APPLICATION OF NATURAL GAS COMPOSITION TO MODELING COMMUNICATION WITHIN AND FILLING OF LARGE TIGHT-GAS-SAND RESERVOIRS, ROCKY MOUNTAINS

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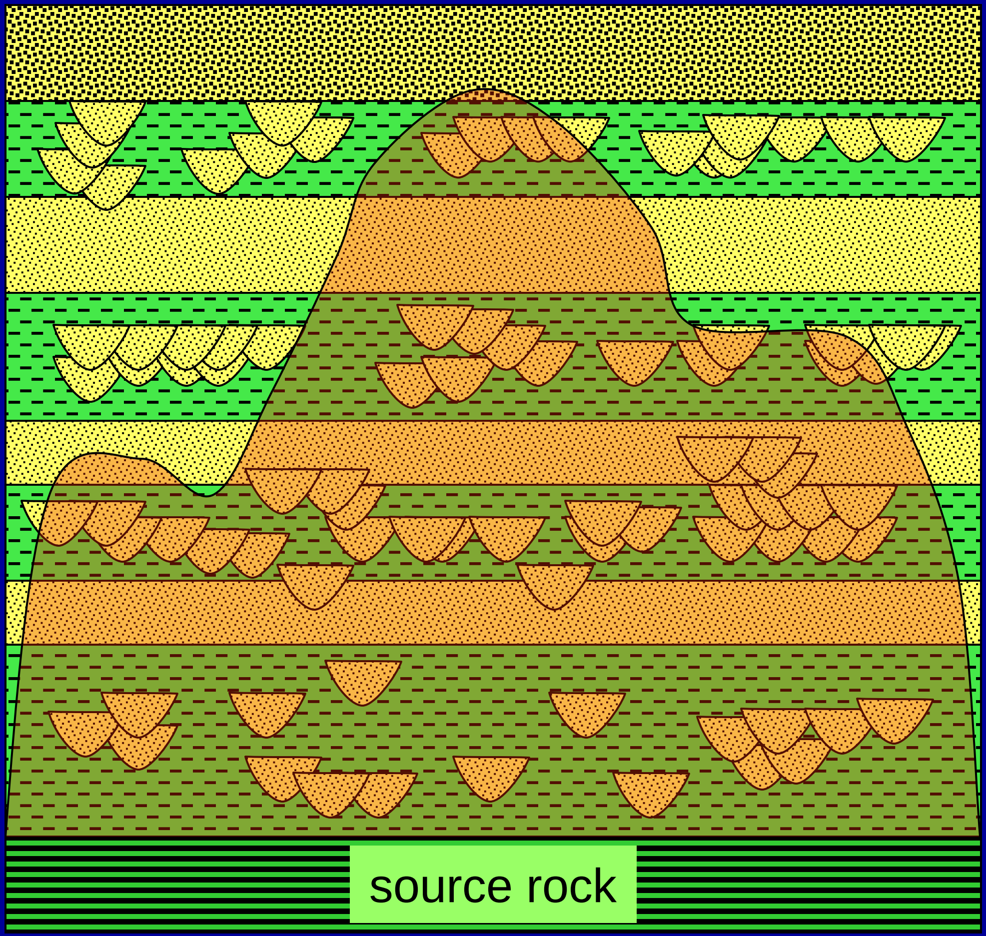
Tight gas-sand reservoirs



These reservoirs differ from conventional reservoir:

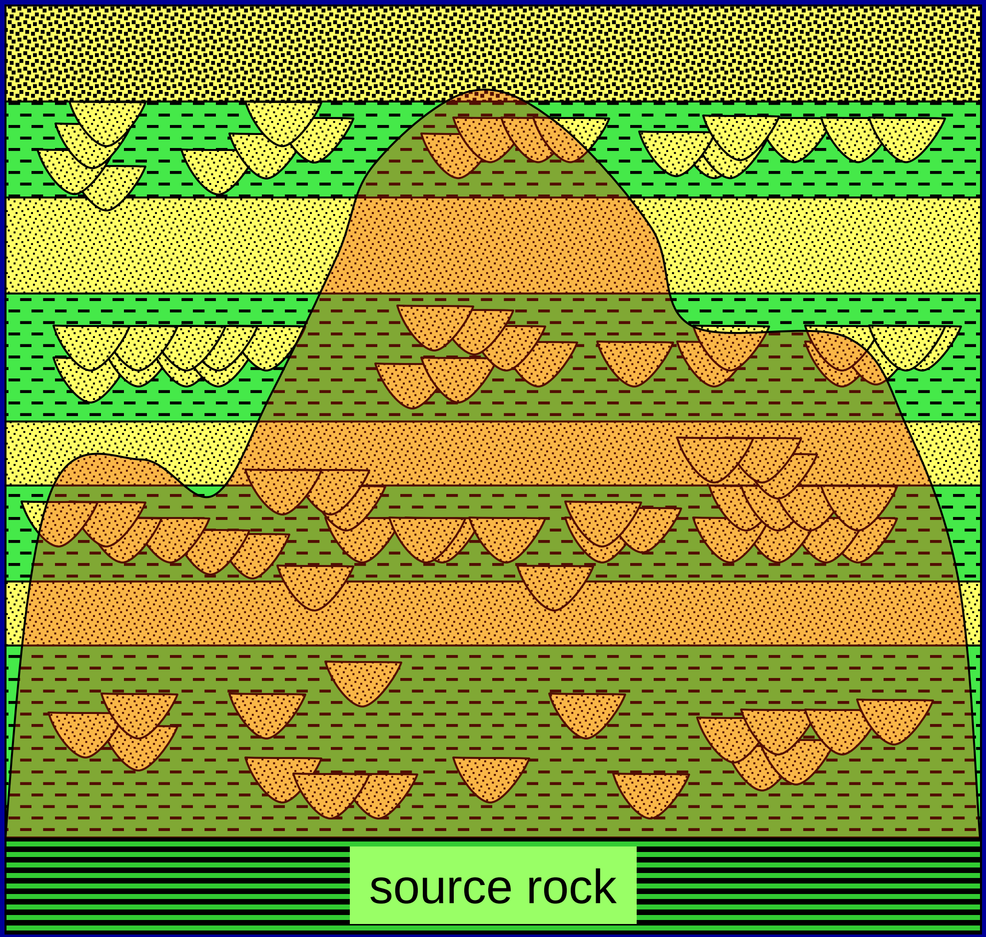
No clearly defined top-seal for these gas reservoirs; instead:

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

2) a fuzzy transition to unproduceable gas.

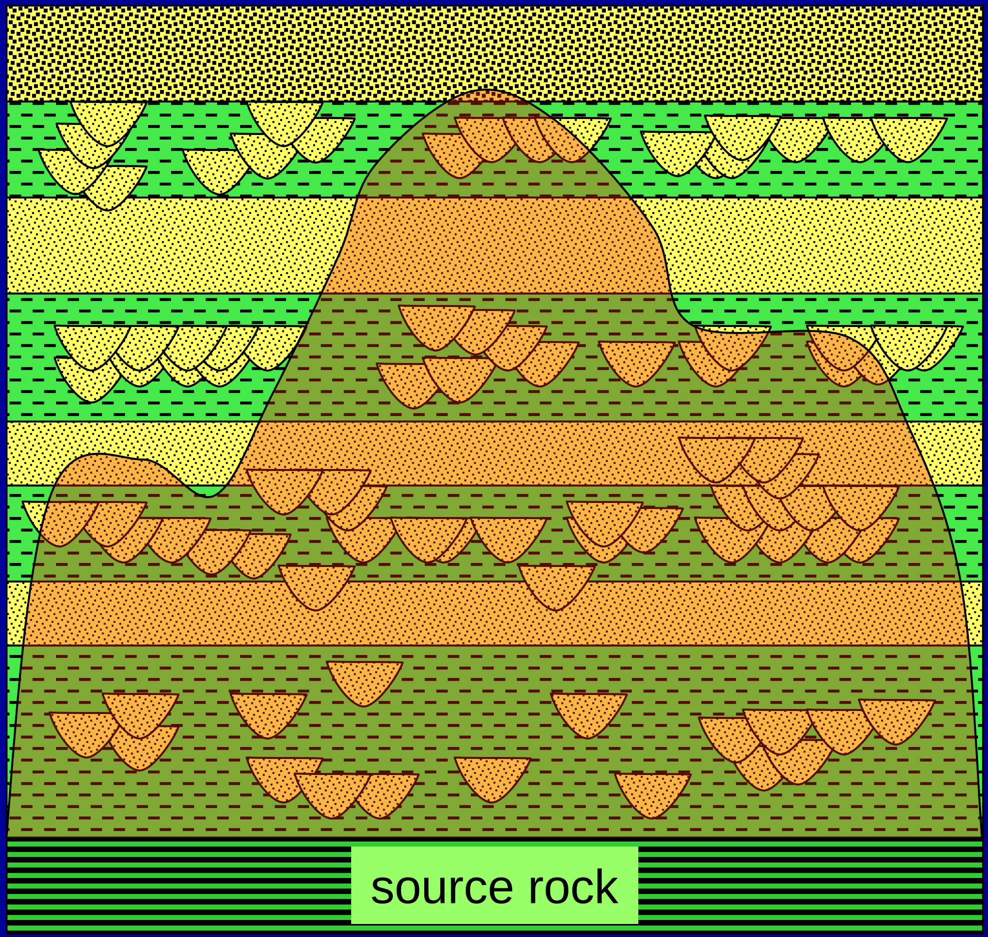
3) may be overpressured or underpressured

Research Objectives



Apply geochemistry of natural gas to:

- Models for migration and filling
- Detect compartmentalization
- Relate gas composition to pressure regime
- Assess basin-centered gas model



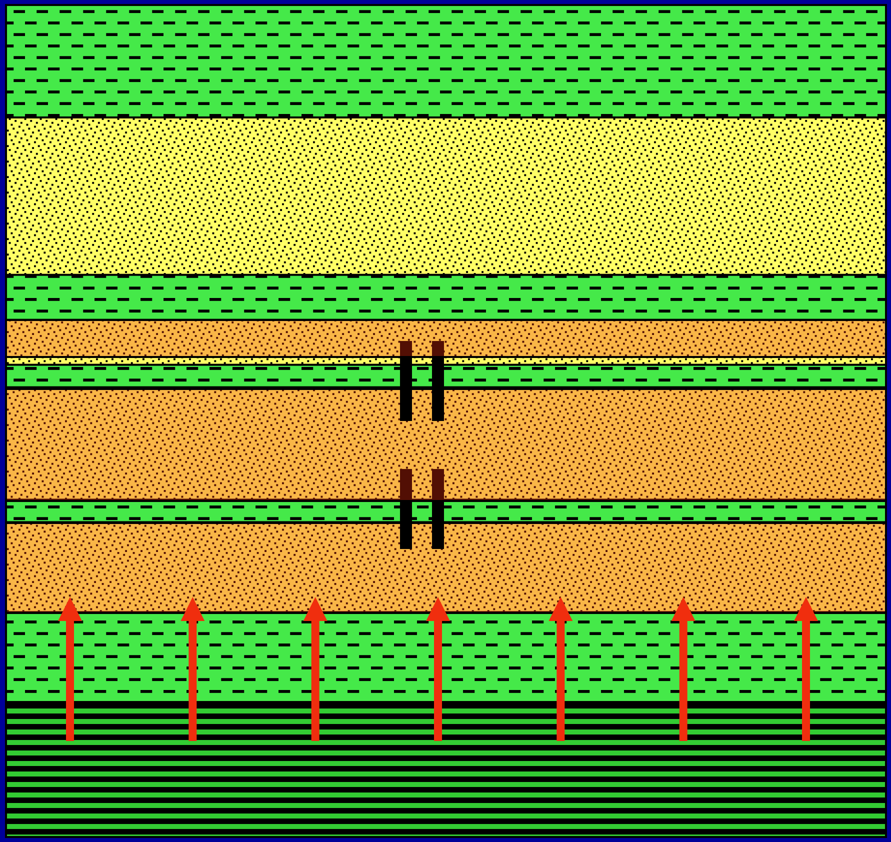
How does gas migrate into and fill these reservoirs?

Possible 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.

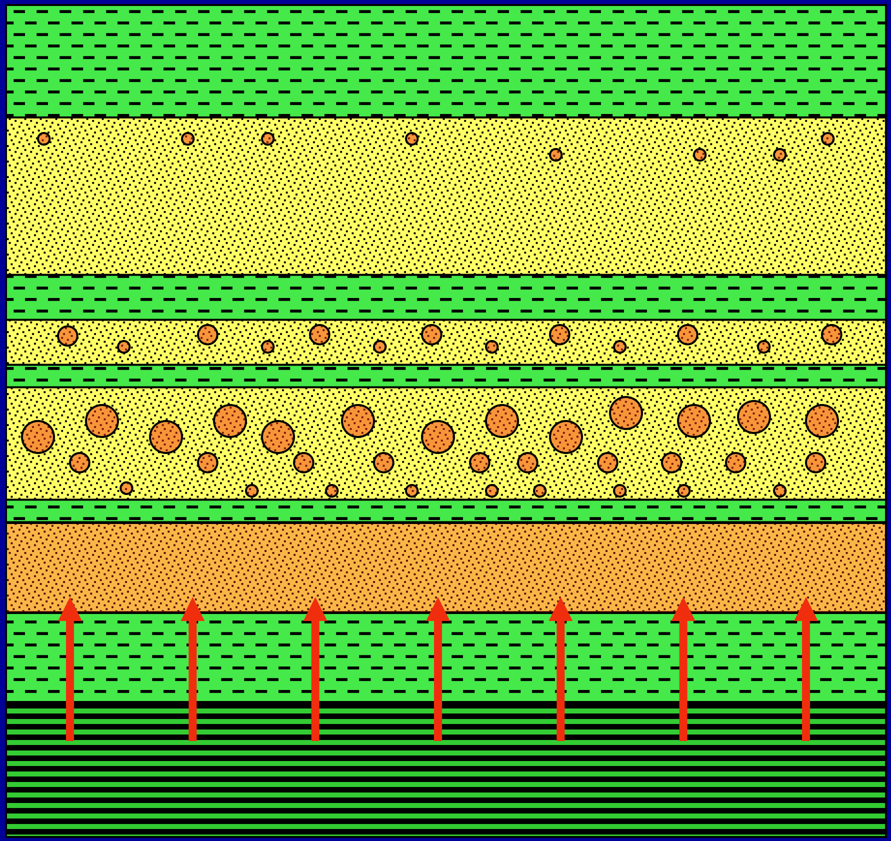
3) Gas migrates along faults.



Model 1 - Self-fracturing (after Cumella and Scheeval, 2008):

The reservoir fills from bottom to top by the successive fill – seal rupture of successive reservoir compartments.

Top-of-gas depends on: (1) differences in fracture strength of intermediate seals; (2) differences in geometry and distribution of lowermost reservoirs.

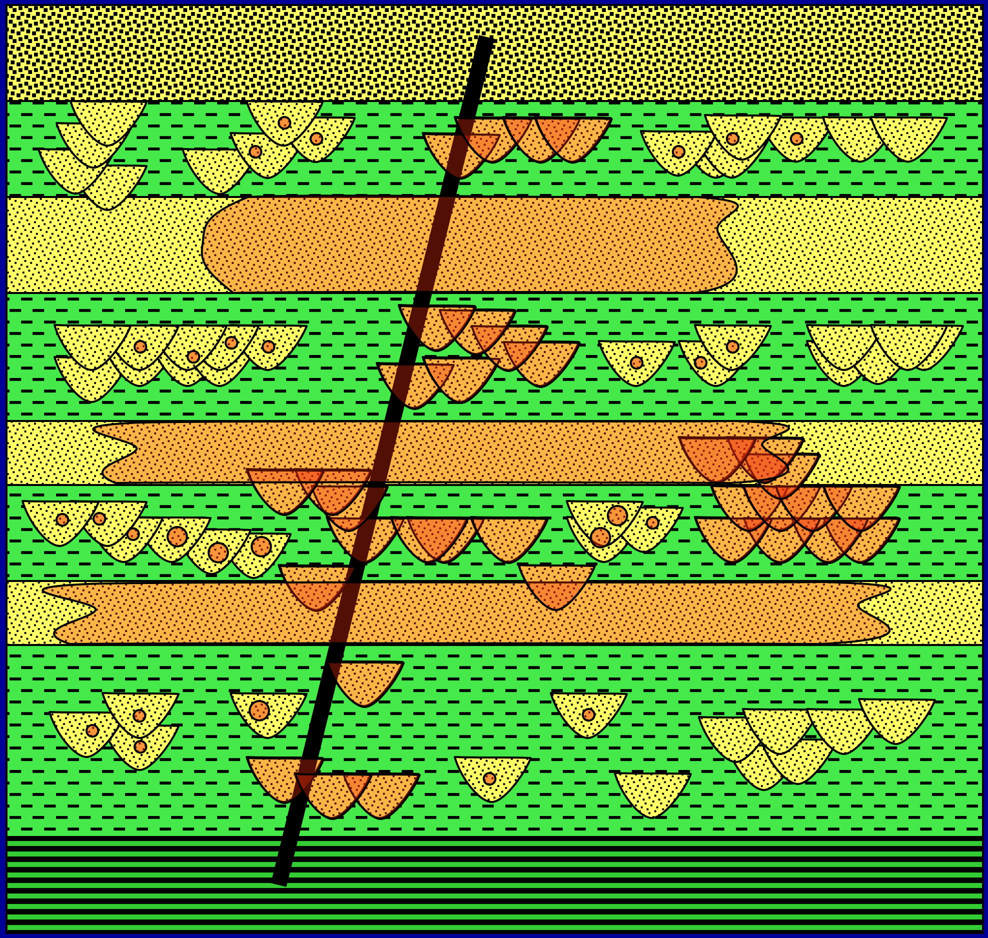


Model 2 - Diffusion:

Reservoir compartments fill by gas diffusion across intermediate seals (semi-permeable membrane).

Diffusion is driven by pressure differences and concentration gradients.

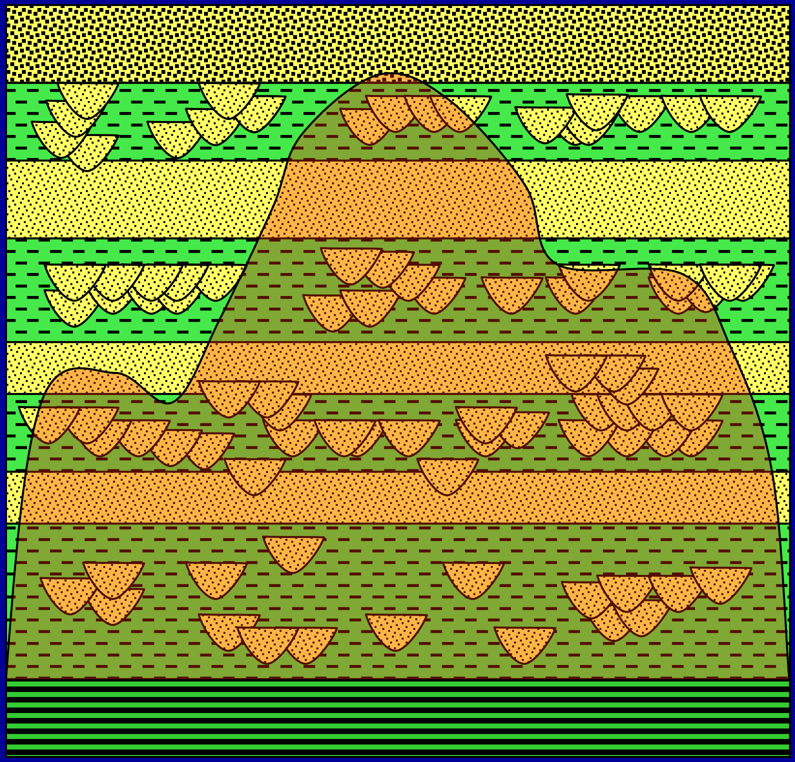
Top-of-gas controlled by: (1) unevenly distributed gas inputs into lowermost reservoir; (2) initial differences in gas distribution; (3) diffusion / permeability pathways.



Model 3 – Migration fairways

Gas migrates vertically along fracture- / fault- controlled permeability pathways.

Gas migrates laterally by flow along continuous reservoir pathways or by diffusion across side-seals.



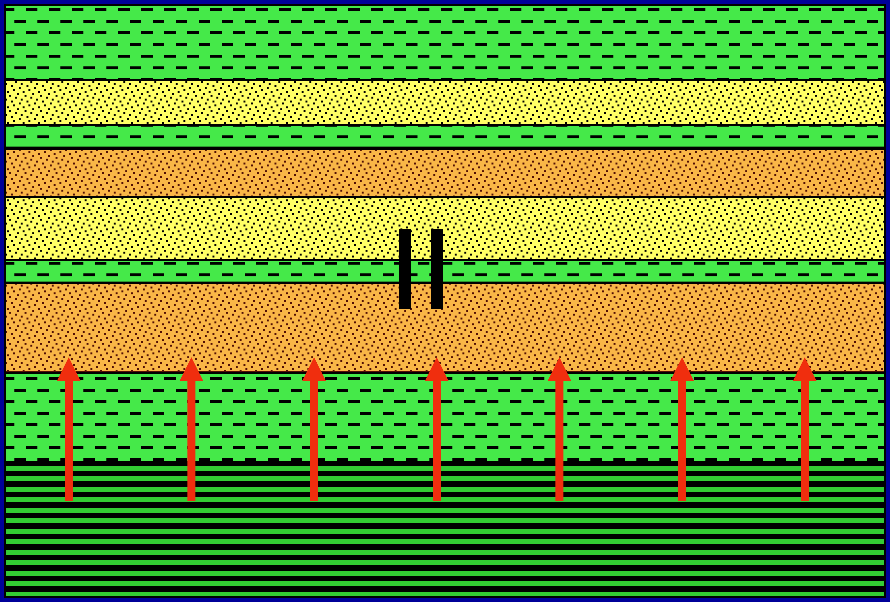
Hypothesis –

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

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

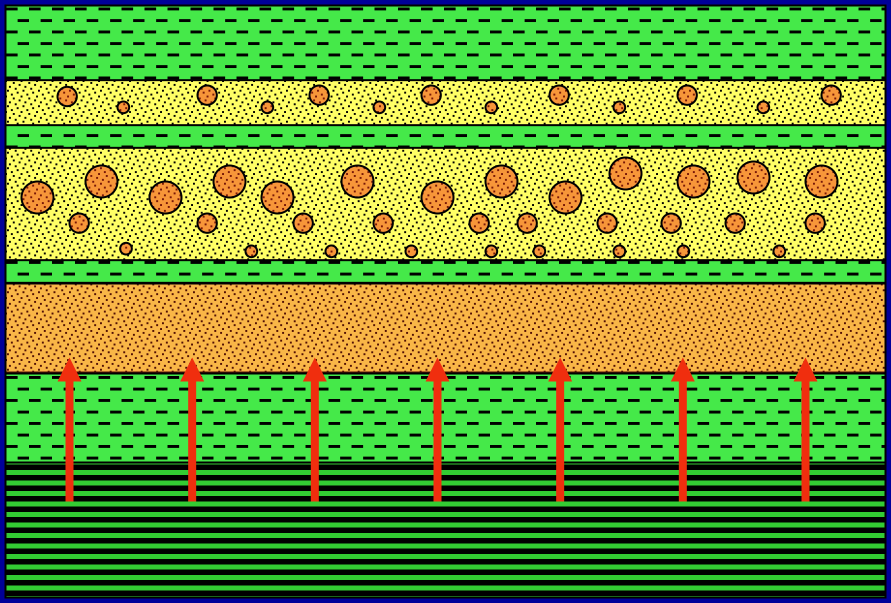
- Many samples, locations carefully chosen.

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



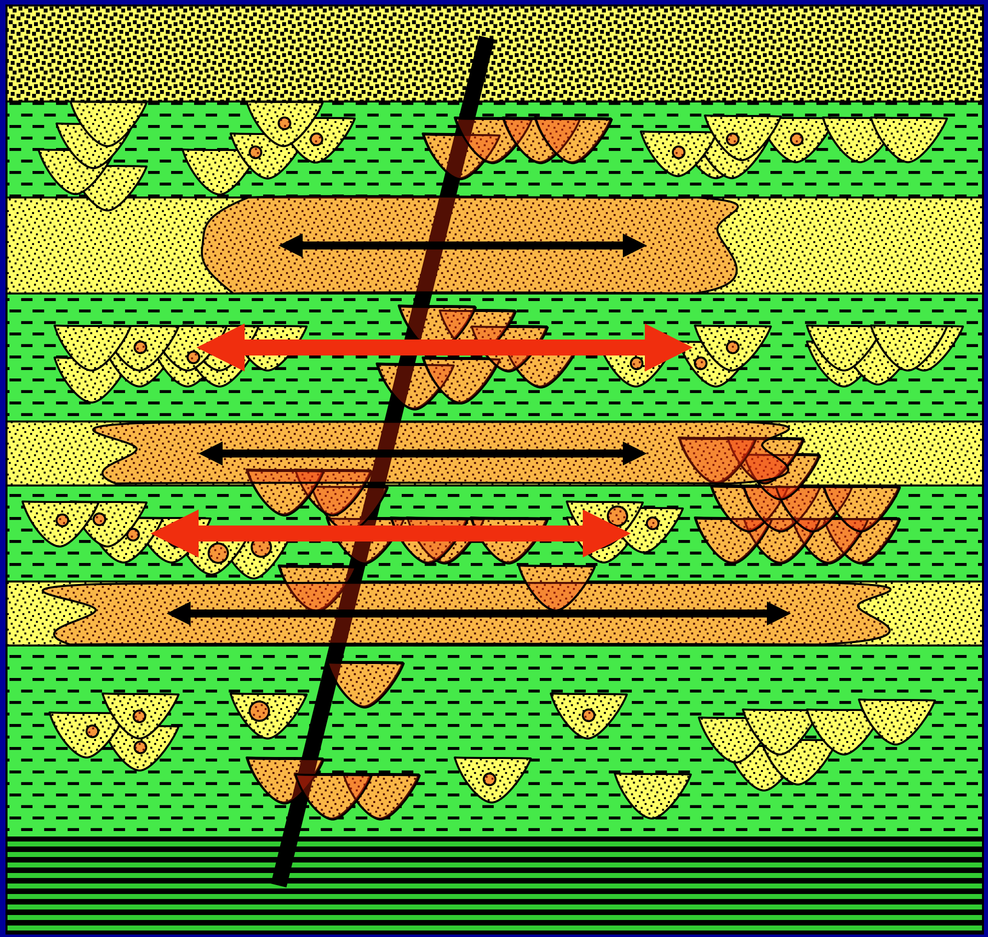
frac model

Little isotopic fraction occurs during explosive gas migration through seal.



diffusion model

C / H isotopic fractionation of hydrocarbon gas compounds



Possible isotopic effects in a fault- / fracture-controlled migration model

Advective transport of gas; little lateral isotopic fractionation

Diffusive transport of gas; strong lateral isotopic fractionation

A three-phase approach:

- Document the composition of gas in three major tight-gas sand fields through intensive sampling and analytical program and fluid inclusion analysis.

- Conduct hydrous pyrolysis experiments to determine the composition entering the reservoir.

- Model the different filling mechanisms using MPath migration modeling program and match to naturally occurring gas compositions

Key Personnel

- Dr. Nick Harris, CSM – project coordinator, advisor to M.S. student, design sampling program

- Dr. Mike Lewan, USGS – hydrous pyrolysis experiment

- Prof. Paul Philp, University of Oklahoma – bulk gas compositions and compound-specific isotopic analysis, supervisor of post-doc

- Prof. Chris Ballentine, University of Manchester (U.K.) – noble and radiogenic gas analysis

Additional collaborators

Permedia Research Group – developers of MPath software

Fluid Inclusion Technology

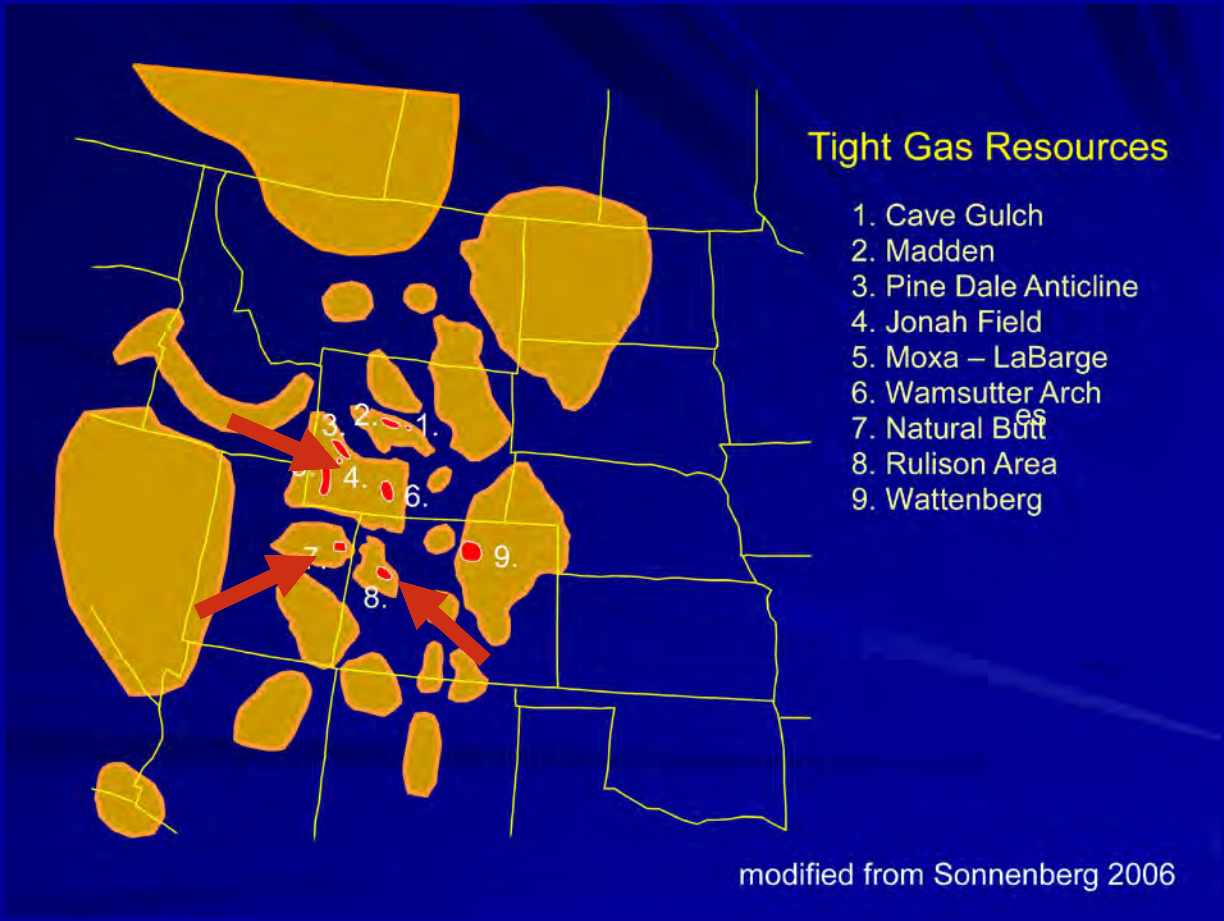
Value of in-kind cost match: $191,000

Financial Cost Match

Anadarko, BP, ConocoPhillips, ExxonMobil, Marathon, Newfield Exploration, Williams

Value of financial cost-match: $185,000

Sample Database



Fields in the study:

1) Jonah Field (Encana)

2) Mamm Creek – Rulison – Parachute – Grand Valley (Williams Co. and Bill Barrett Corp.)

3) Greater Natural Buttes (Anadarko)

Project Status

Sampling and analyses to date

Jonah Field: 175 mud gas samples (56 for compound-specific isotope analysis)

21 production gas samples

14 noble gas samples

6 wells sampled for fluid inclusion analysis

Piceance fields: 135 mud gas samples (55 for compound-specific isotope analysis

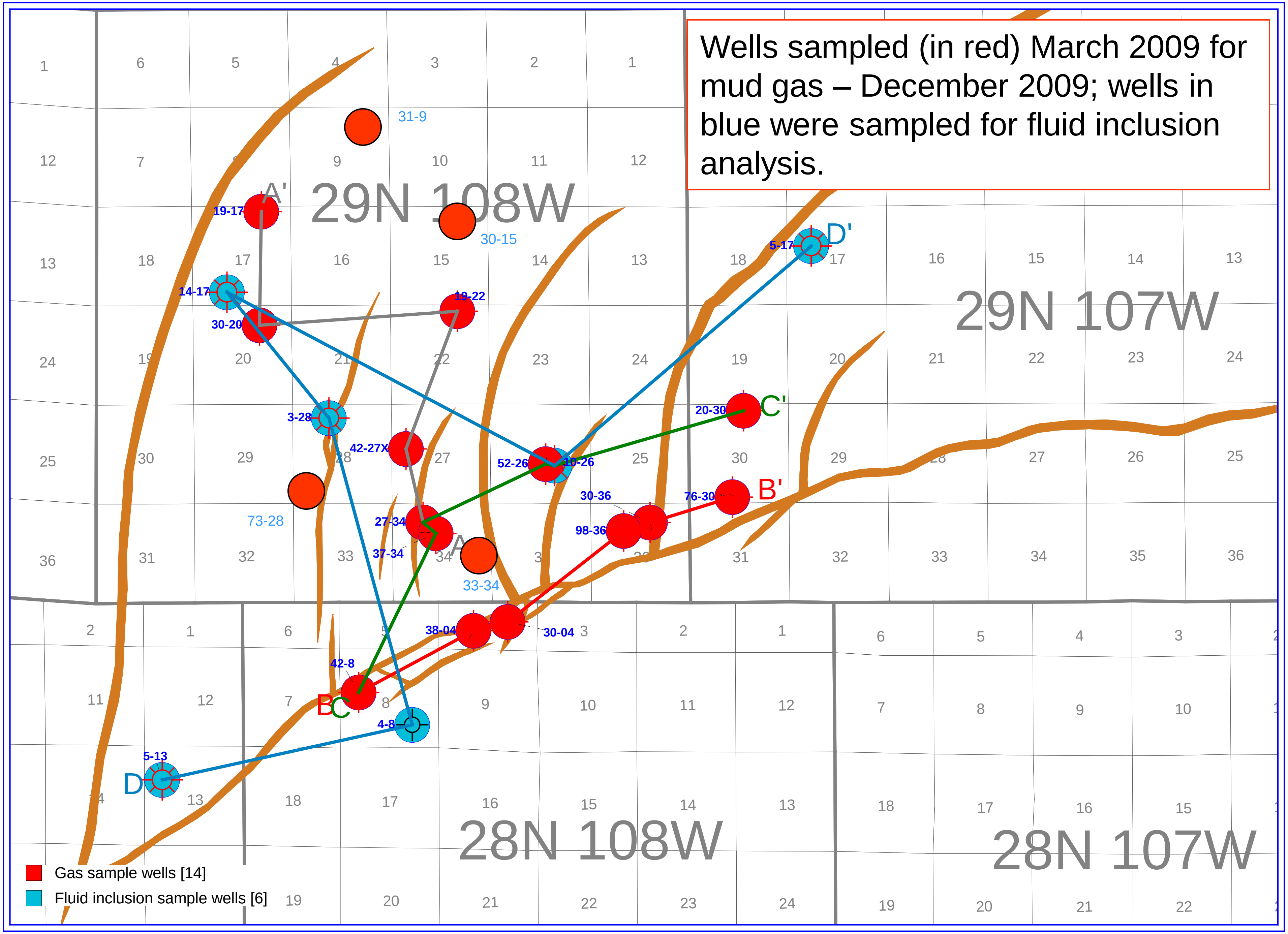
33 production gas samples

31 noble gas samples

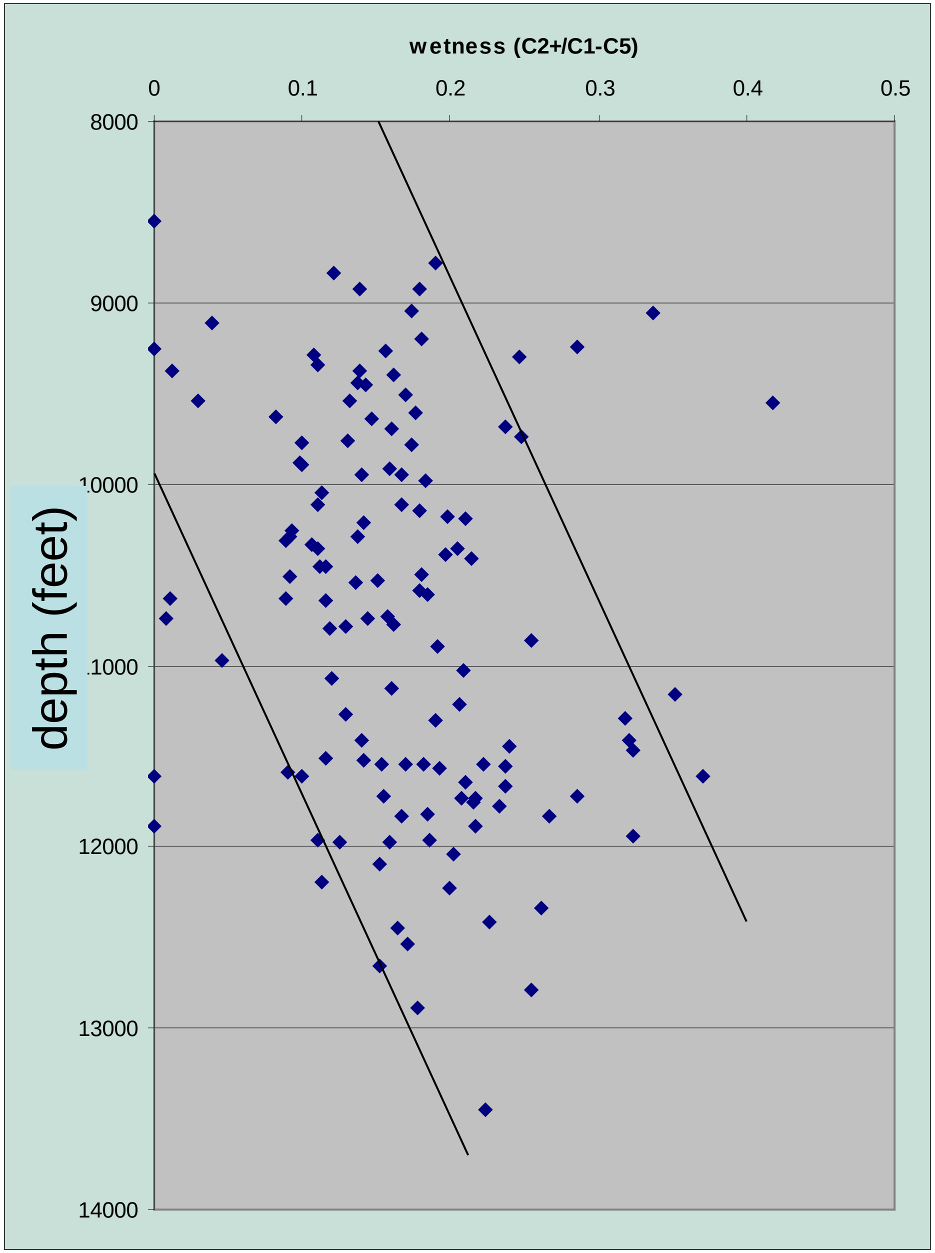

mud gas sampling


mud gas sampling


Production gas sampling for noble gases

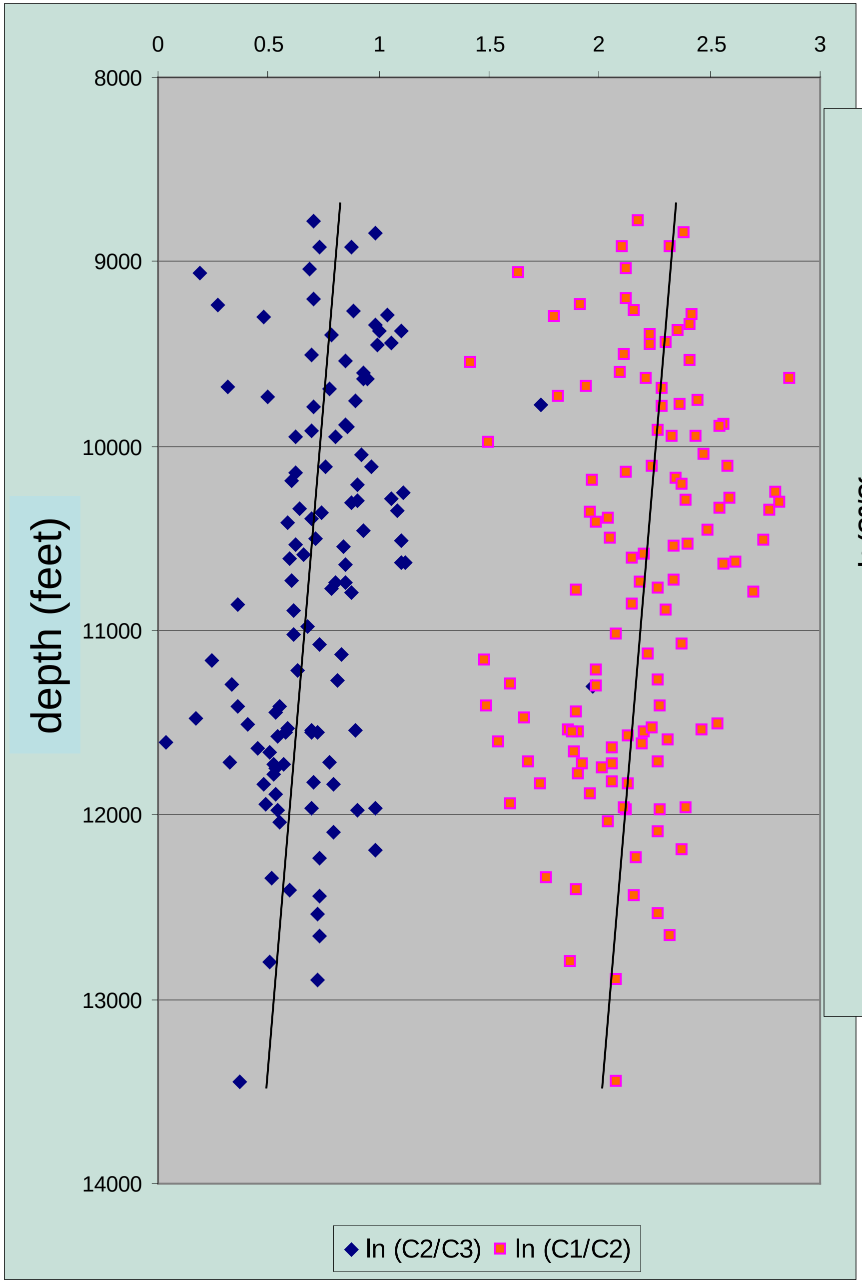


Wells sampled (in red) March 2009 for mud gas – December 2009; wells in blue were sampled for fluid inclusion analysis.
29N 108W
29N 107W
28N 108W
28N 107W
A'
A
B'
B
C'
C
D'
D
31-9
30-15
19-17
14-17
30-20
19-22
5-17
20-30
3-28
42-27X
52-26
10-26
30-36
76-30
98-36
73-28
27-34
37-34
33-34
38-04
30-04
42-8
4-8
5-13
Gas sample wells [14]
Fluid inclusion sample wells [6]

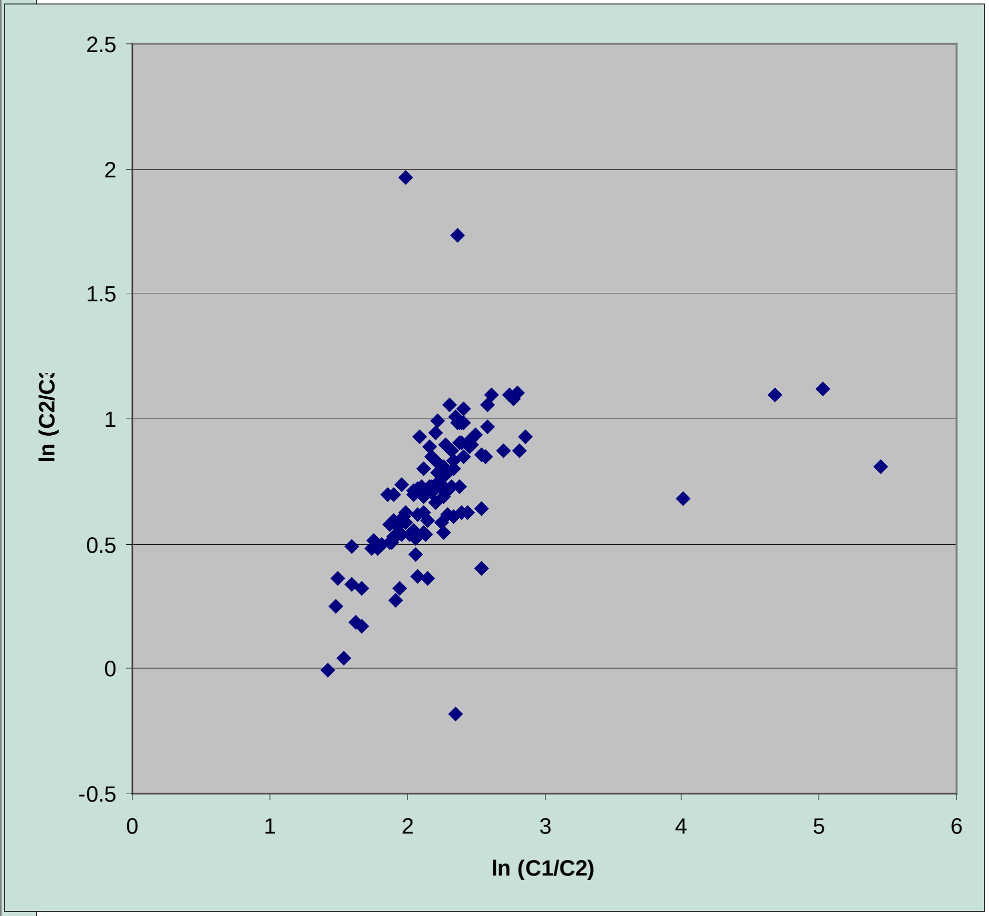


Jonah Field:

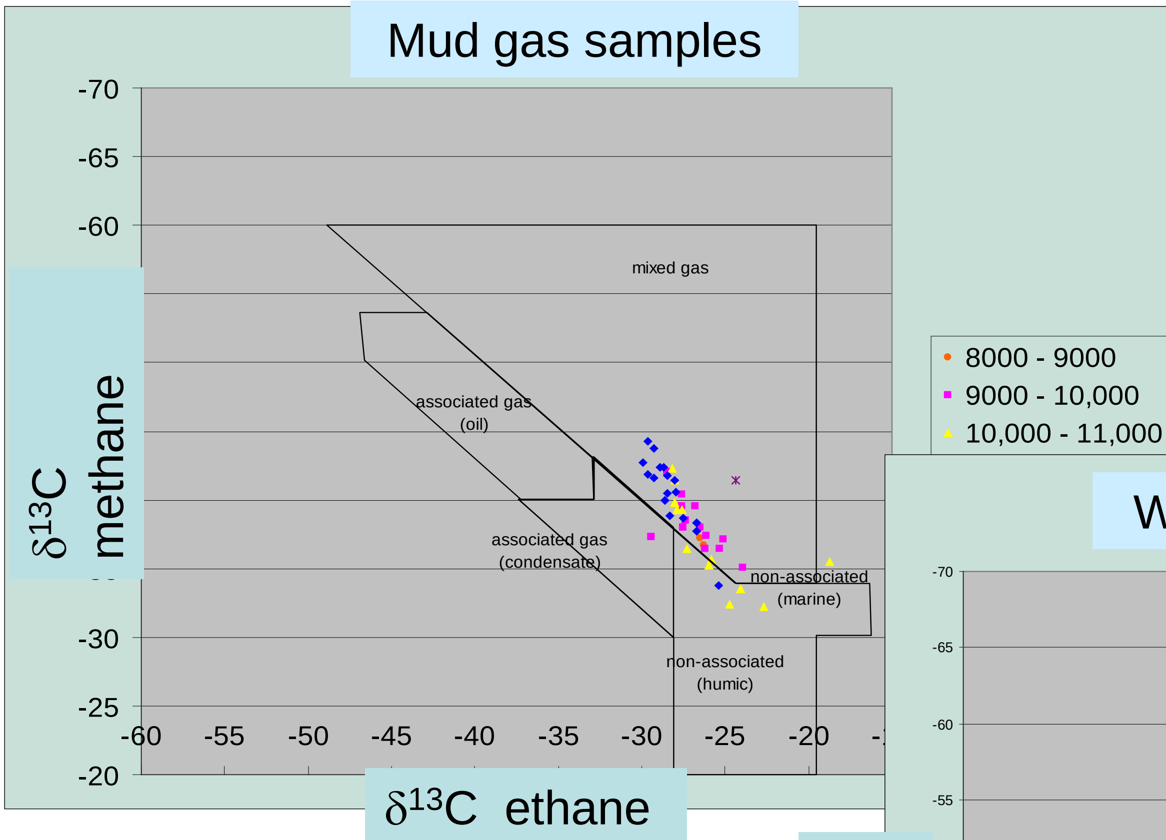
Gas compositions become systematically wetter with depth. All mud gas data.



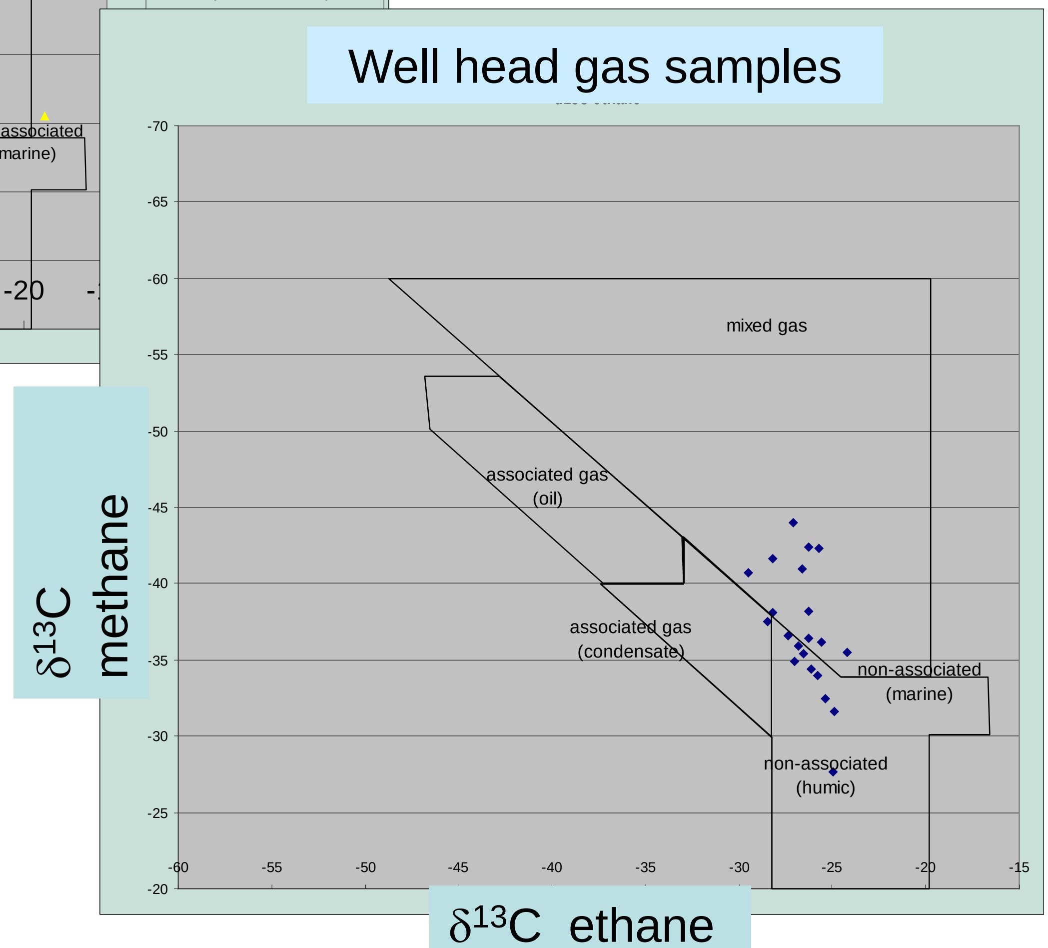
0
0.5
1
1.5
2
2.5
3
8000
9000
10000
11000
12000
13000
14000
depth (feet)
ln (C2/C3)
ln (C1/C2)



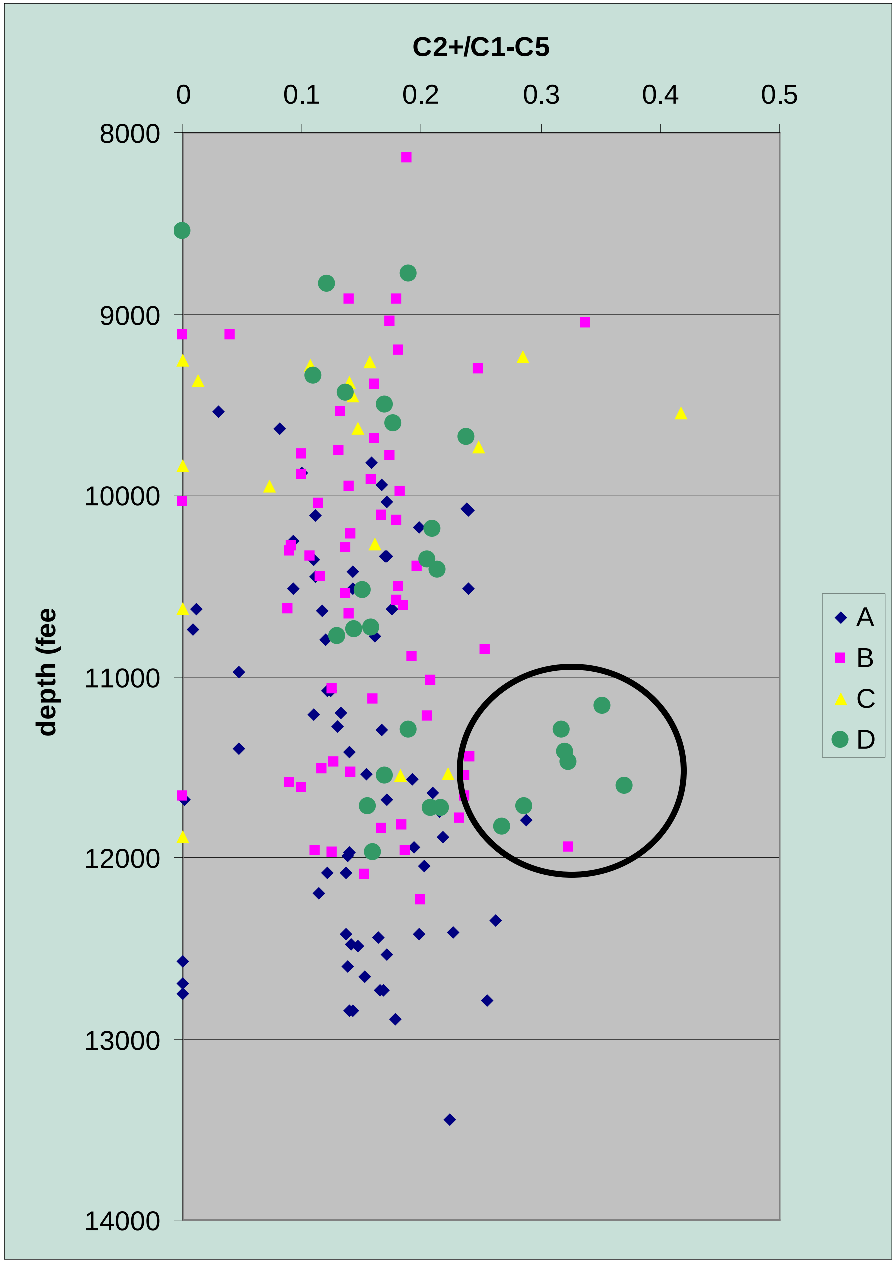
2.5
2
1.5
1
0.5
0
-0.5
0
1
2
3
4
5
6
ln (C1/C2)



Mud gas samples
-70
-65
-60
-30
-25
-20
mixed gas
associated gas (oil)
associated gas (condensate)
non-associated (marine)
non-associated (humic)
8000 - 9000
9000 - 10,000
10,000 - 11,000
-60
-55
-50
-45
-40
-35
-30
-25
-20
δ13C methane
δ13C ethane



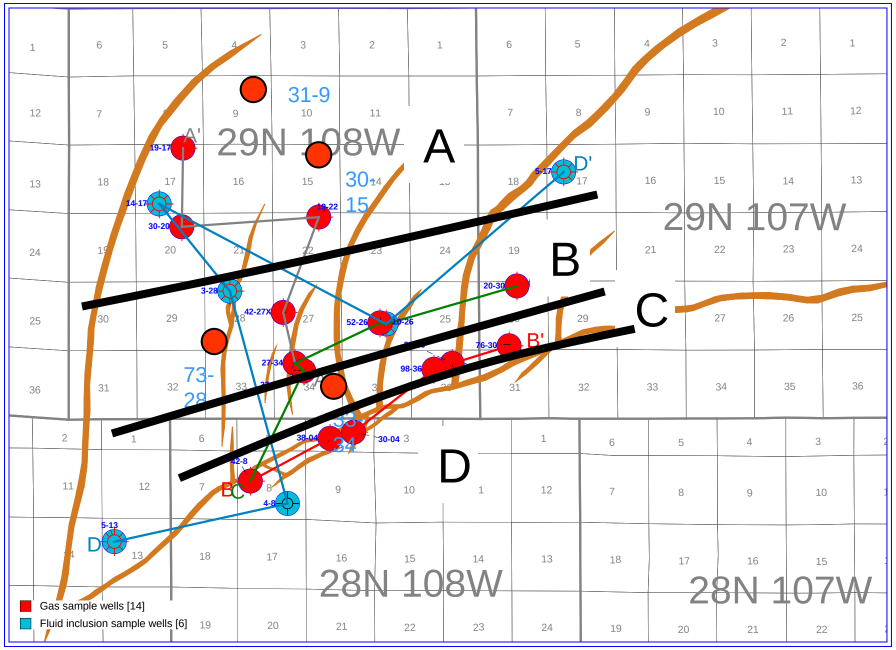
Well head gas samples
-70
-65
-60
-55
-50
-45
-40
-35
-30
-25
-20
mixed gas
associated gas (oil)
associated gas (condensate)
non-associated (marine)
non-associated (humic)
-60
-55
-50
-45
-40
-35
-30
-25
-20
-15
δ13C methane
δ13C ethane



No differentiation by distance from southern fault.

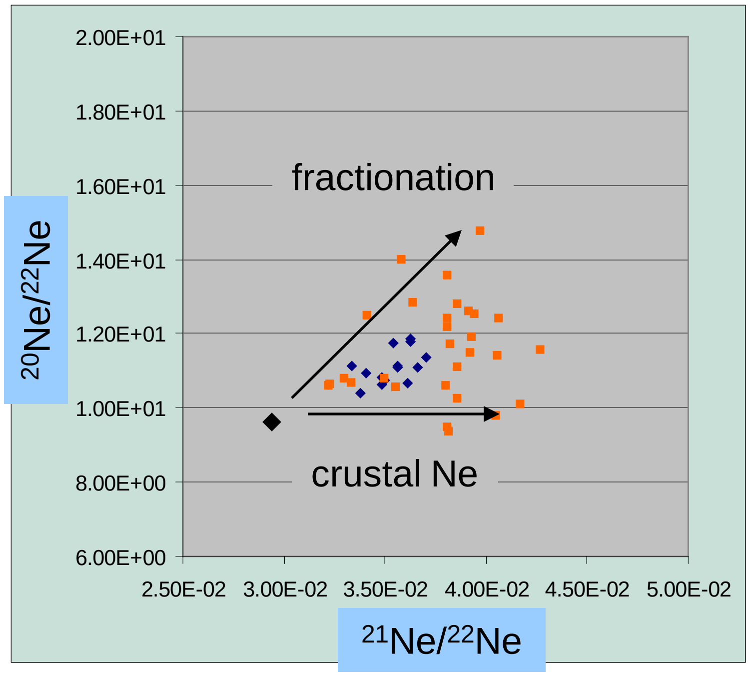
Samples near the fault (group 5) may be wetter than average.

Inference is the southern boundary fault may be source of gas.

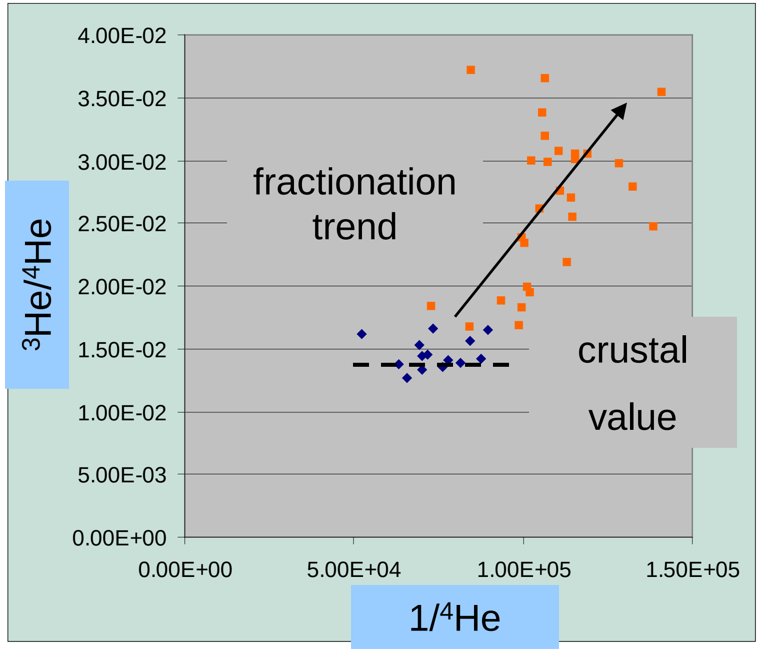


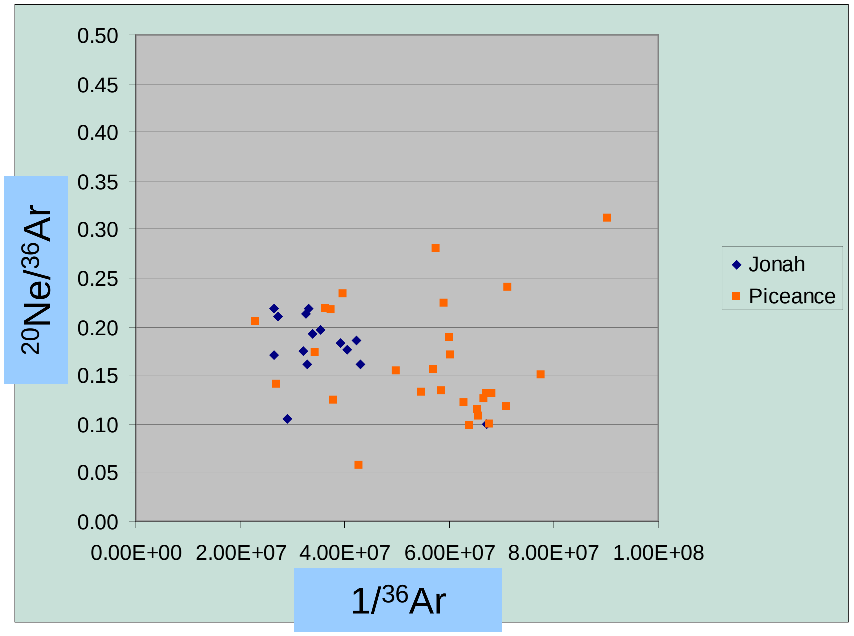
Evidence from noble gas data:

1) Jonah is a relatively simple system.
2) Piceance shows evidence of complex fractionation and mixing.



Jonah Piceance





Project Status - Future Plans

Field data – sampling campaign at Jonah, Piceance, Greater Natural Buttes this summer

Hydrous pyrolysis experiments –

- characterize compositions of gases from different source rocks at different thermal maturities
- will start in next month; expect results by mid-late summer

MPath modeling –

- modeling flow paths and compositional changes
- will start in the summer

Summary:

• Scientific premise and approach are valid … so far.

• Can rule out diffusion model.

• Gas compositions suggest mix of marine and coaly sources, possibly with marine sources dominant.

• Tentatively identify a fault conduit for gas migration in gas compositions and fluid inclusion data; gas compositions linked to pressure compartments.

• Complexity for the Piceance system suggested in hydrocarbon and noble gases.