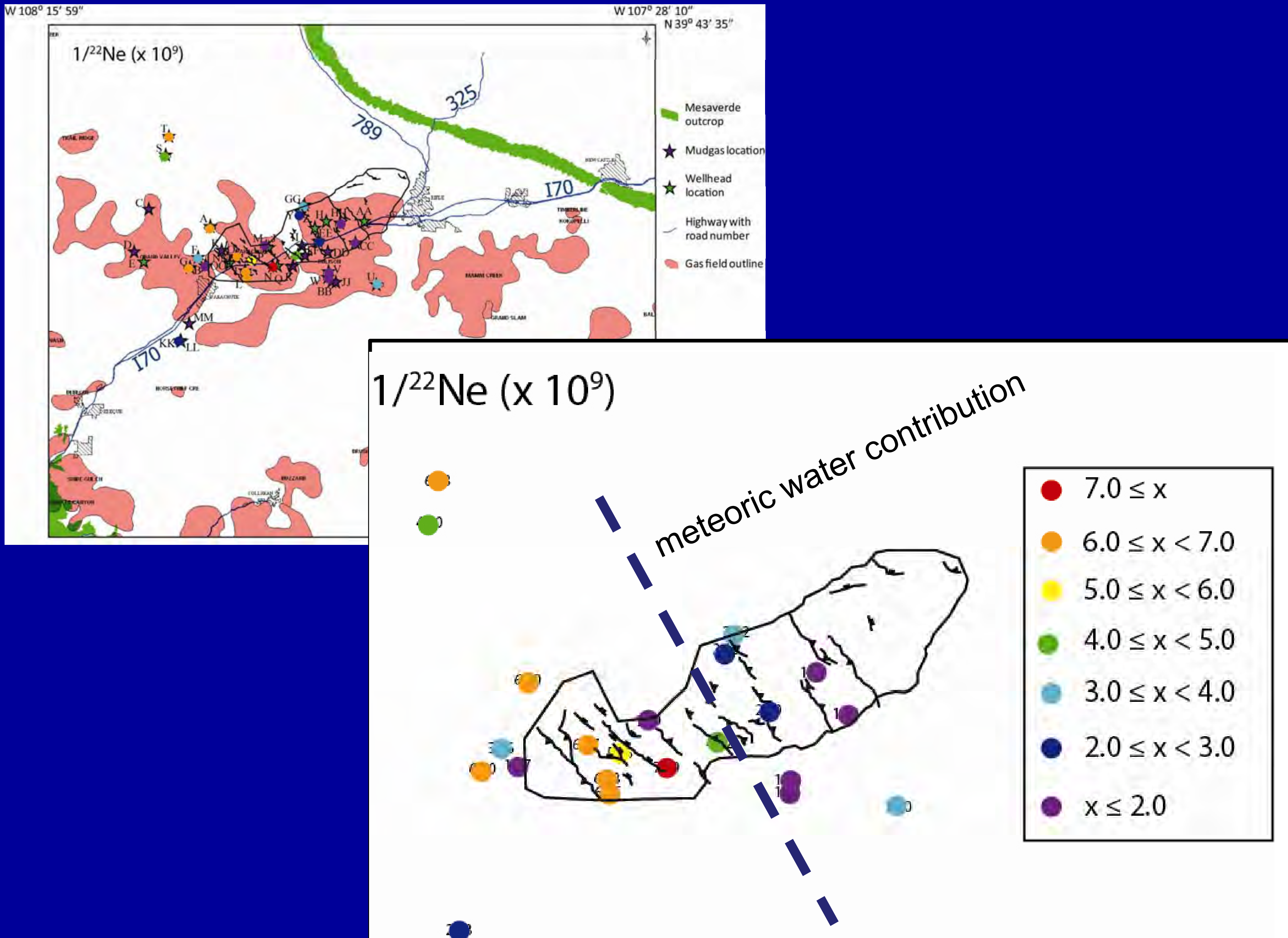


All Jonah gases show meteoric water contribution

Piceance gases show varying meteoric water contributions

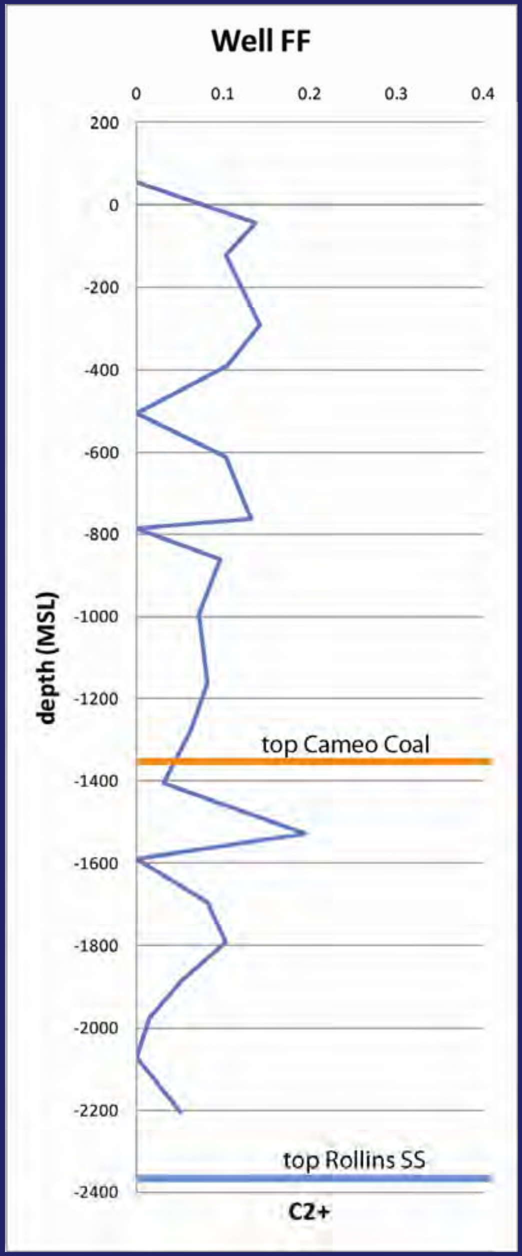


Clear differences in $\delta^{13}C$ CO_2 between fields but not in $\delta^{13}C$ methane

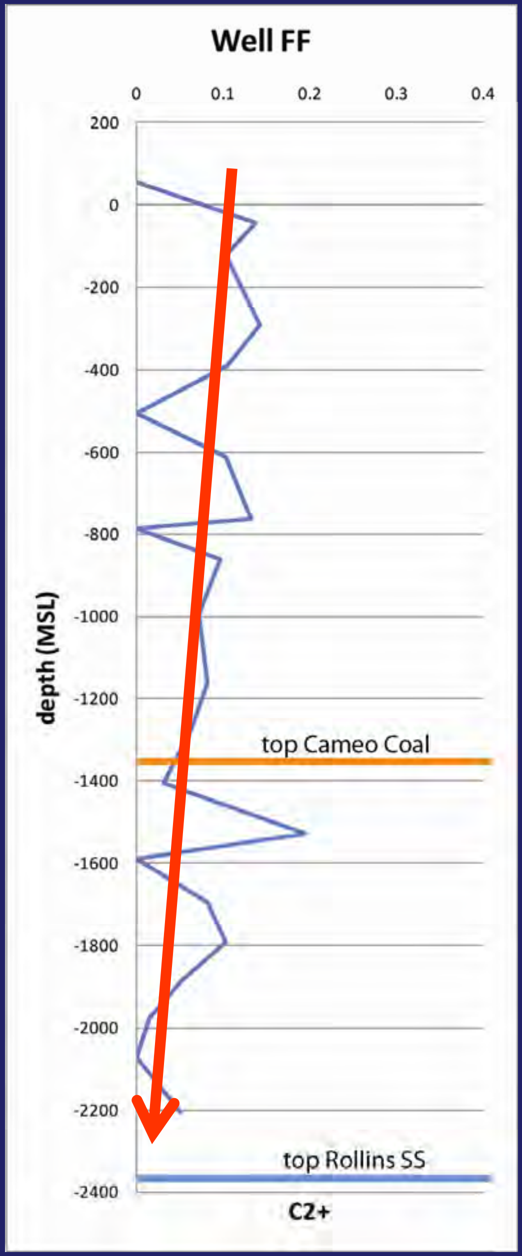


W 108° 15′ 59″
W 107° 28′ 10″
N 39° 43′ 35″
1/22Ne (x 10^9)
325
789
I70
Mesaverde outcrop
Mudgas location
Wellhead location
Highway with road number
Gas field outline
1/22Ne (x 10^9)
meteoric water contribution
7.0 ≤ x
6.0 ≤ x < 7.0
5.0 ≤ x < 6.0
4.0 ≤ x < 5.0
3.0 ≤ x < 4.0
2.0 ≤ x < 3.0
x ≤ 2.0

Piceance Basin mud gas

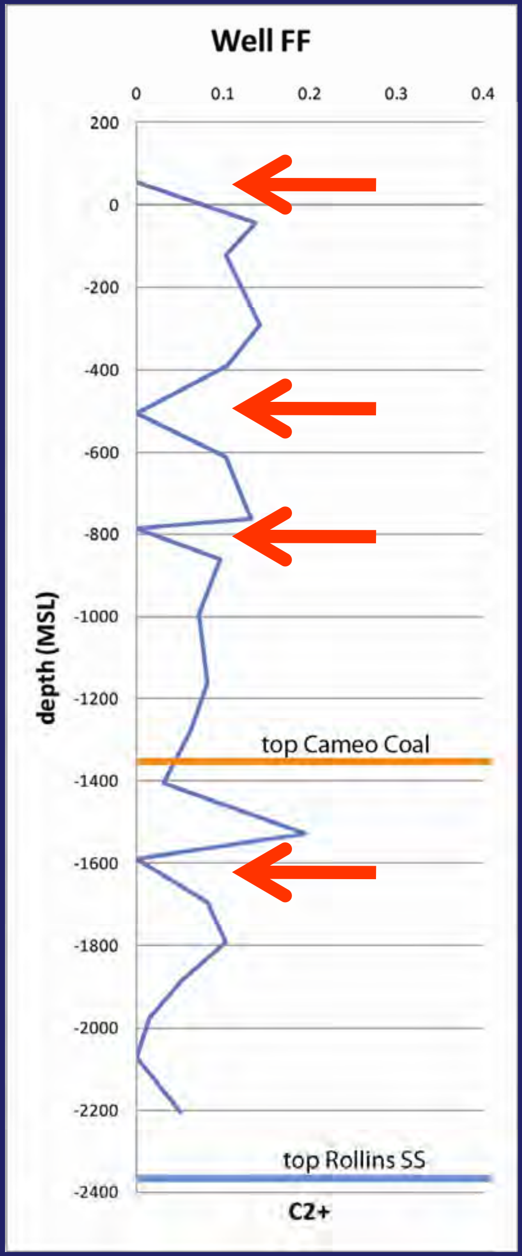


Piceance Basin samples

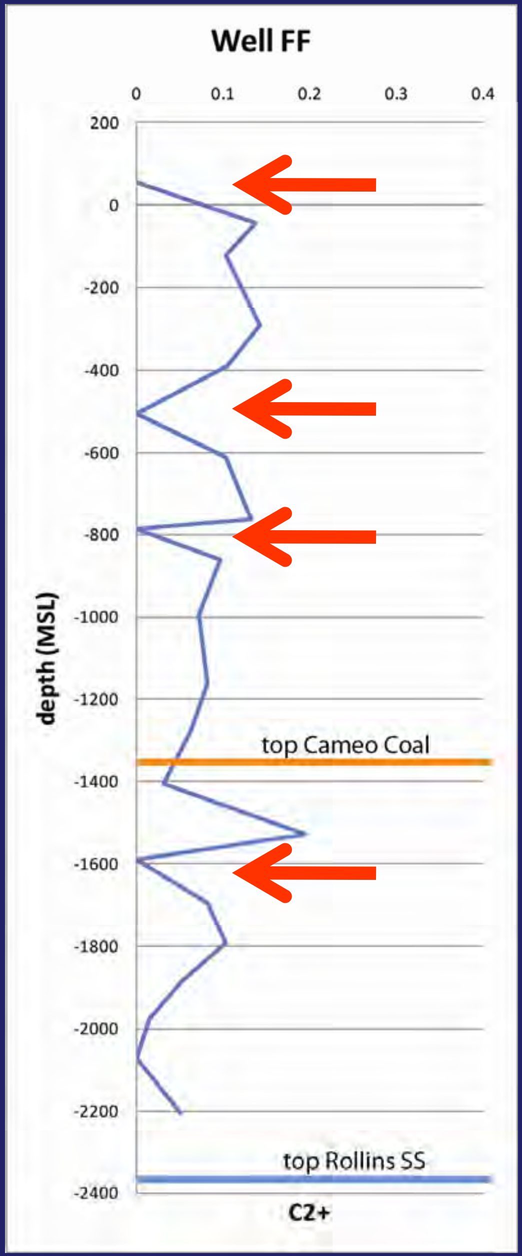


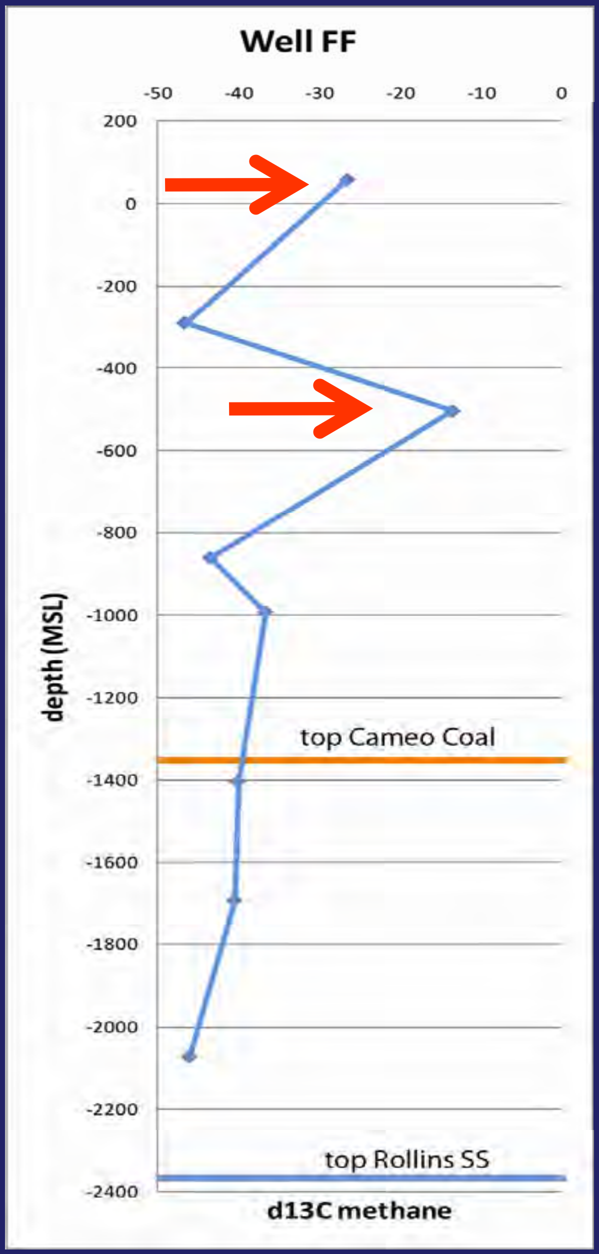
- Gases become drier with depth.
- No clear change in gas compositions associated with Cameo Coal.

Piceance Basin samples

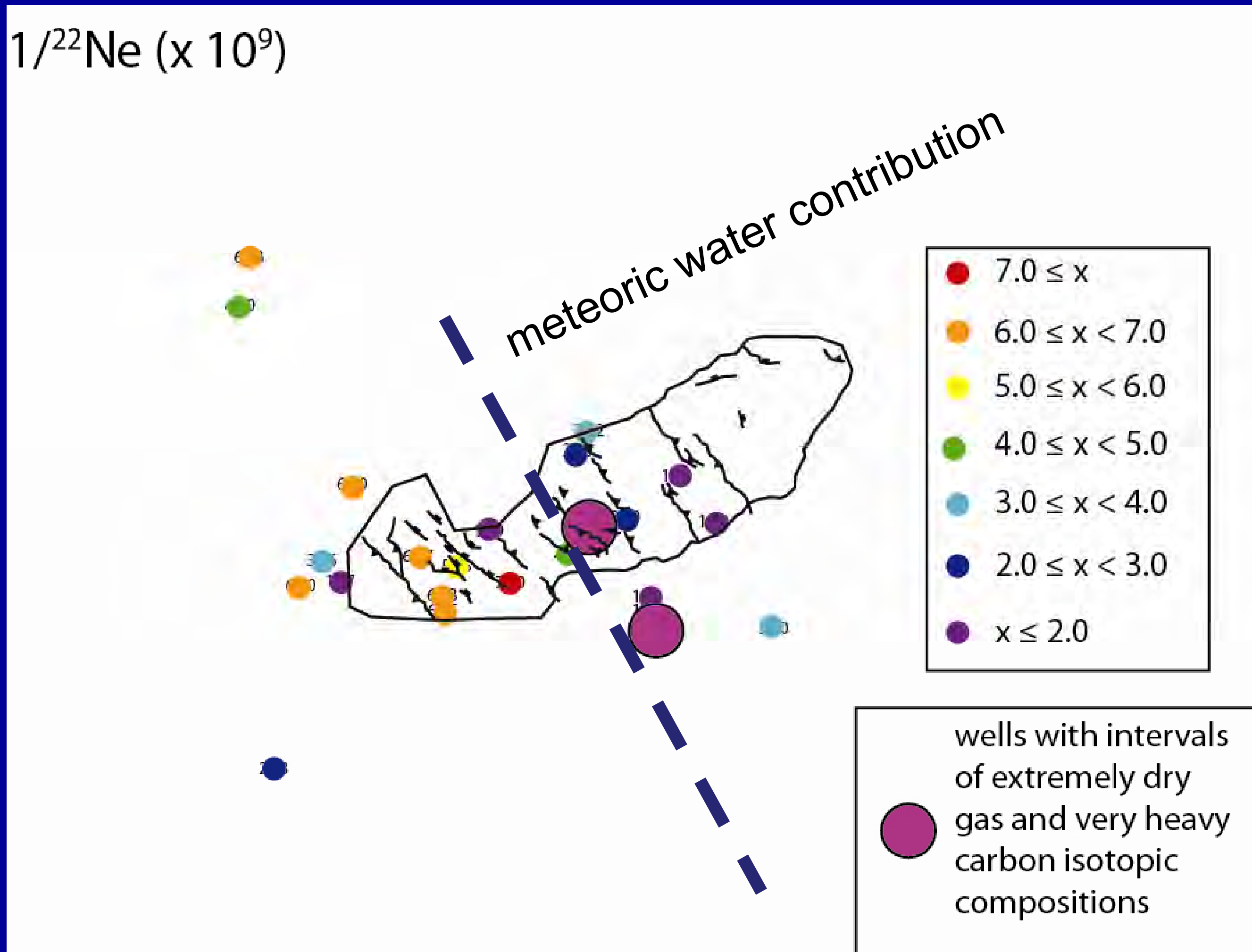


- A few samples of pure methane.



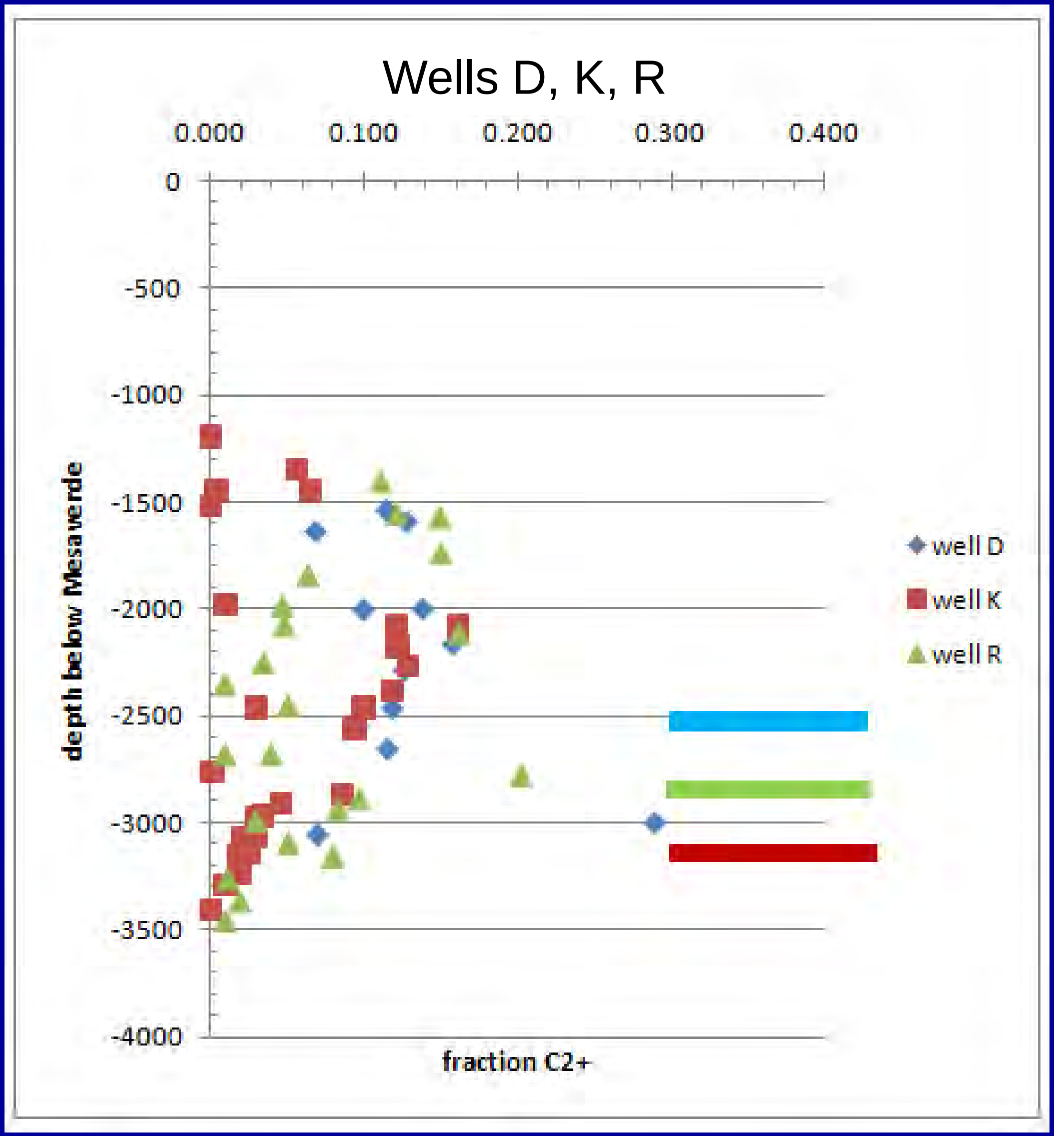


- Very pure methane samples have ‘heavy’ carbon isotopes
- Evidence for microbial alteration of gases – selective destruction of wetter gases and of the lighter carbon in methane



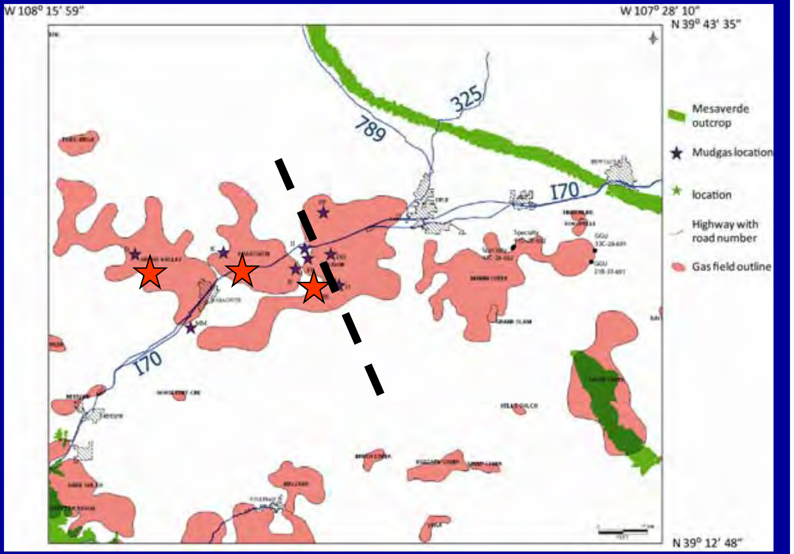
1/22Ne (x 10^9)
meteoric water contribution
7.0 ≤ x
6.0 ≤ x < 7.0
5.0 ≤ x < 6.0
4.0 ≤ x < 5.0
3.0 ≤ x < 4.0
2.0 ≤ x < 3.0
x ≤ 2.0
wells with intervals of extremely dry gas and very heavy carbon isotopic compositions

western wells / mud gas sampling

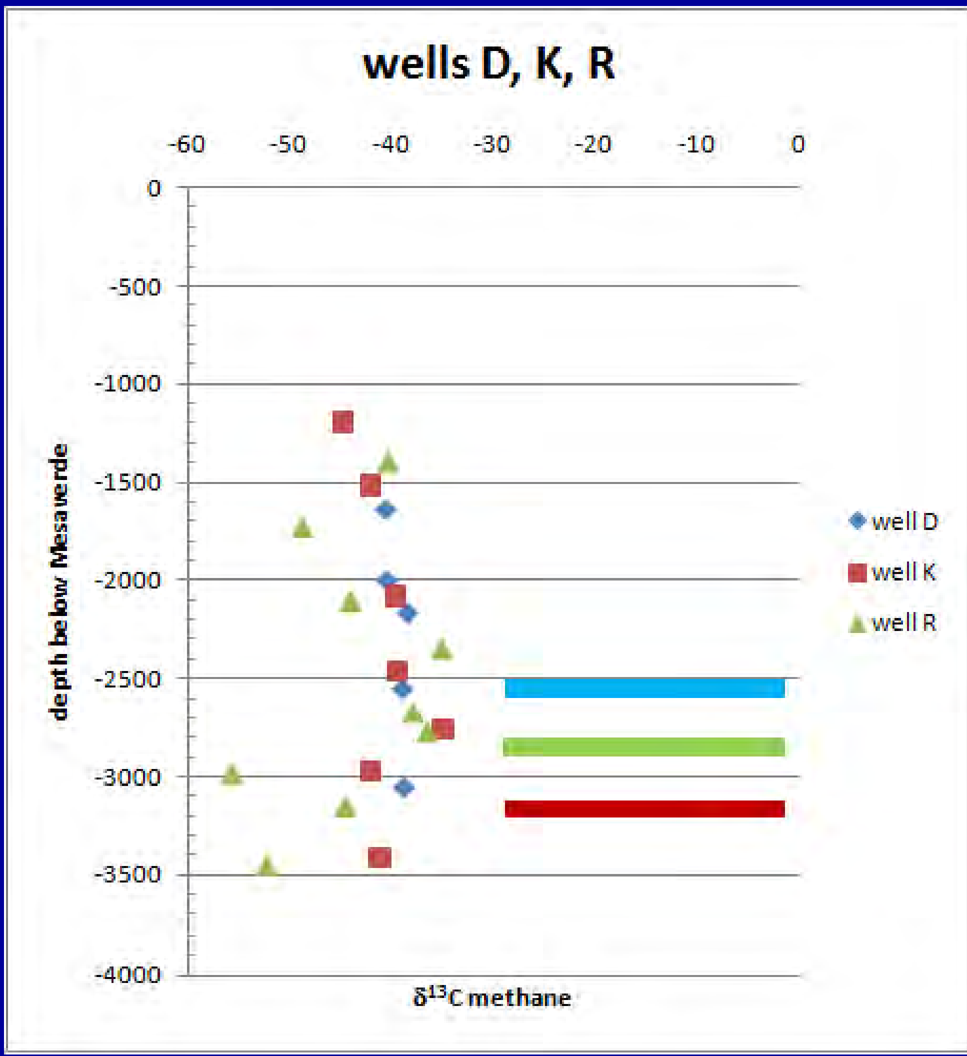


Gases at maximum C2+ 1500-2000 feet blow top MV, 500 to 1000 feet above Cameo

Gases become dry below Cameo

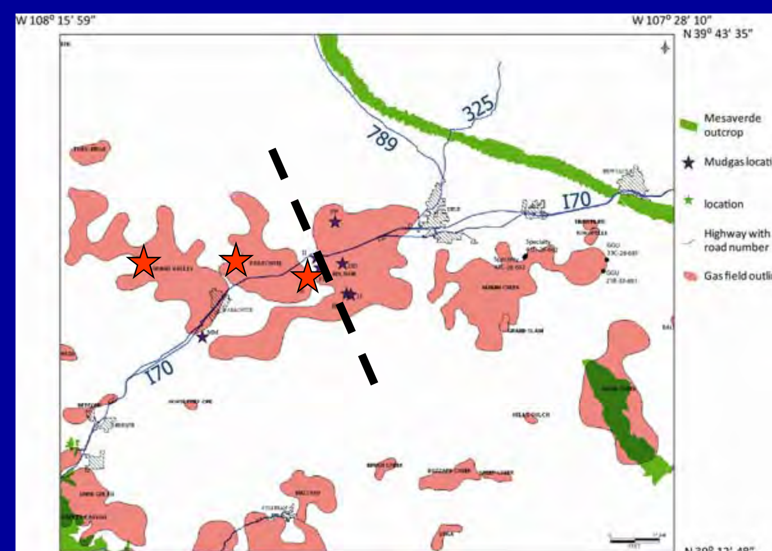


western wells / mud gas sampling

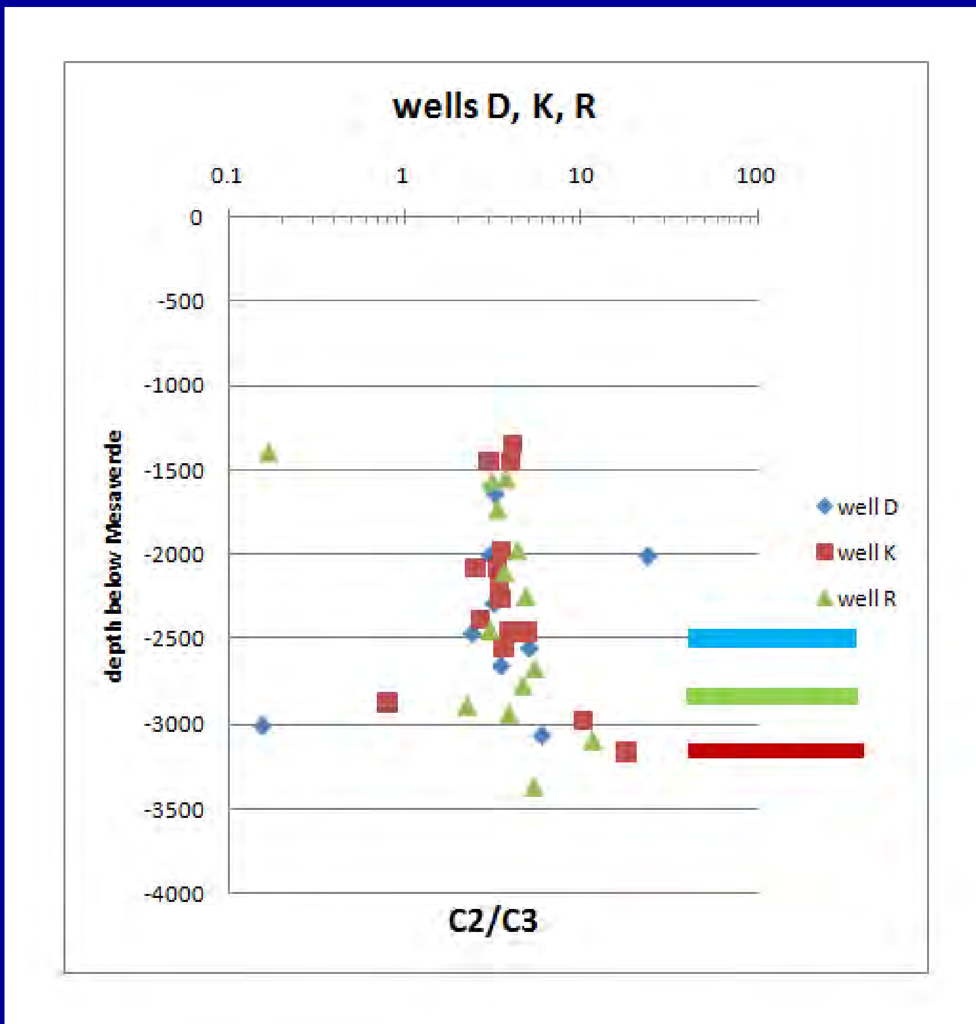


Gases at heaviest $\delta^{13}C$ at Cameo level

Gases become start to become significantly more negative below Cameo

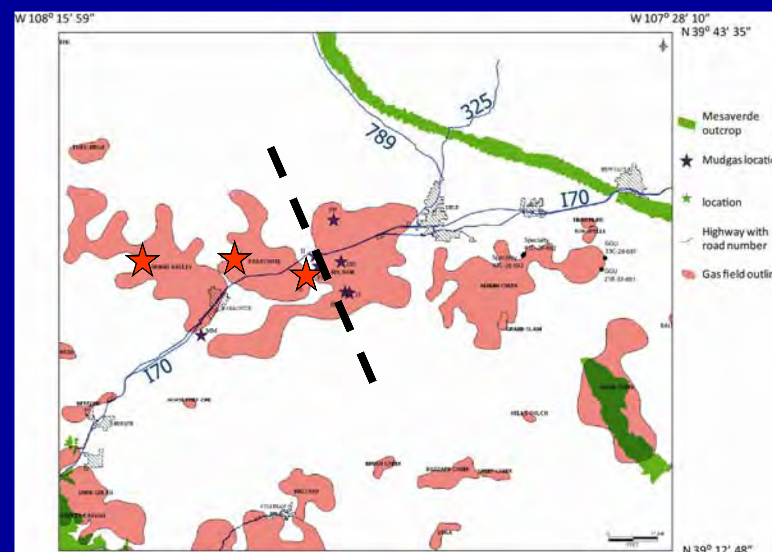


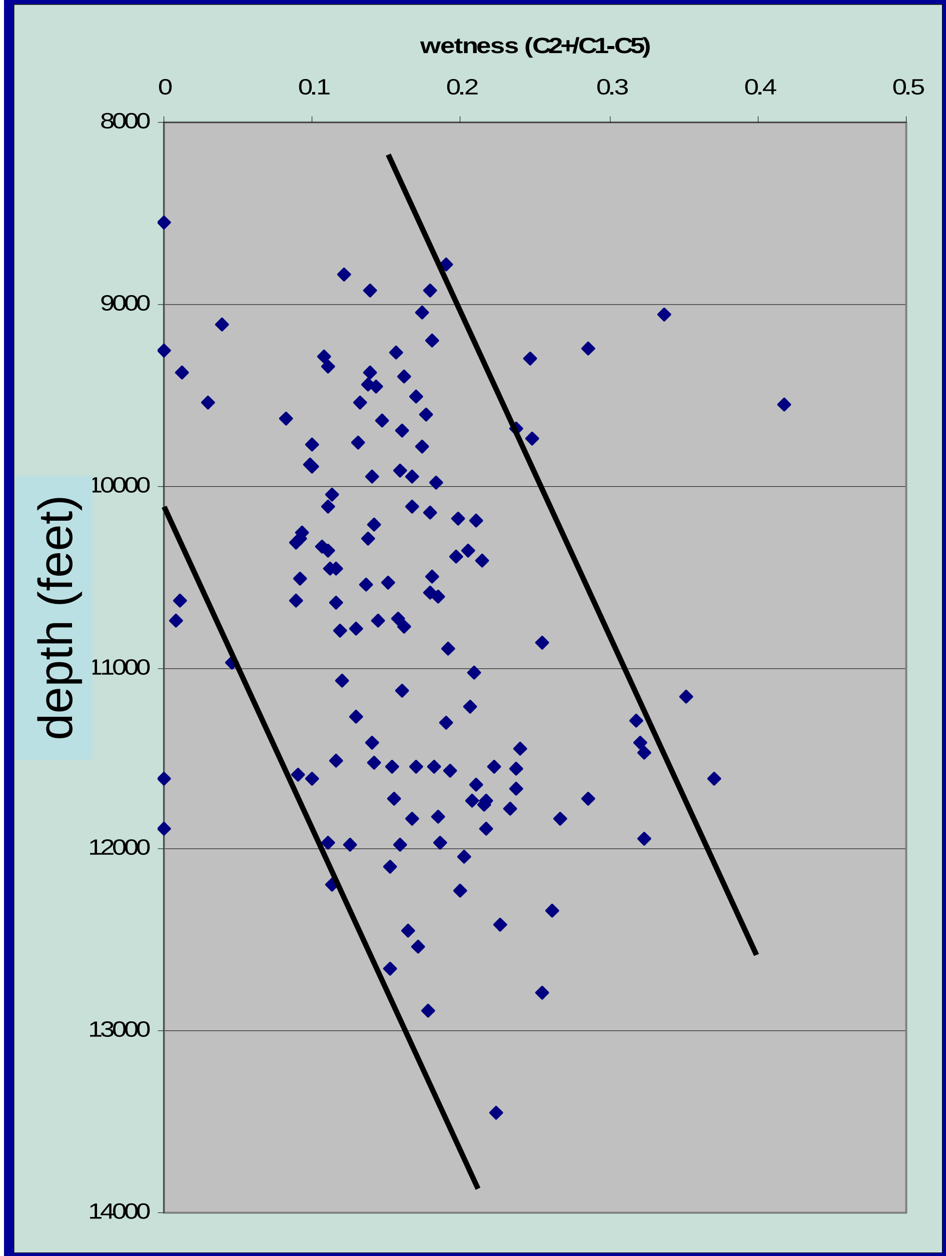
western wells / mud gas sampling



C2/C3 increases with depth

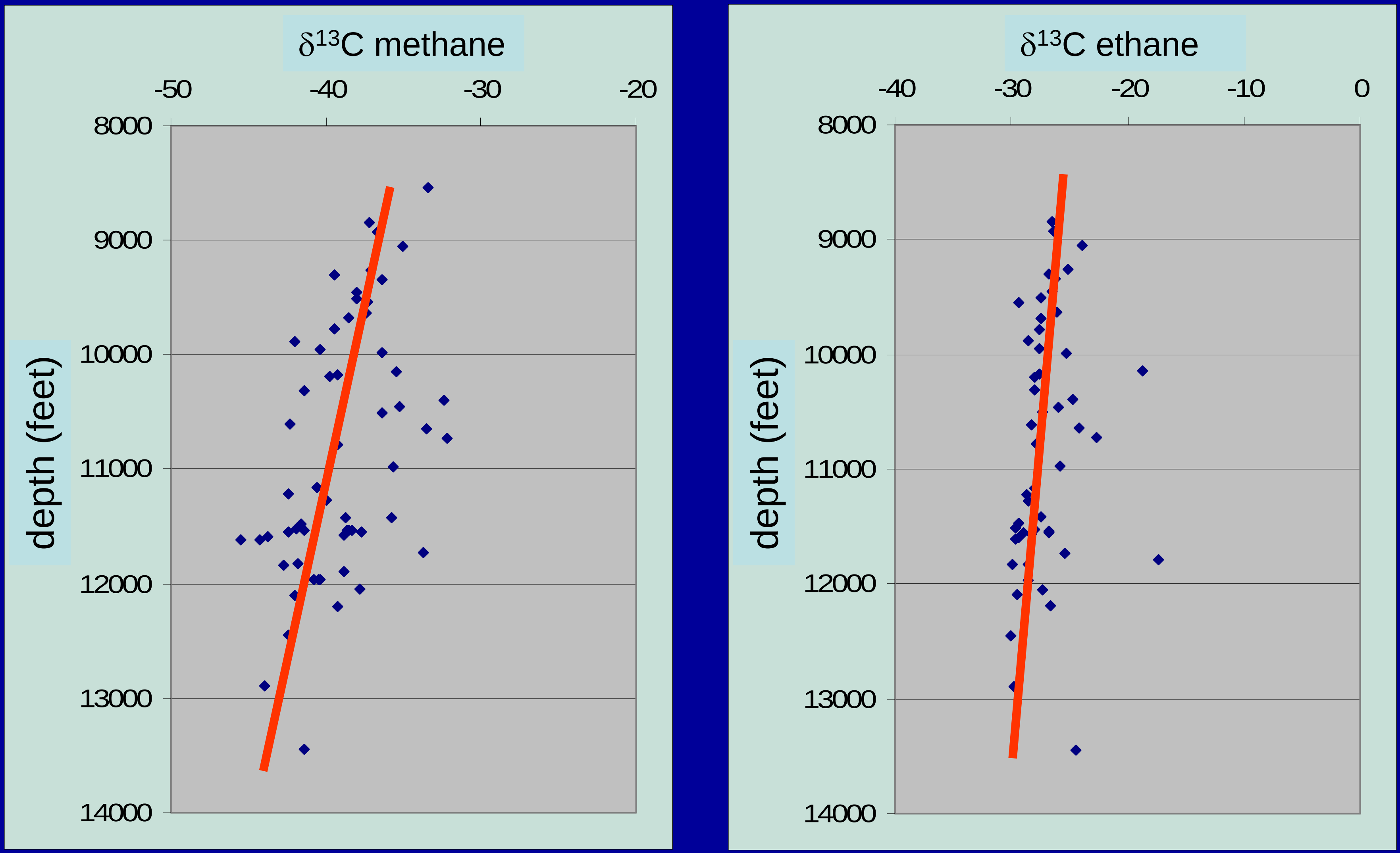
Suggests an increasing component from secondary cracking with depth



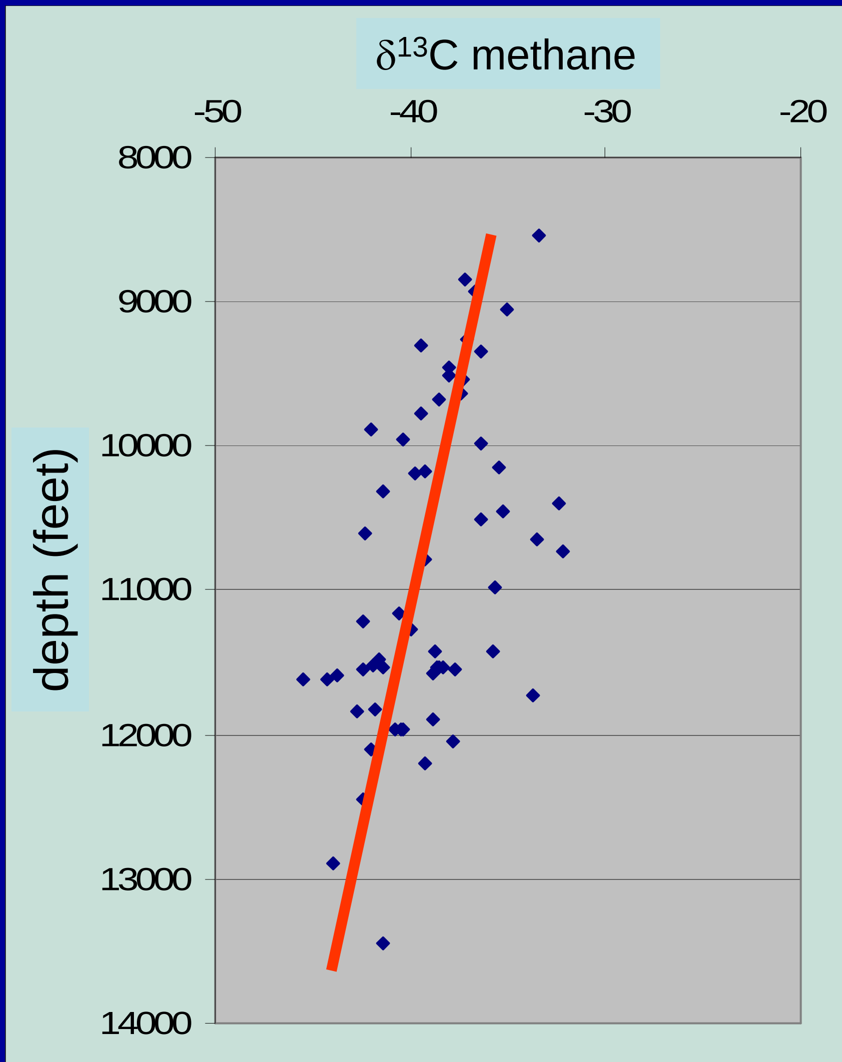


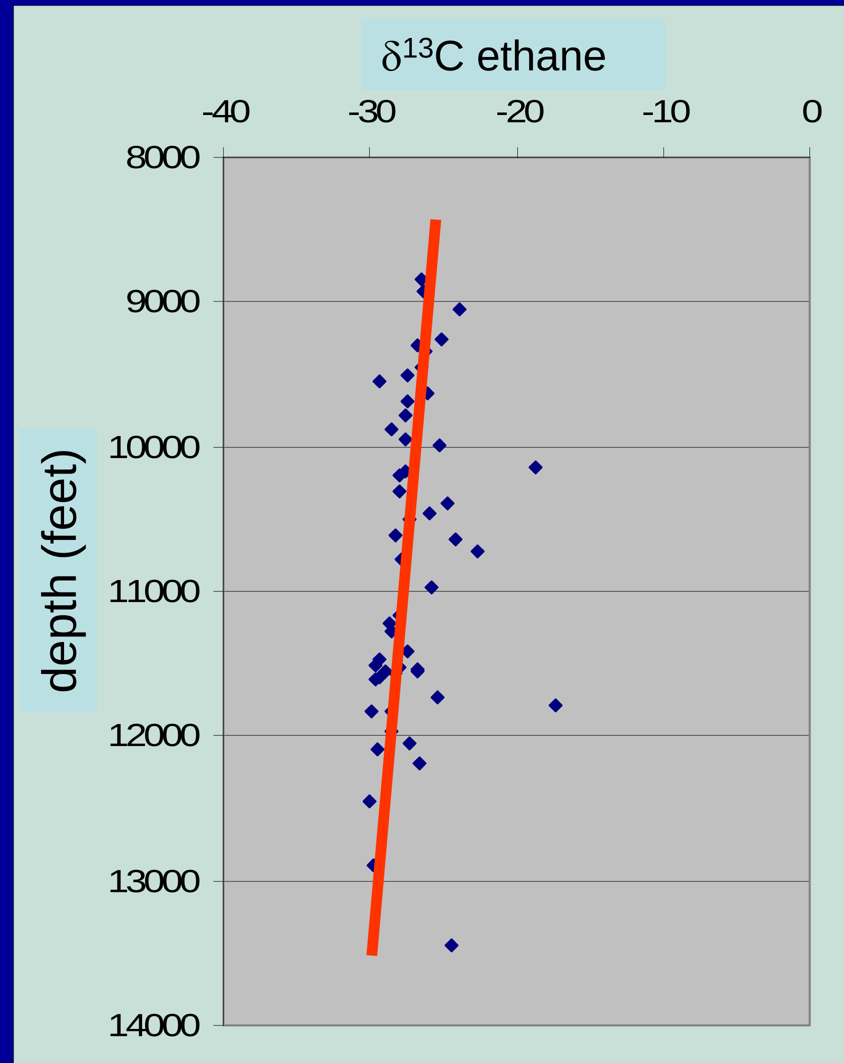
Jonah Field mud gas:

Gas compositions become systematically wetter with depth.

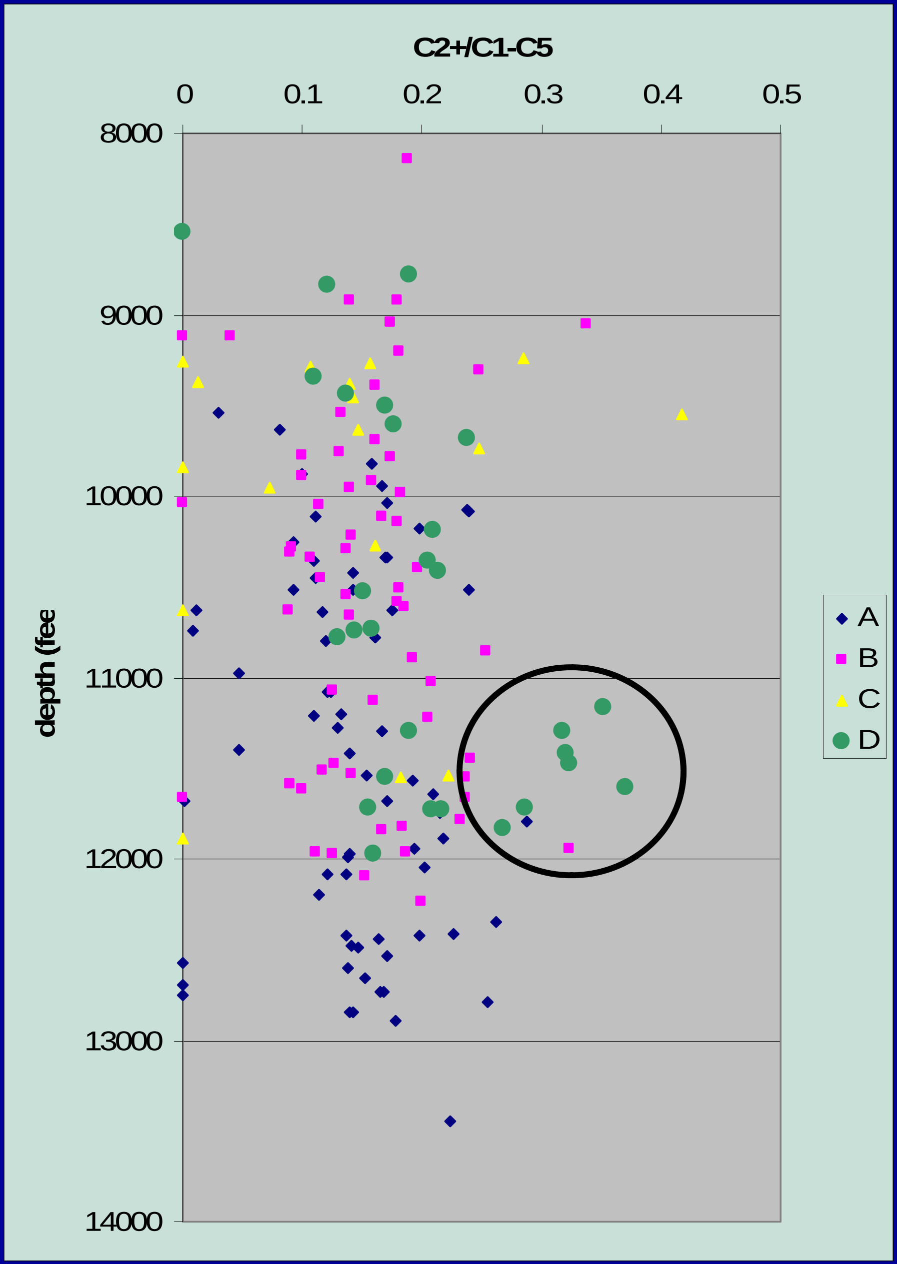


Carbon isotopic compositions become lighter with depth. Not consistent with a diffusion model.





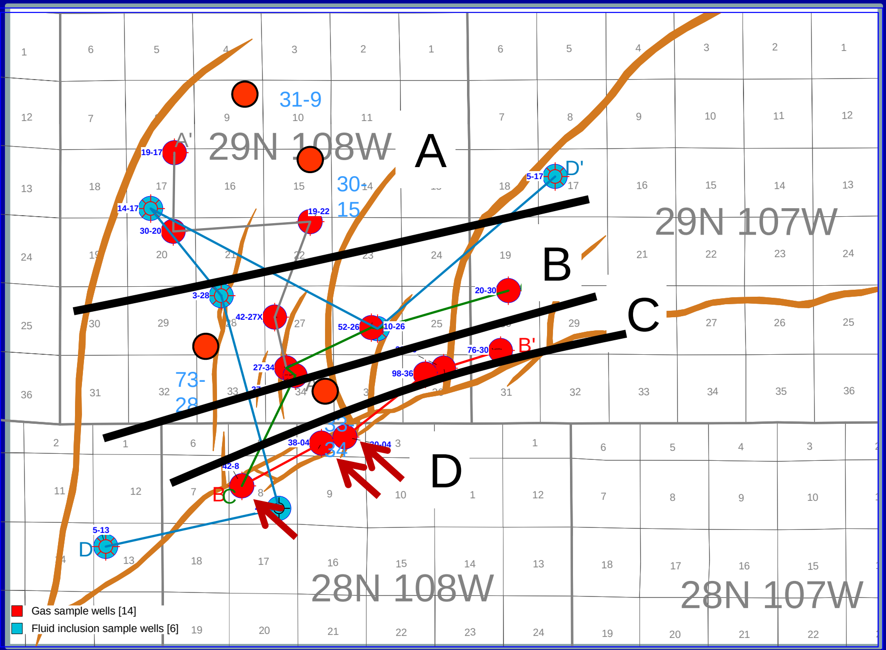
Decrease of 8‰ in $\delta^{13}C$ methane cannot be explained by differences in source rocks or varying thermal maturity in primary cracking

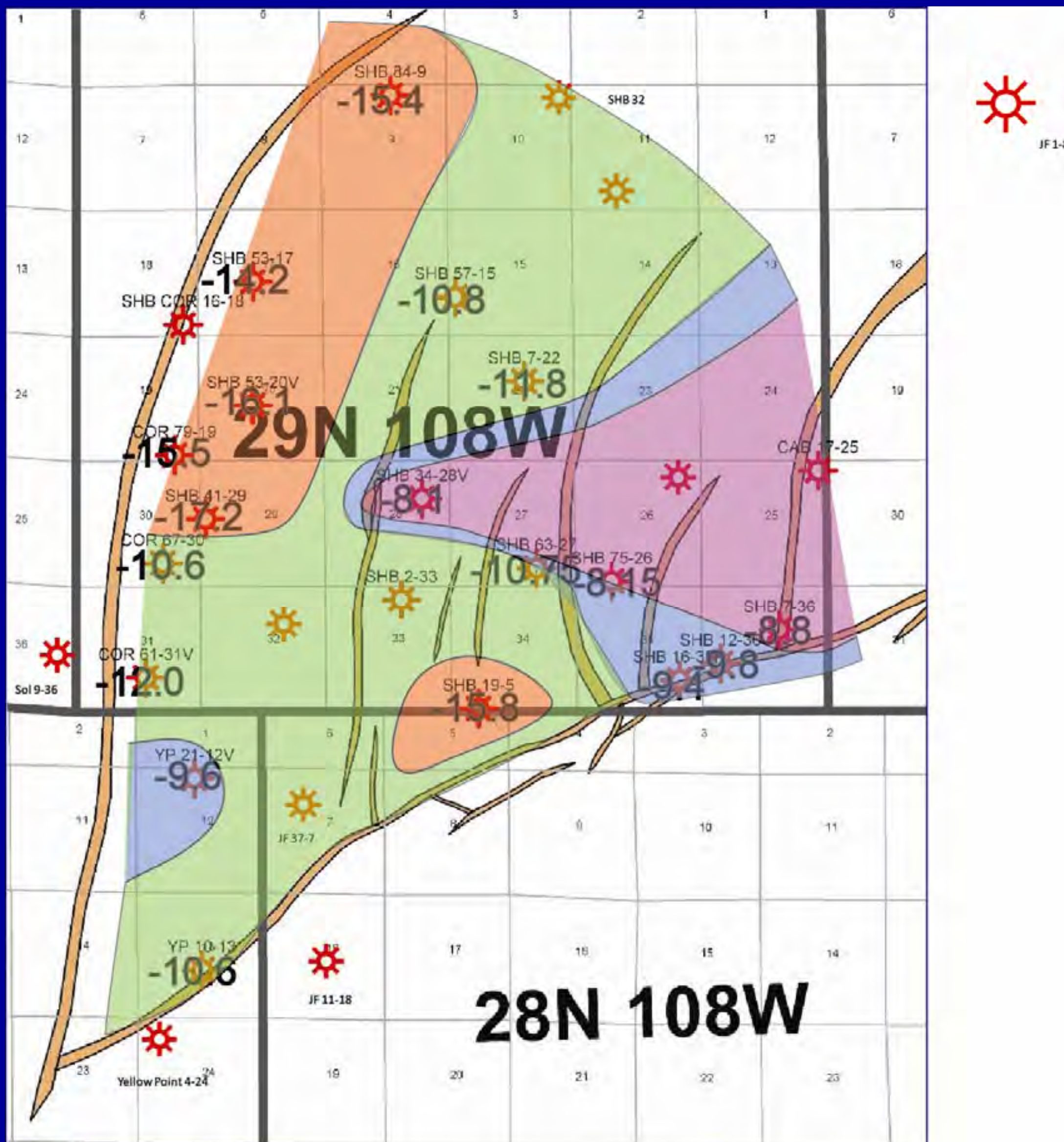


Samples near the fault (group D) may be wetter than average.

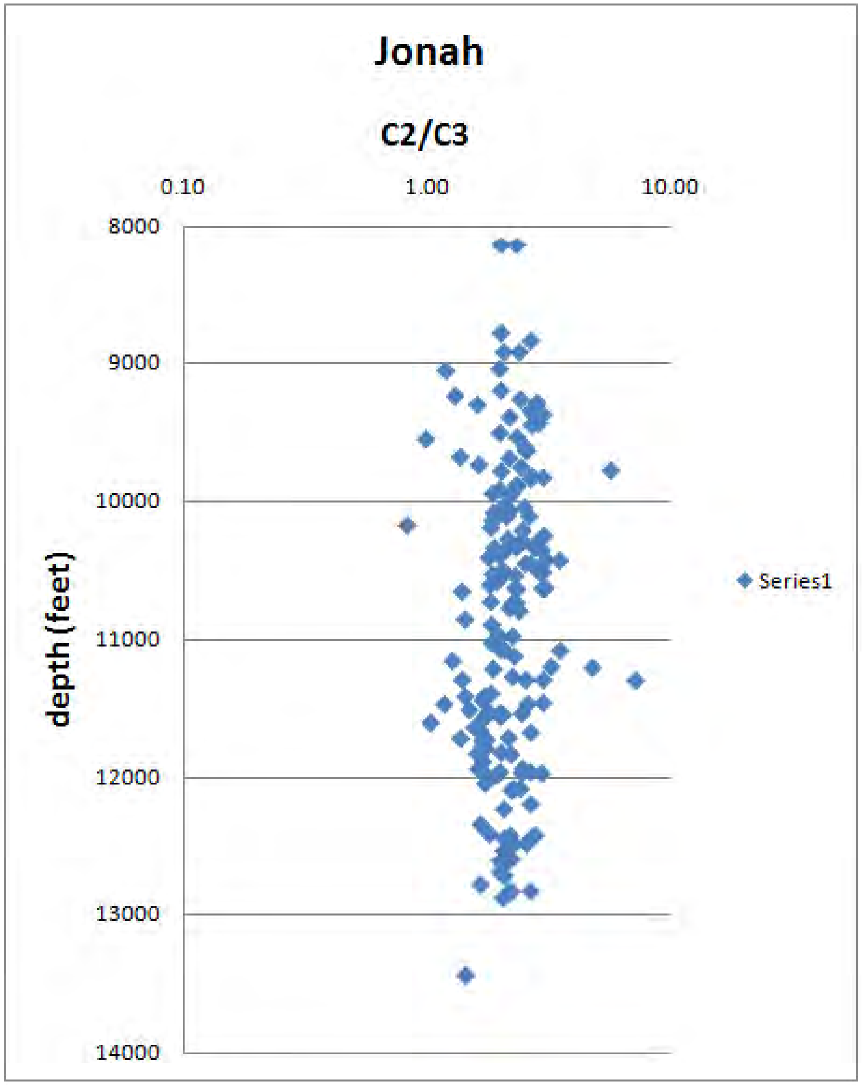
Indicate recharging by fresh (unaltered gas) from fault?

Do pressure compartments affect gas compositions?



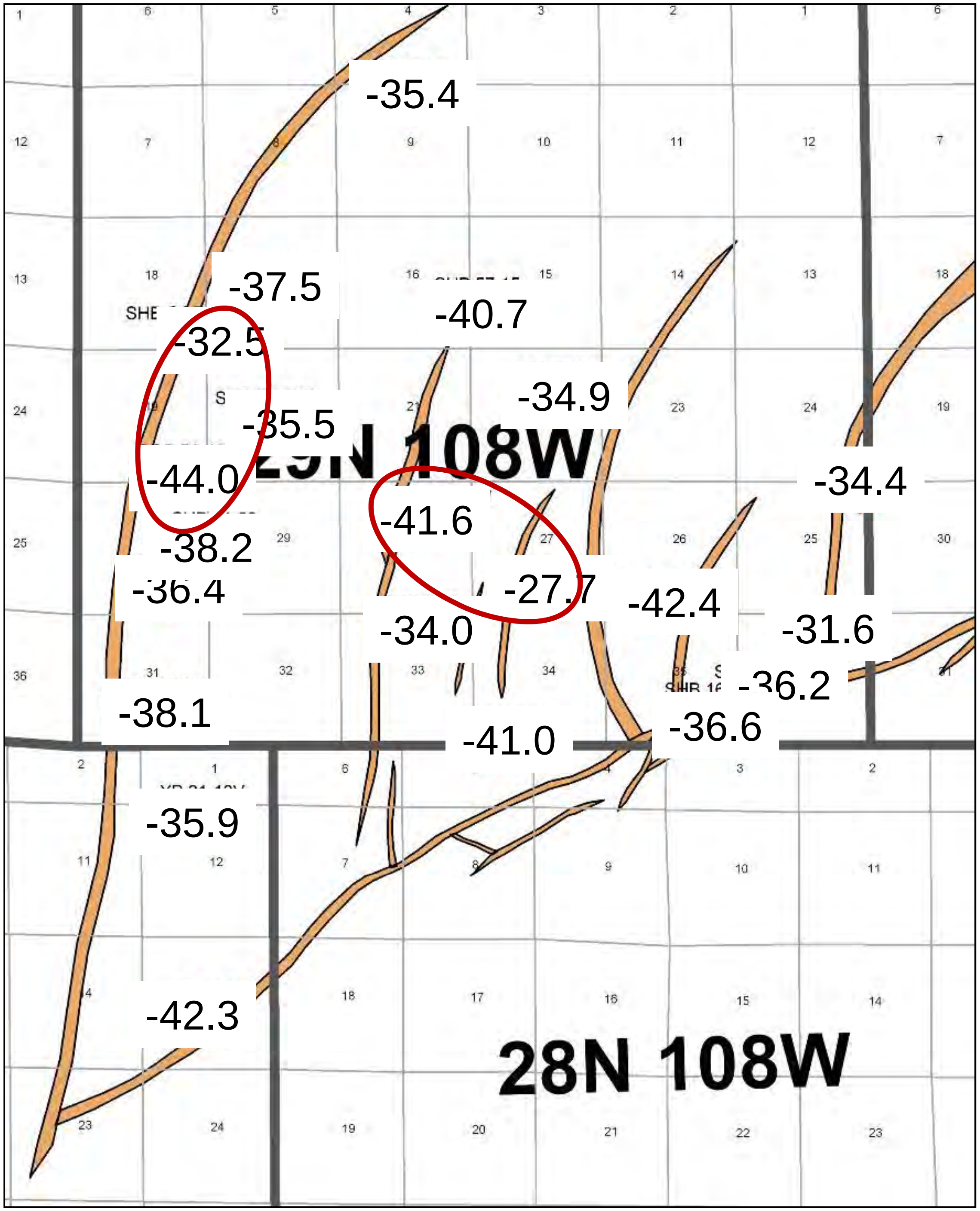


Most negative $\delta^{13}C$ CO_2 occur along western bounding fault, suggesting meteoric water incursion.



C2/C3 ratios decrease with depth

No indication of gases from secondary cracking.



$\delta^{13}C$ methane

Significant short term variability over short distances. Tapping in to different source formations?

Production from different stratigraphic intervals?

Or variable microbial degradation of gas?

Summary:

- Can rule out diffusion model.
- Gas compositions suggest predominantly marine sources.
- Tentatively identify fault control for meteoric water infiltration and possibly for gas migration.
- Generally little indication of secondary cracking (oil to gas) except in deep Piceance samples
- Complexity for the Piceance system suggested in hydrocarbon and noble gases.

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