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

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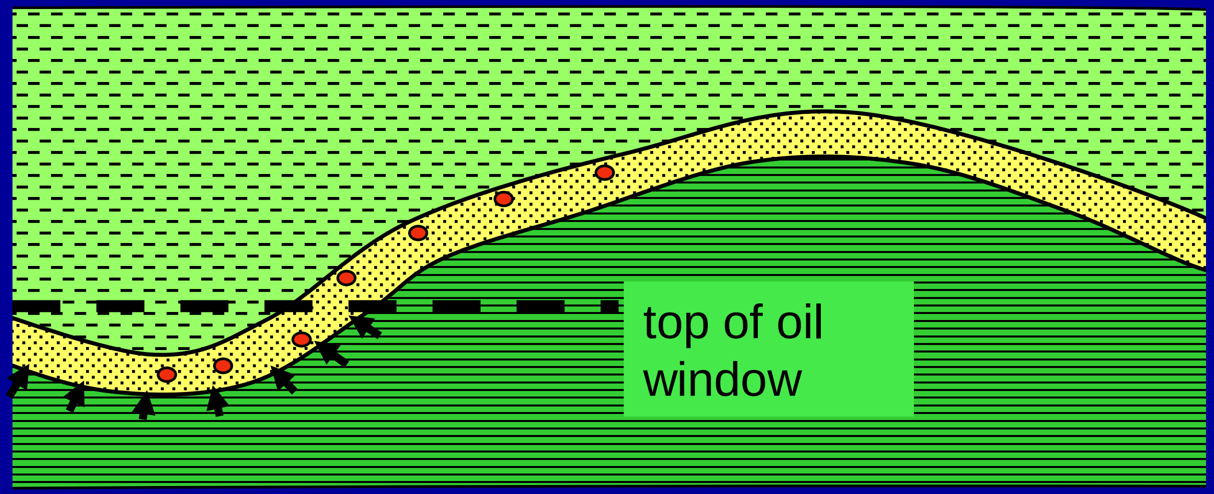
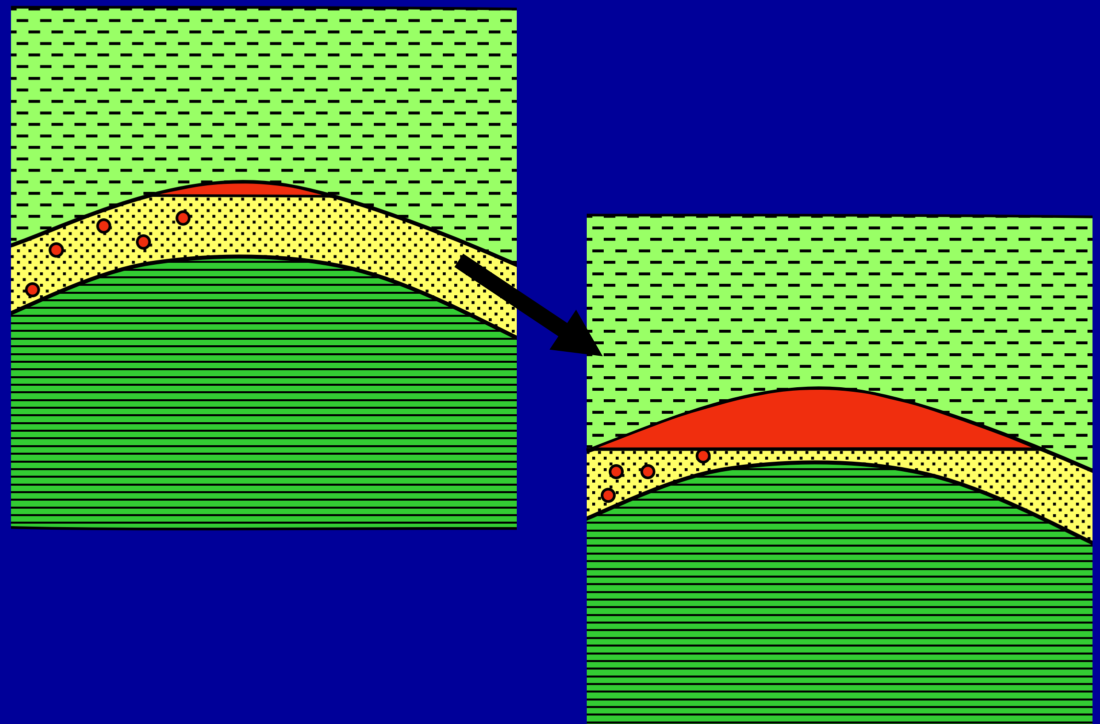
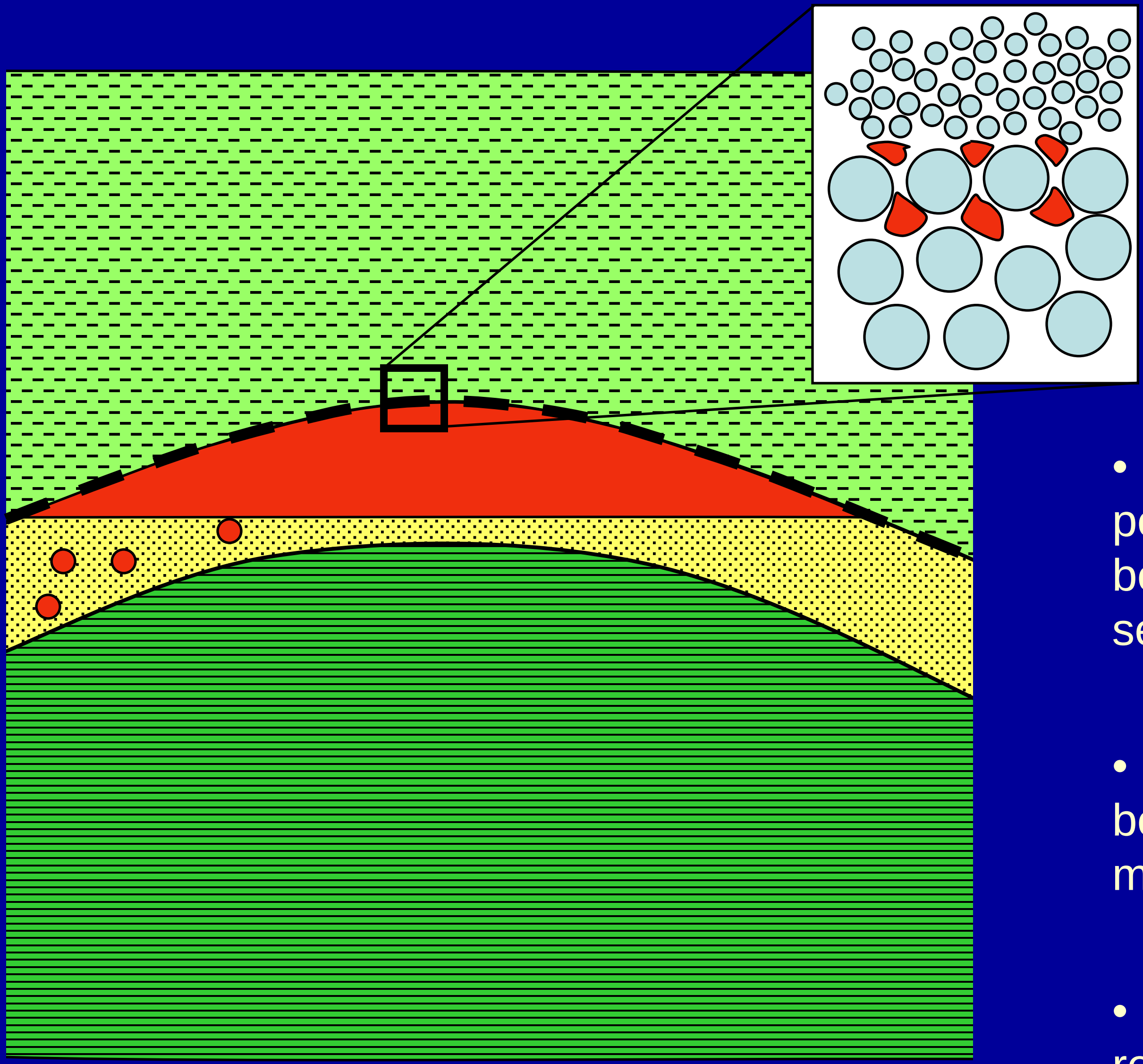
Filling processes in conventional traps and reservoirs



Hydrocarbons are expelled from source into carrier bed and migrate to trap.



Traps fill from top-seal downward.

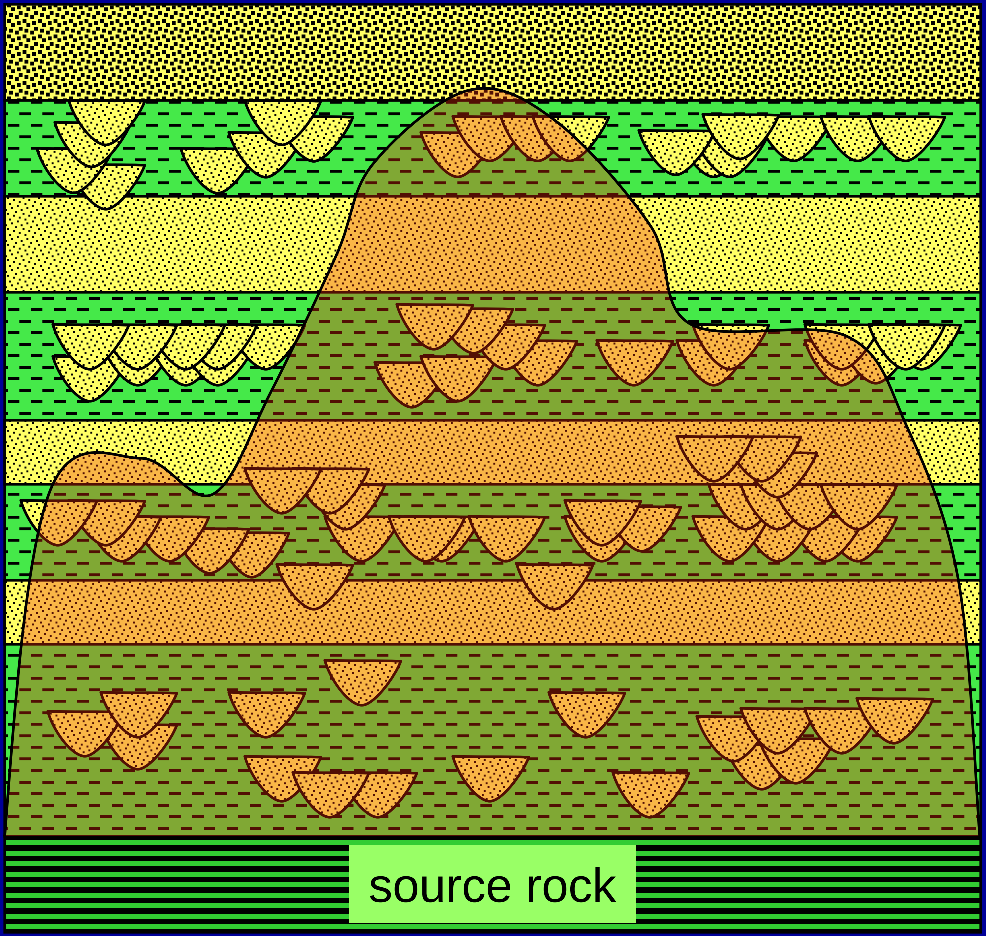


- Top seal relies on a permeability contrast between reservoir and sealing material.

- Reservoir and carrier beds are high permeability materials;

- Migration takes place relatively quickly.

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

Problems associated with tight-gas-sand reservoirs

1. Top-of-gas and top-of-producible-gas cannot be predicted from one field to another without test data; well logs can be ineffective, especially near top-of-gas → risky exploration outside of known accumulations.

2. Gas pressures cannot be effectively predicted without test data.

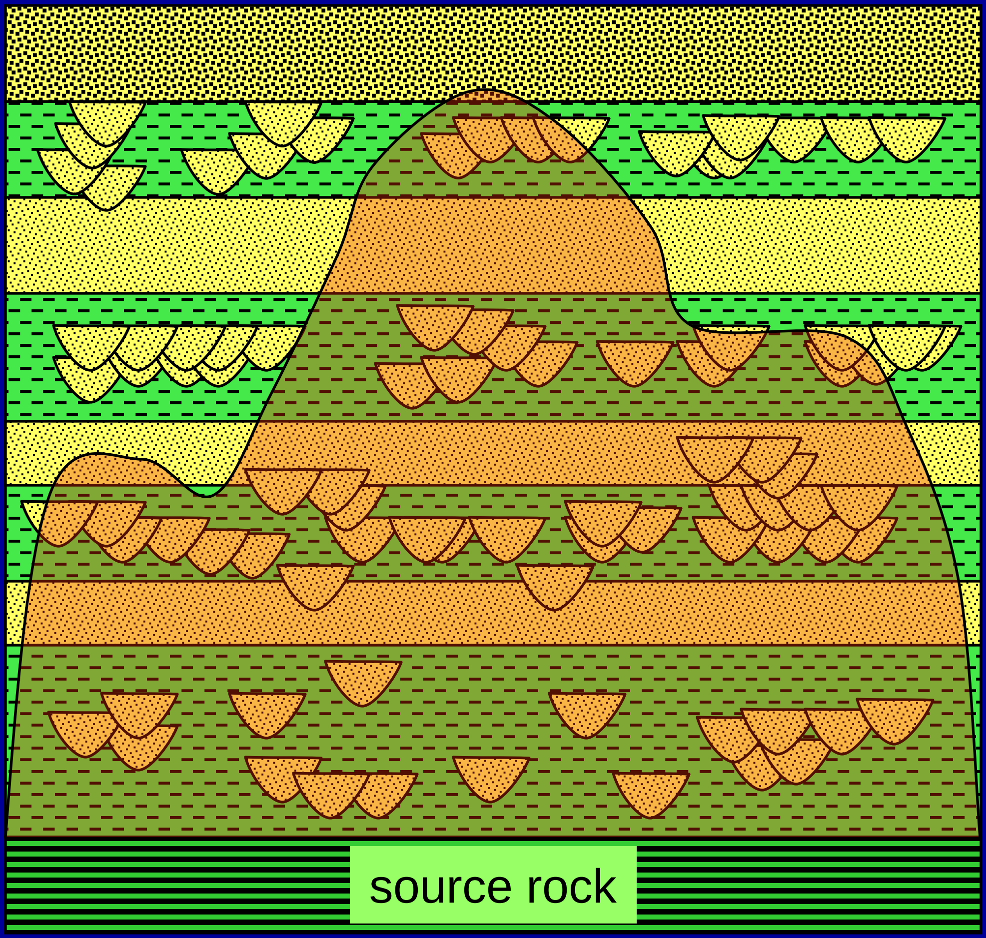
3. Gas composition cannot be effectively predicted without test data; → implications for commercial value, drilling.

4. Predicting reservoir compartmentalization is problematic → issues of reservoir drainage.

5. Limited geophysical capability → detecting gas fronts and active migration.

6. Is the basin-centered gas model correct? Implications for reserve assessments.

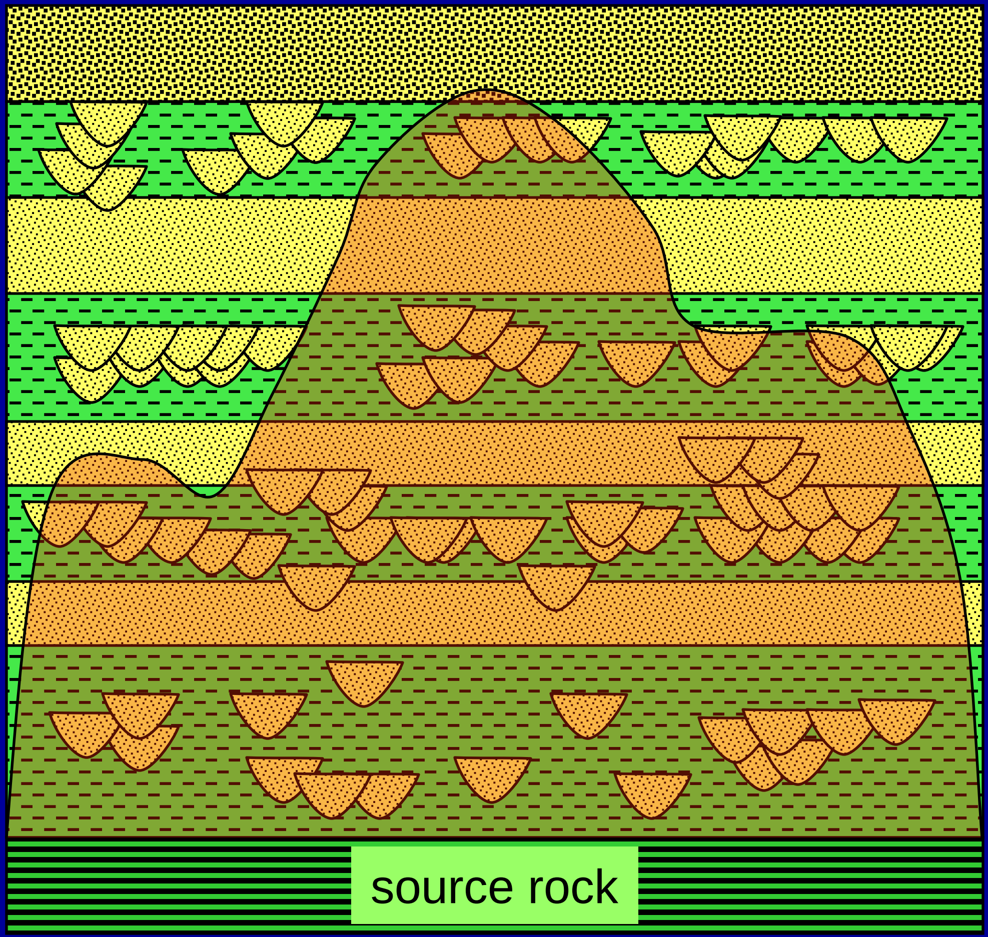
Research Objectives



Apply geochemistry of natural gas to:

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

Current Status of Technology

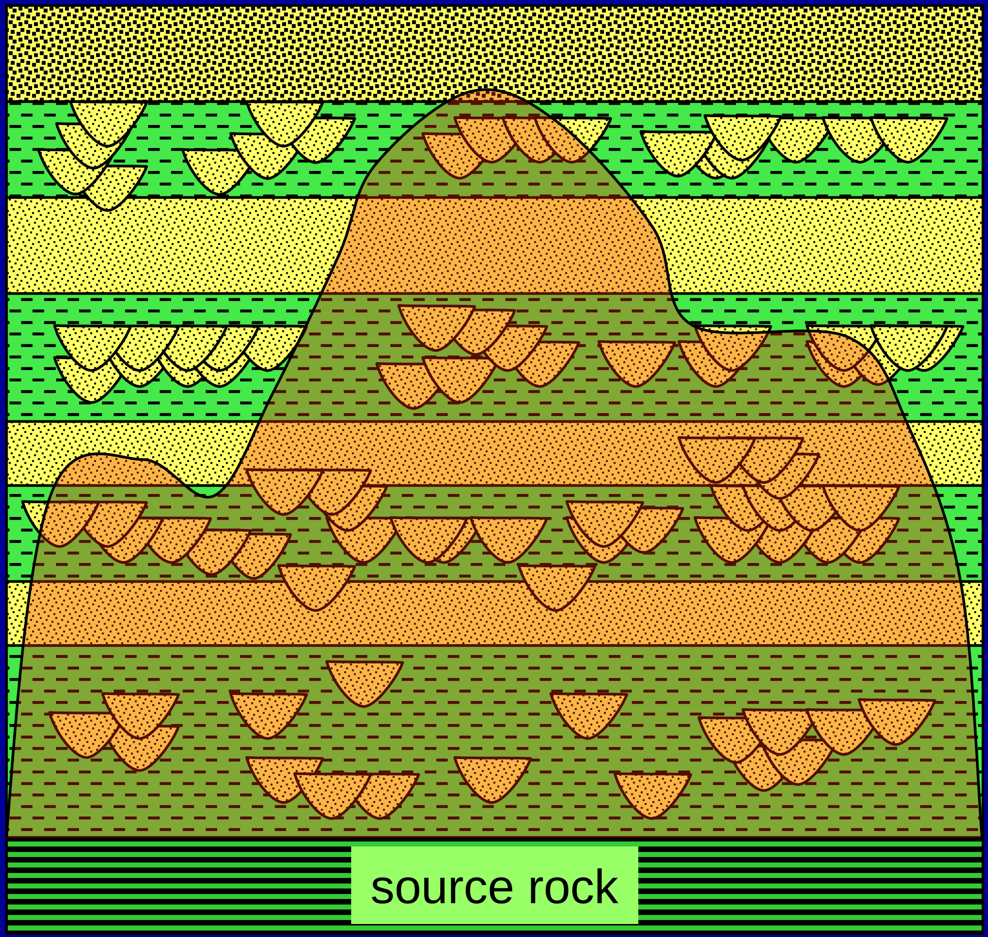


No substantial public database of gas compositions

Considerable porosity, permeability, mercury injection – capillary pressure data

But very limited thermal maturation / hydrocarbon generation modeling

And no rigorous migration modeling.



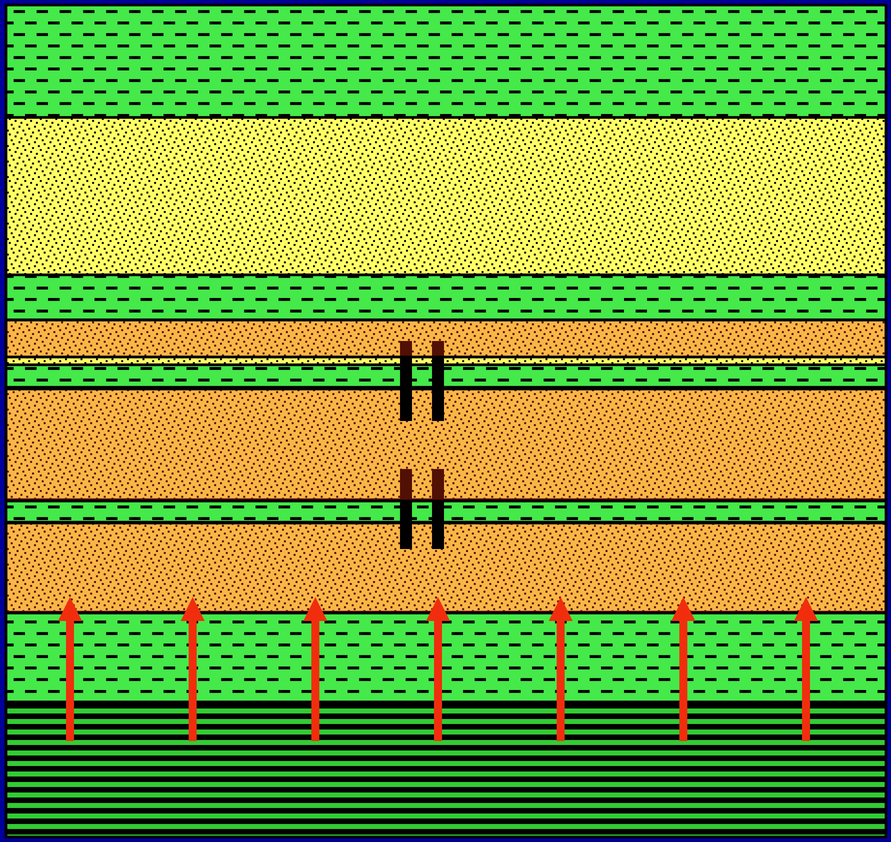
How does gas migrate into and fill these reservoirs?

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.

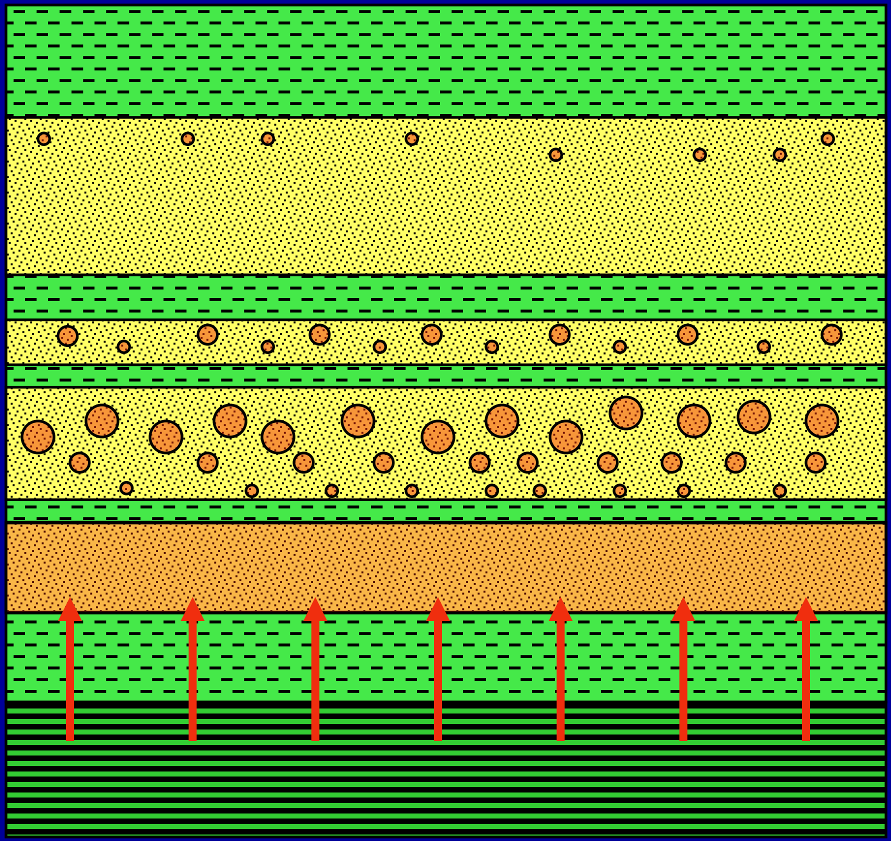
3) Gas migrates along faults.



Model 1 - Self-fracturing:

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.

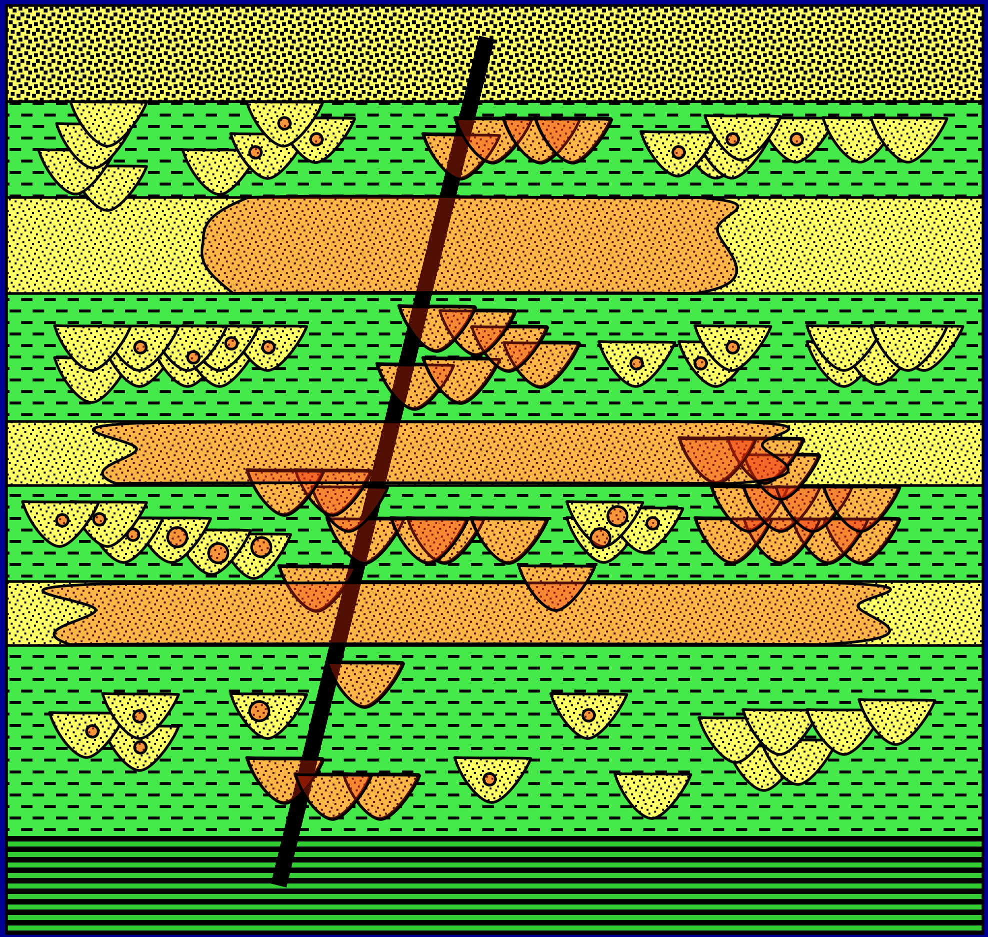


Model 2 - Diffusion:

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

Diffusion is driven by pressure differences and concentration gradients.

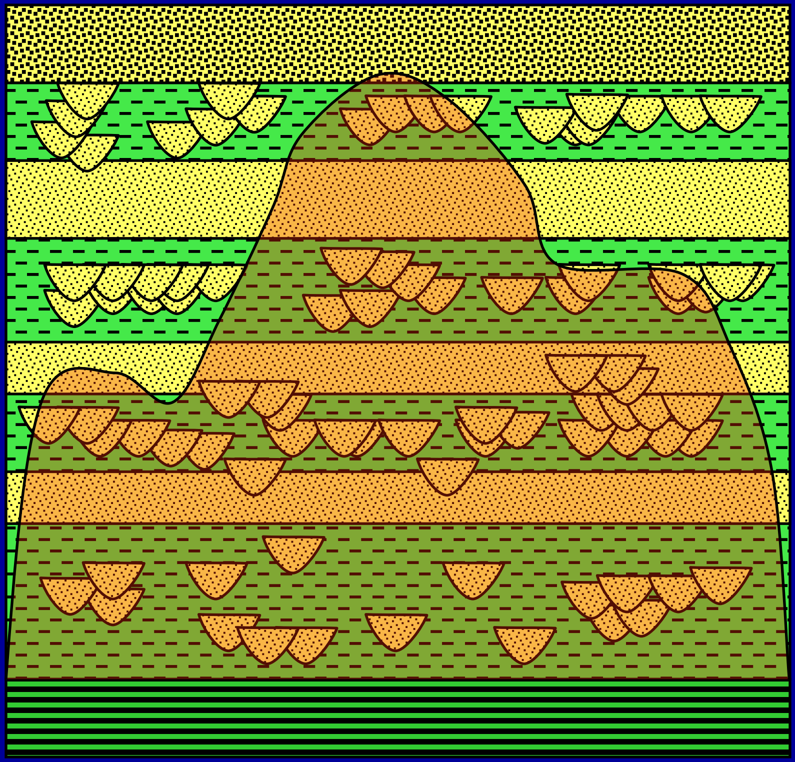
Top-of-gas controlled by: (1) unevenly distributed gas inputs into lowermost reservoir; (2) initial differences in gas distribution; (3) diffusion / permeability pathways.



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.

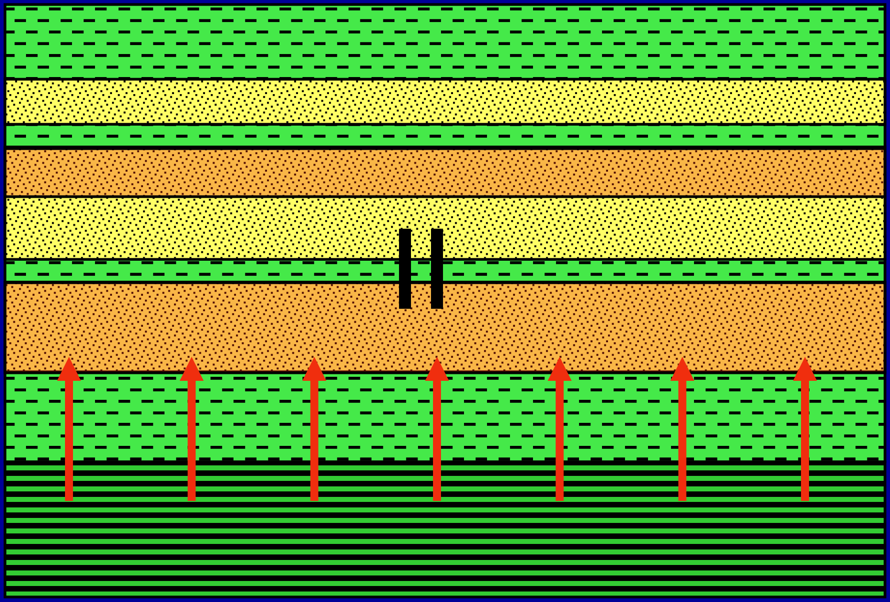


Hypothesis –

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

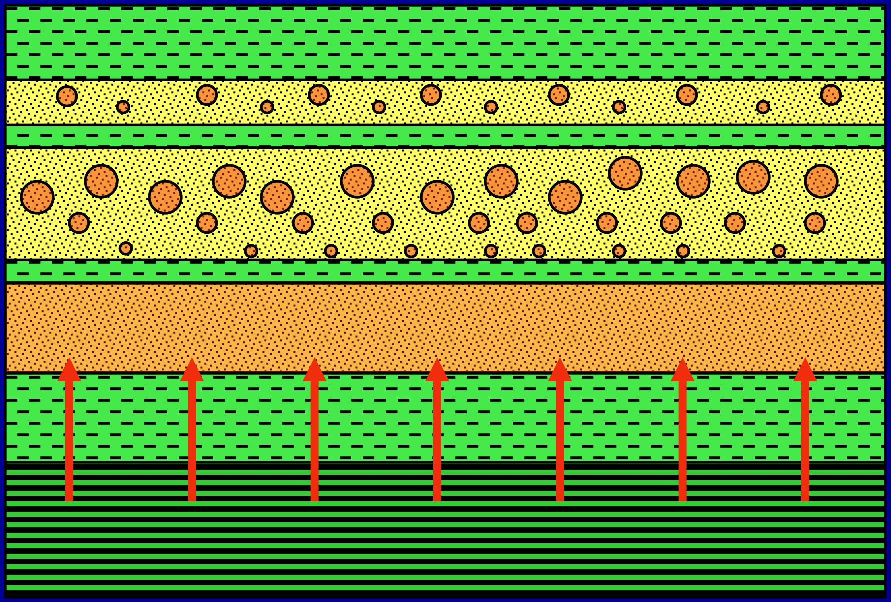
By analysis of an extensive and complete dataset, we can identify the critical mechanism(s).

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



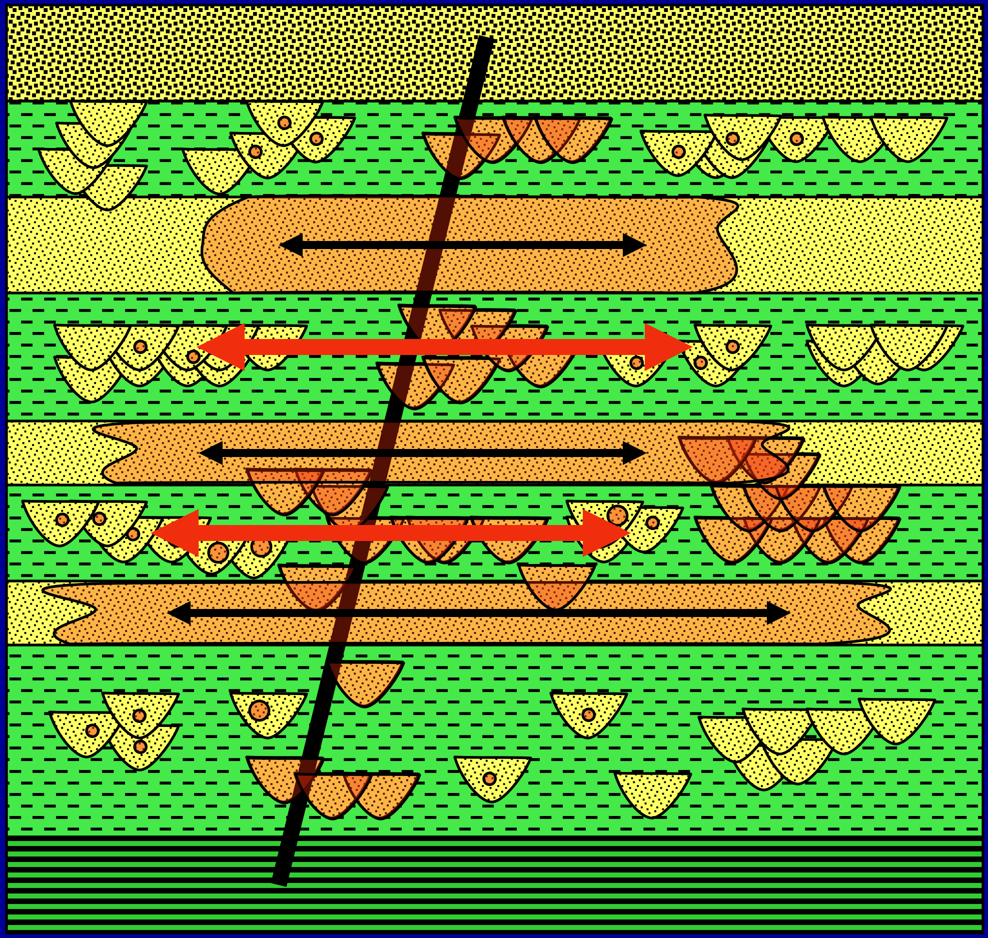
frac model

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

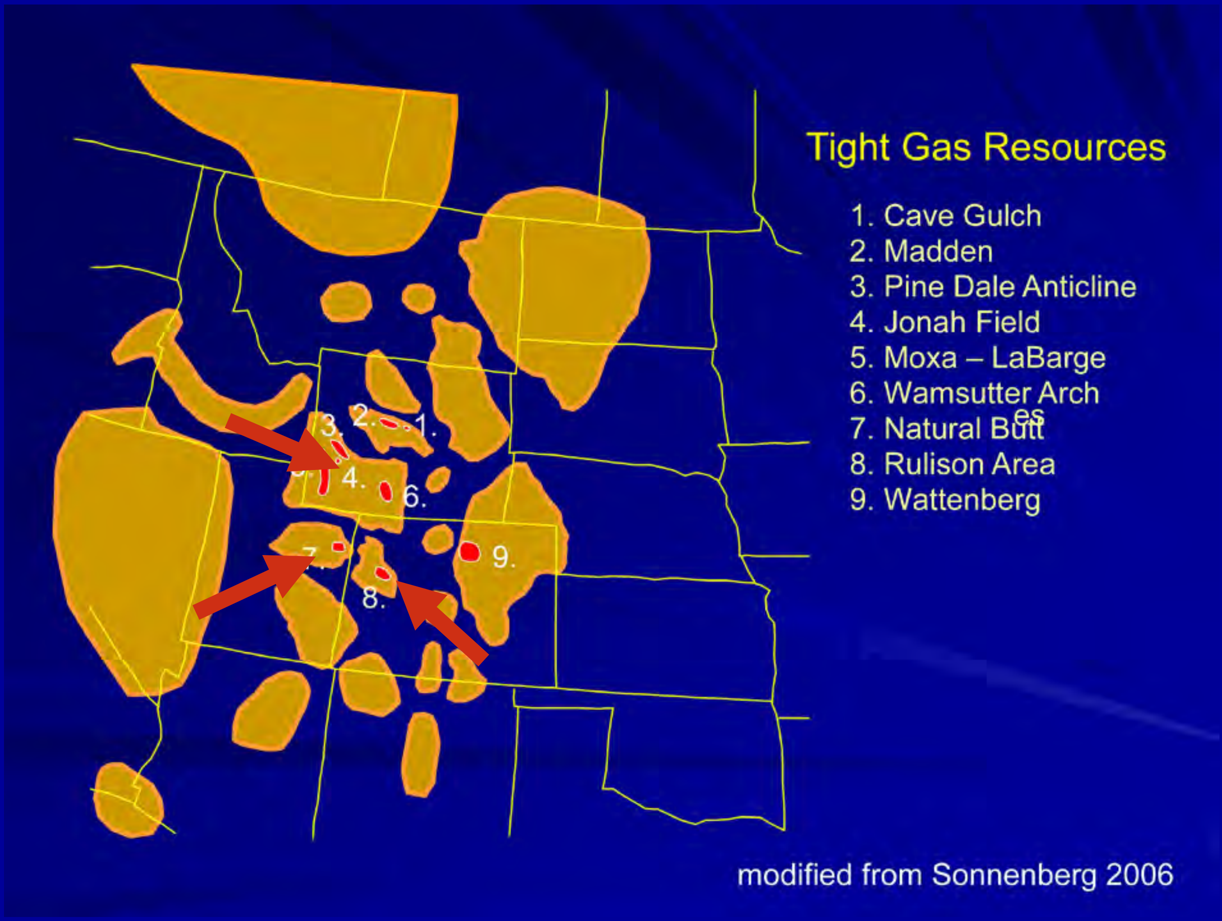
Advective transport of gas; little lateral isotopic fractionation

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.
- 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

Sample Database

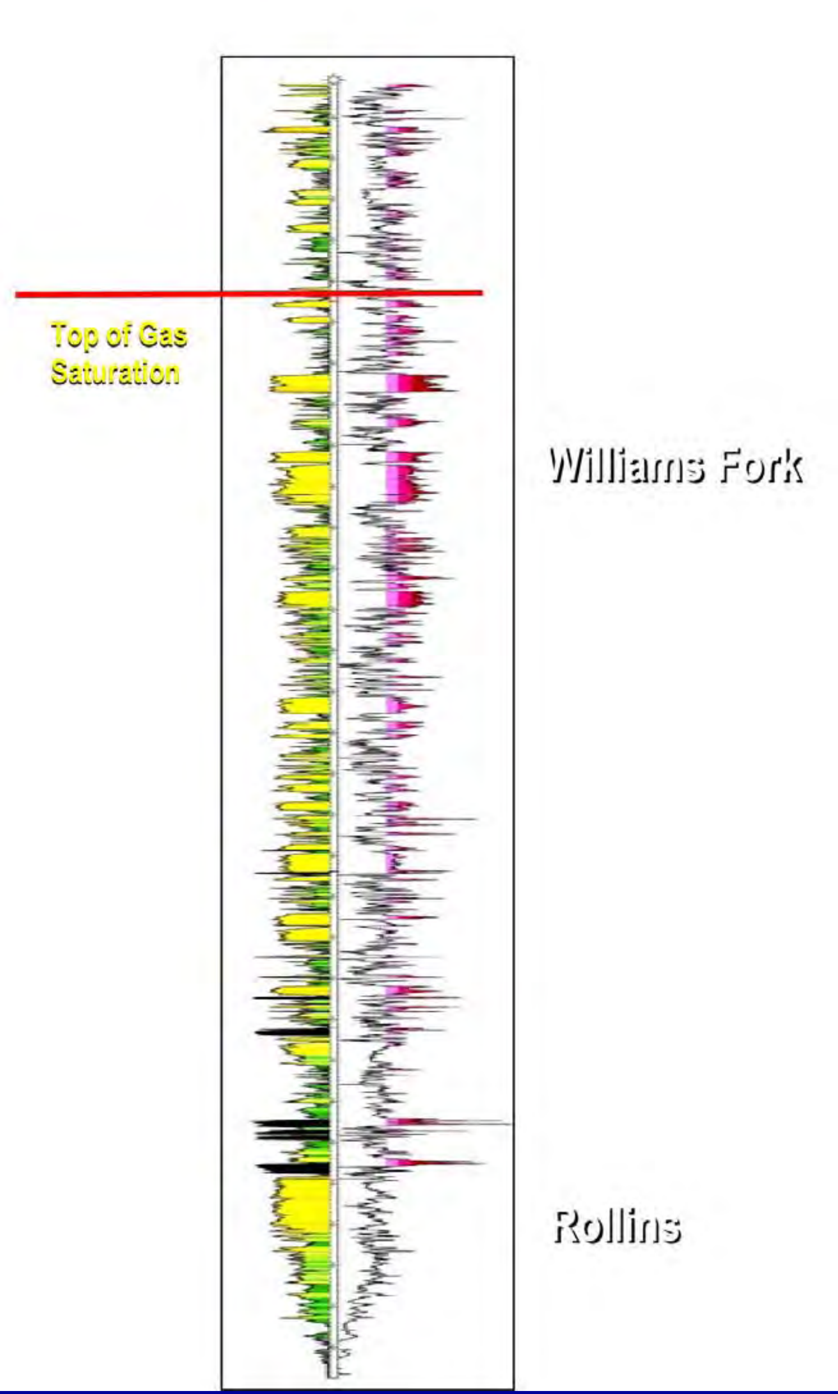


Fields in the study:

1) Jonah Field (Encana)

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

3) Greater Natural Buttes (Anadarko)



Sampling strategy

- 6 to 8 wells in Jonah Field, 15 to 20 wells in the southern Piceance Basin fields and 2 wells at Greater Natural Buttes Field
- 30+ mud gas samples per well in initial suite of wells
- Production test samples where operator is testing isolated zones
- Produced gas sample where operator is producing from isolated zones
- Cuttings samples from subset of wells


solube
Gas Sampling System
ISOTECH
NOTE:

Analytical Program

1. All samples (~ 1000) will be analyzed for bulk gas composition (C1 to C4, CO_2, N_2)

2. ~ 100 samples will be analyzed for compound-specific isotopic composition ($\delta^{13}C$, δD) on hydrocarbon gases and CO_2

3. ~ 50 samples will be analyzed for N_2 isotope and noble / radiogenic isotopic composition, including He, Ne and Ar

4. Analyze gases in cuttings from 12 wells (~400 samples)

Compositions will be mapped across the fields and related to stratigraphy, structure, temperature and reservoir connectivity.

Key Personnel

- Dr. Nick Harris, CSM – project coordinator, advisor to Ph.D. 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

– will work with us on model migration effects, provide training in MPath

Fluid Inclusion Technology

– will analyze gas compositions in cuttings samples from 12 wells

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

Samples and Data

Jonah Field – Encana

Piceance Basin fields – Williams Co. and Bill Barrett Corp.

Greater Natural Buttes Field – Anadarko Petroleum

Financial Cost Match

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

Value of financial cost-match: $185,000

Progress to date:

Tech transfer – underway.

- Project website set up.
- Initial presentations scheduled at AAPG, GCAGS meetings.

Collection of gas samples – underway.

- An initial set of 60 samples collected;
- Sampling protocol established for Jonah and Piceance Basin fields.
- Ph.D. student trained in sampling.

Deliverables:

Technology status document.

Technology transfer – website, presentations at meetings, publications, basis for a short course.

- Public database of gas compositions.
- Presentations and papers describing models for gas migration.
- Presentations and papers assessing basin-centered gas model.
- Presentations and papers describing methodology for application of gas compositions.

Progress to date:

Technology status document submitted.

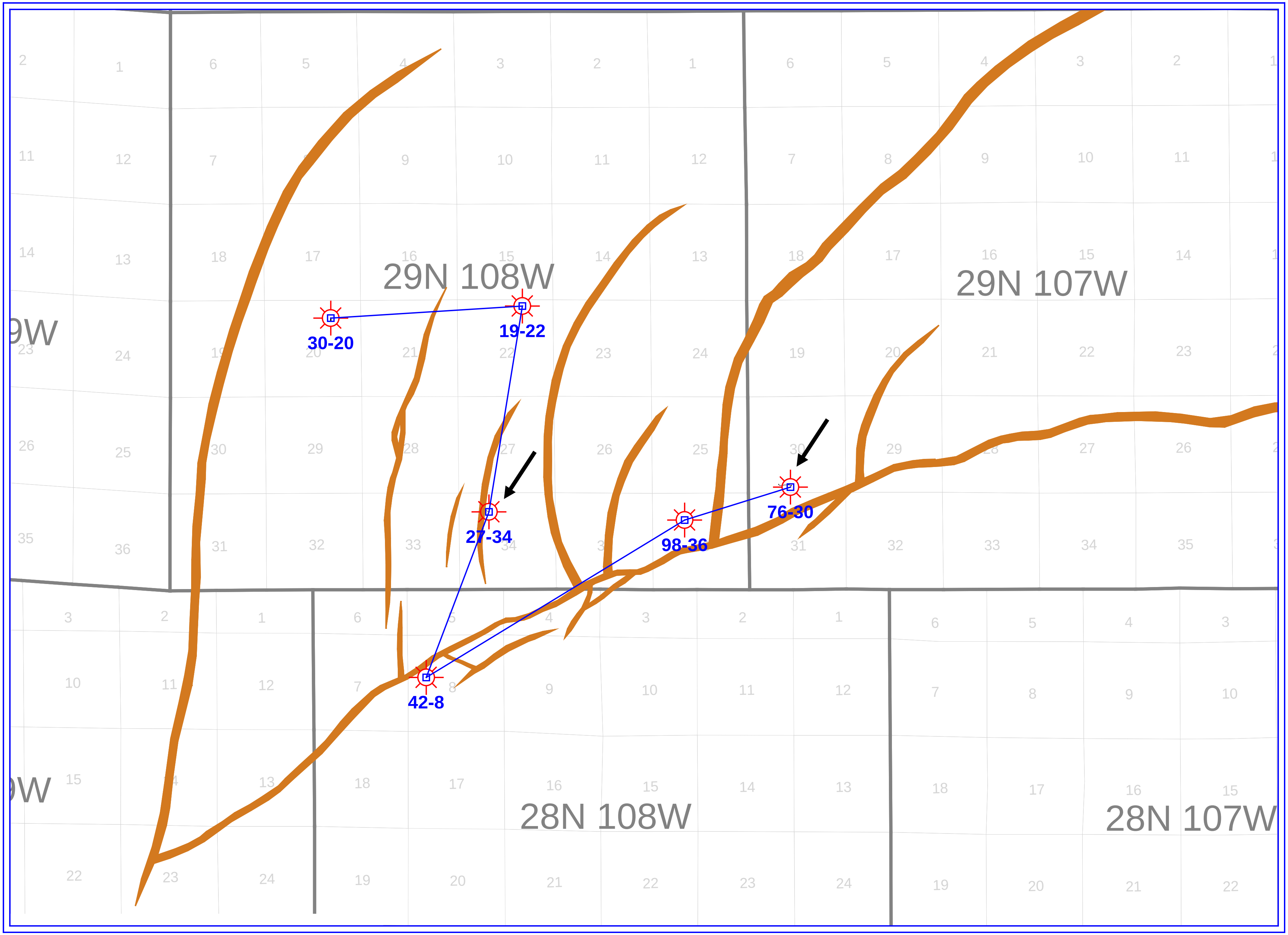
Project website is online, with resources for the general public.

Analysis of gas samples – underway.

- Initial set of bulk gas and compound-specific isotopic analyses – complete.

Migration modeling – underway

- Training in MPath is complete.
- Ph.D. student now developing a preliminary migration model for Jonah Field.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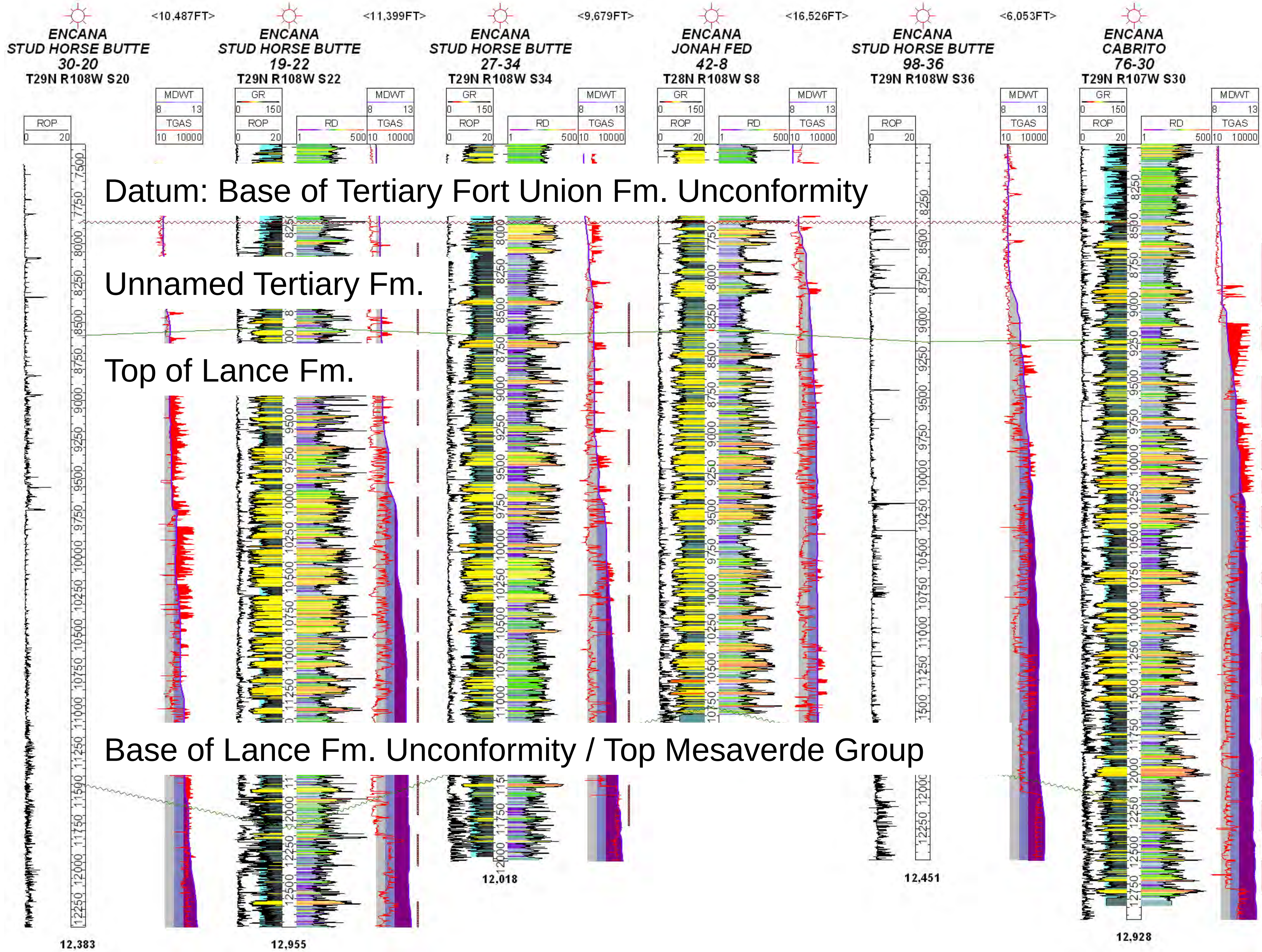
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ROP
MDWT
TGAS
GR
RD
Datum: Base of Tertiary Fort Union Fm. Unconformity
Unnamed Tertiary Fm.
Top of Lance Fm.
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12,383
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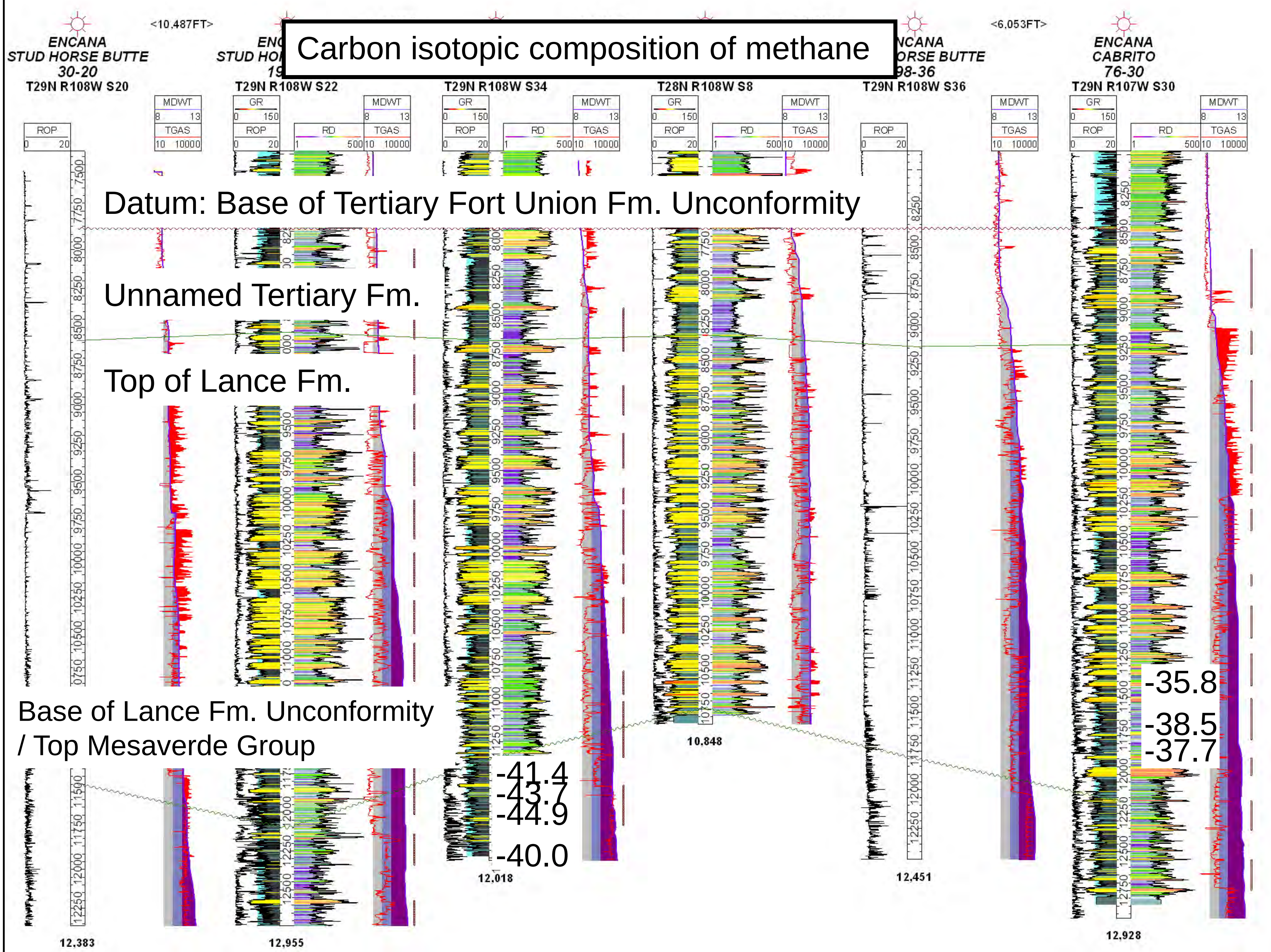
12,928

Carbon isotopic composition of methane



Technical Issues:

Gas sampling –

- Companies (EnCana, Williams) have been extremely helpful.
- Sampling program is technically feasible but slower than expected.
- Will require a concerted field effort during the summer (> 8 man-weeks).
- Decrease in rig count reduces sampling efficiency.

Summary:

- Scientific model is valid … so far.

- Research approach is workable …so far.

- Progress depends on developing a substantial database

  - This will require a major field effort from June – September and additional manpower (grad student + field assistant).

- Good cooperation from companies and attracting continuing industry interest

  - One additional company (Marathon) signed up.