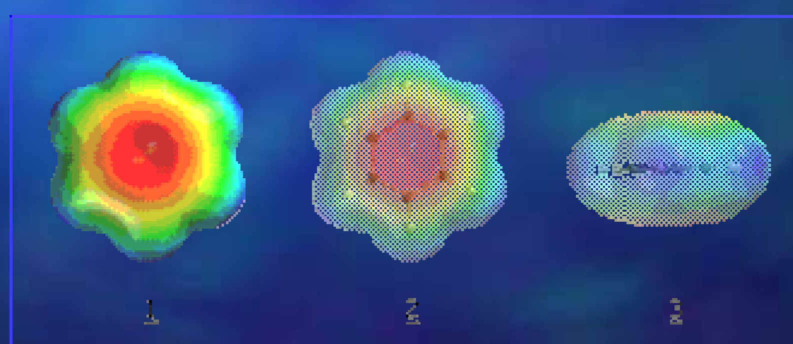
GEOCHEMISTRY OF TRENTON/BLACK RIVER GASES IN THE APPALACHIAN BASIN

A PRELIMINARY REPORT



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  - Isotech Laboratories
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  - Fortuna Energy Inc.
  - Hay Exploration
  - K Petroleum
  - CGAS Exploration/Enervest

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  - Jeff Bowers (Fortuna)
  - Monte Hay (Hay Petroleum)
  - Bill Grubaugh (Enervest)
  - Katharine Lee Avery (WVGS)
  - Dave Harris (KGS)
  - Larry Wickstrom (OGS)
  - Dennis Coleman and Martin Schoell (Isotech)

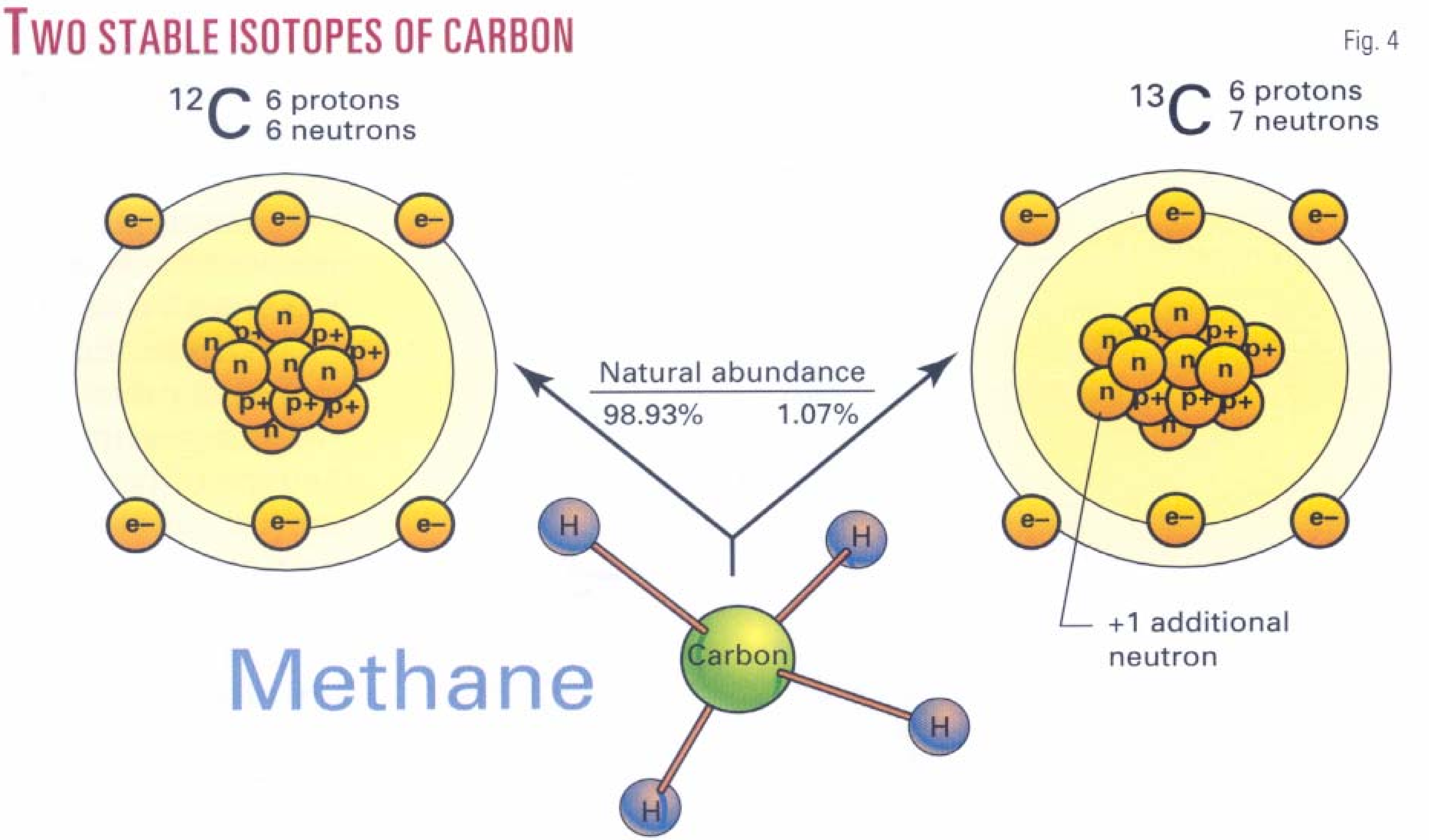
OUTLINE

- Utility of isotope geochemistry in natural gas exploration and development
- Purpose of Trenton/Black River natural gas study
- Natural gas sample distribution
- Results to date
- Preliminary conclusions and future work

UTILITY OF ISOTOPE GEOCHEMISTRY IN NATURAL GAS EXPLORATION AND DEVELOPMENT

- Genetic Information
- Recognize and Quantify Gas Mixing
- Reservoir Identification
- Fault Block Mapping

GENETIC INFORMATION



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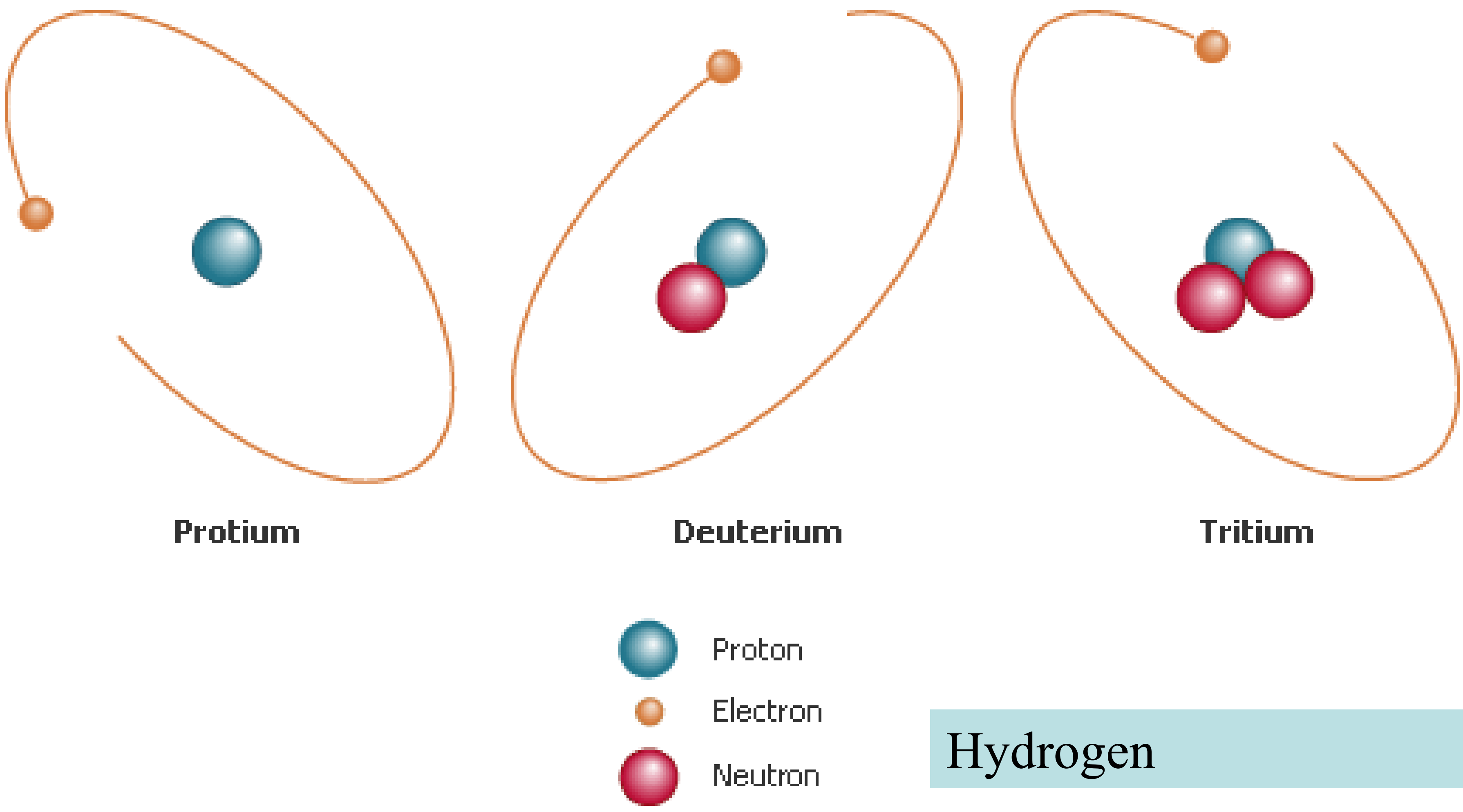
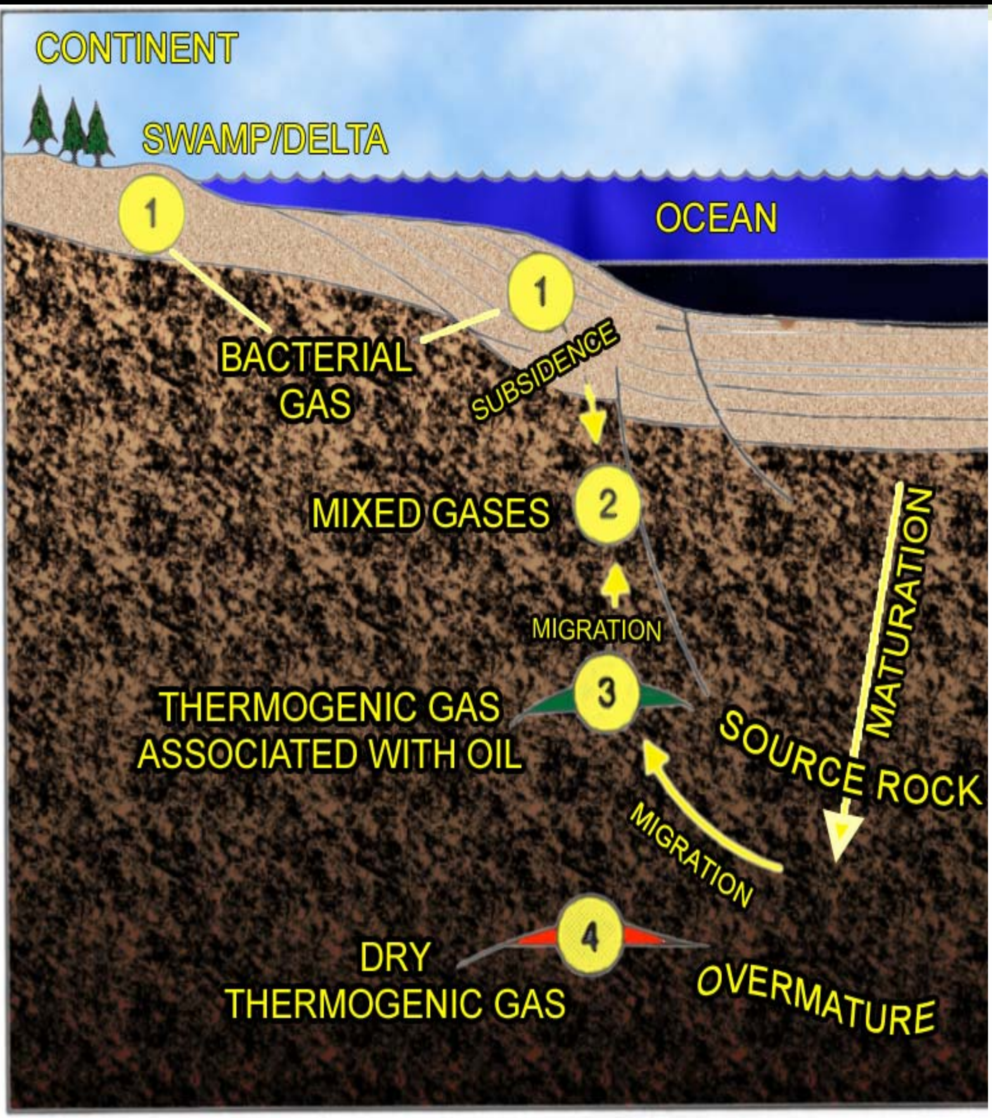
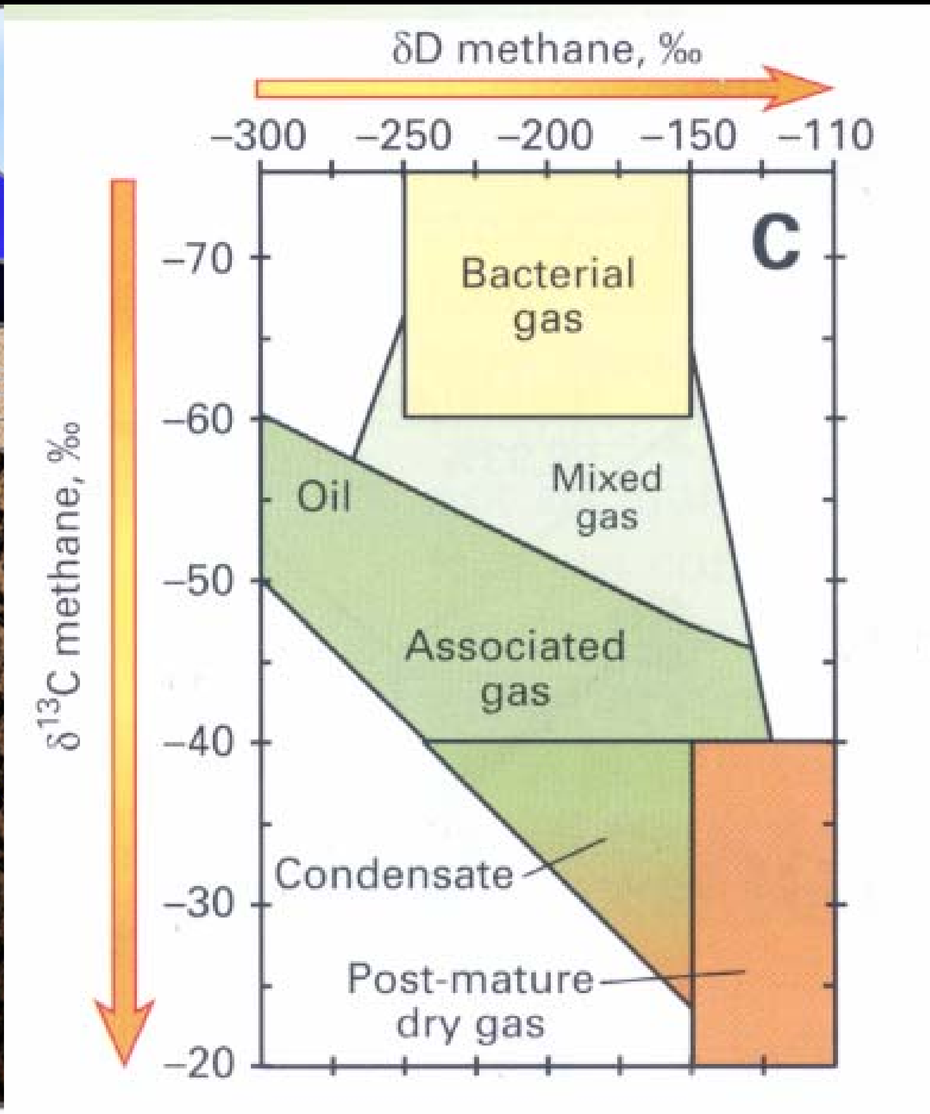


Hydrogen

GENETIC INFORMATION





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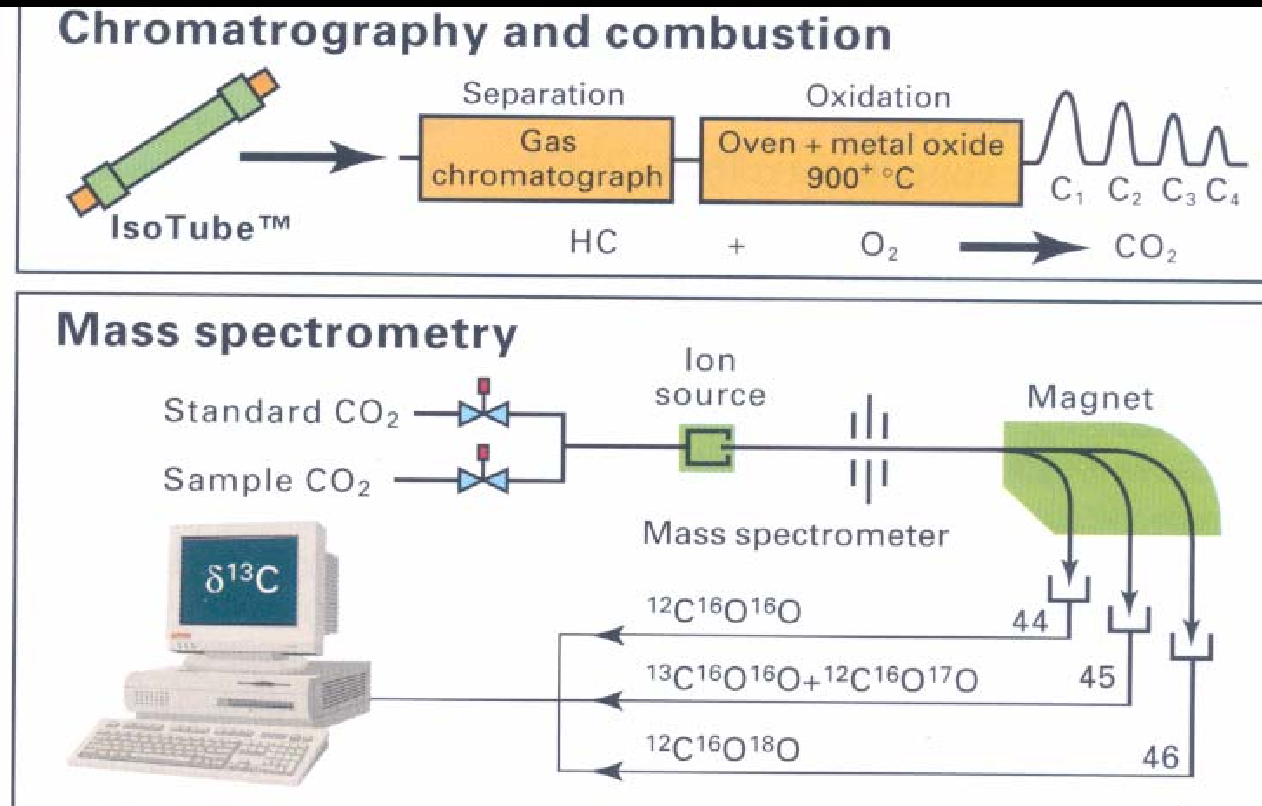


UTILITY OF ISOTOPE GEOCHEMISTRY IN NATURAL GAS EXPLORATION AND DEVELOPMENT

Natural gases vary in chemical and isotope composition as a function of their formation and migration history.

Individual gas components (CH_4 ,C_2H_6 , etc.) can be characterized by their stable carbon ($^{13}C/^{12}C$) and hydrogen ($^2H/^1H$) isotopic compositions

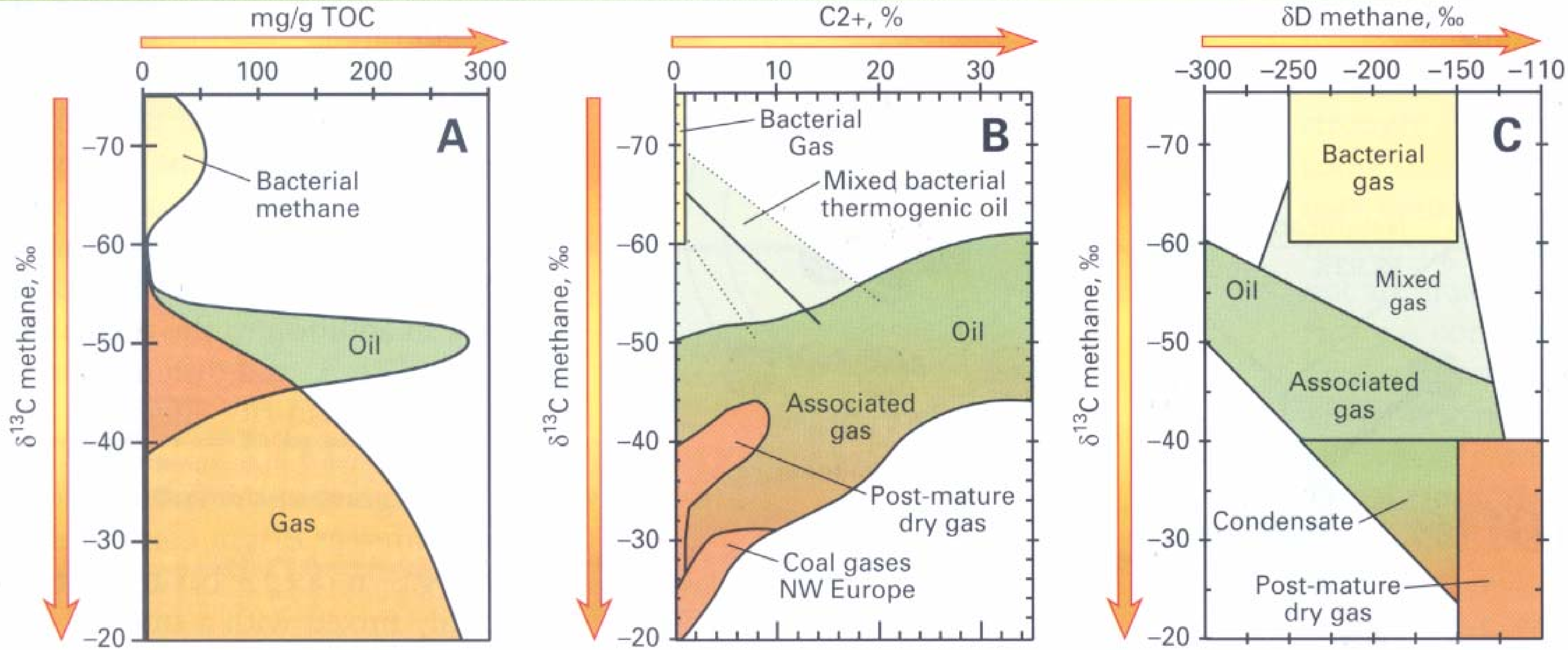
$$\delta\, ^{13}C \text{ (permil)} = [\ (^{13}C/\ ^{12}C)_{sample} / (^{13}C/\ ^{12}C)_{PDB} - 1\ ]\ 1000$$

$$\delta\, D \text{ (permil)} = [\ (D/H)_{sample} / (D/H)_{SMOW} - 1\ ]\ 1000$$

Genetic characterization of gases

Fig. 5

Hydrocarbon formation



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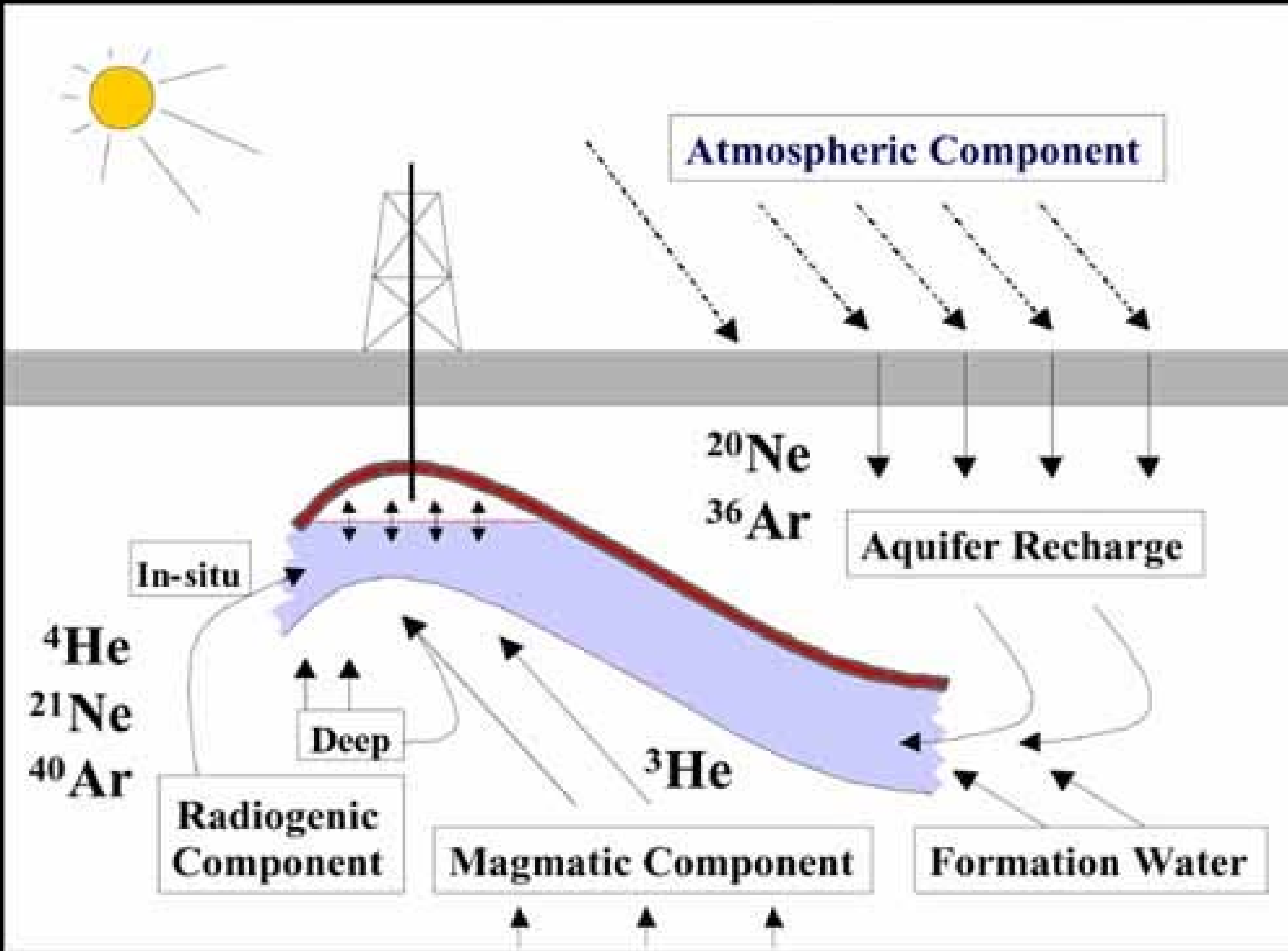
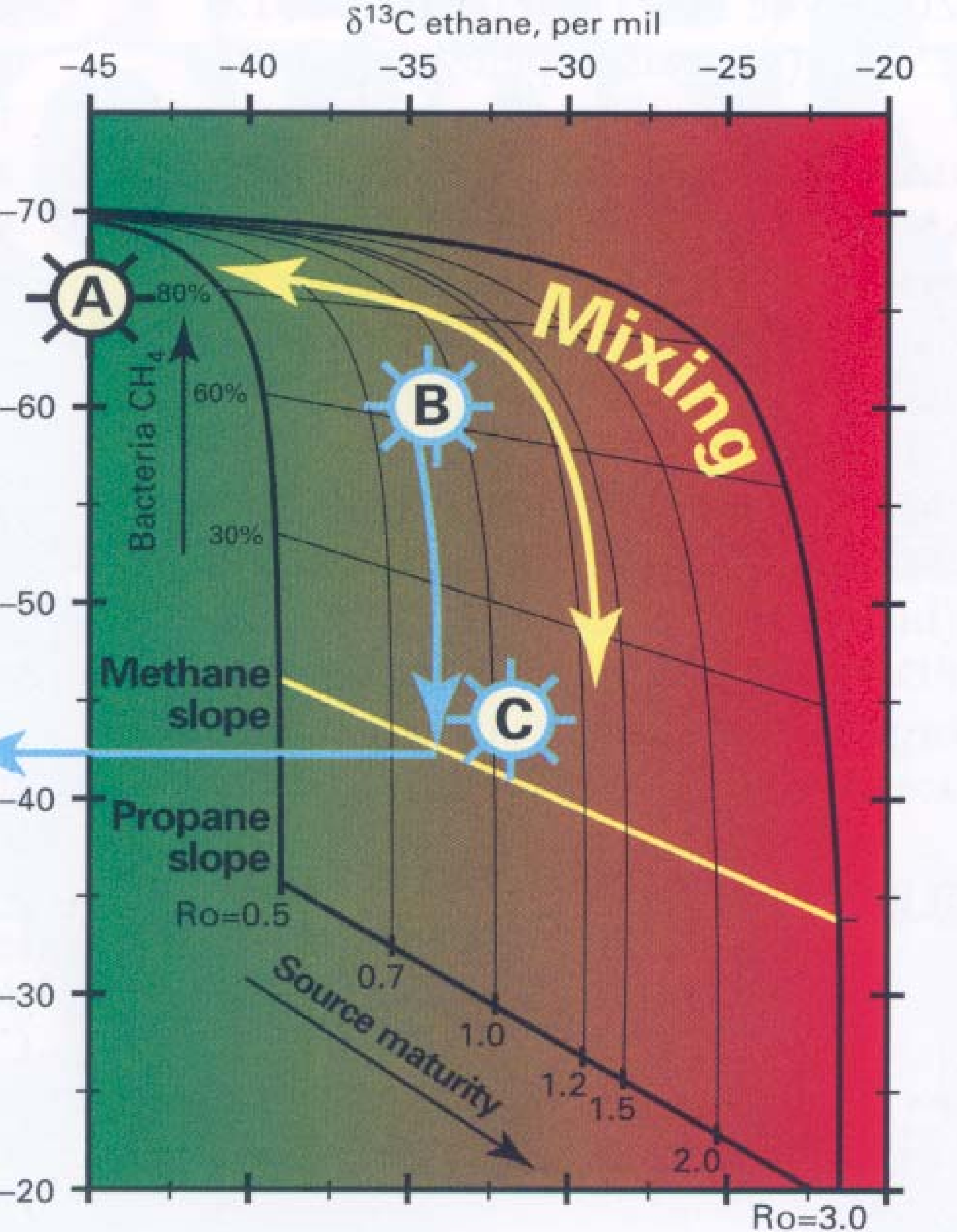
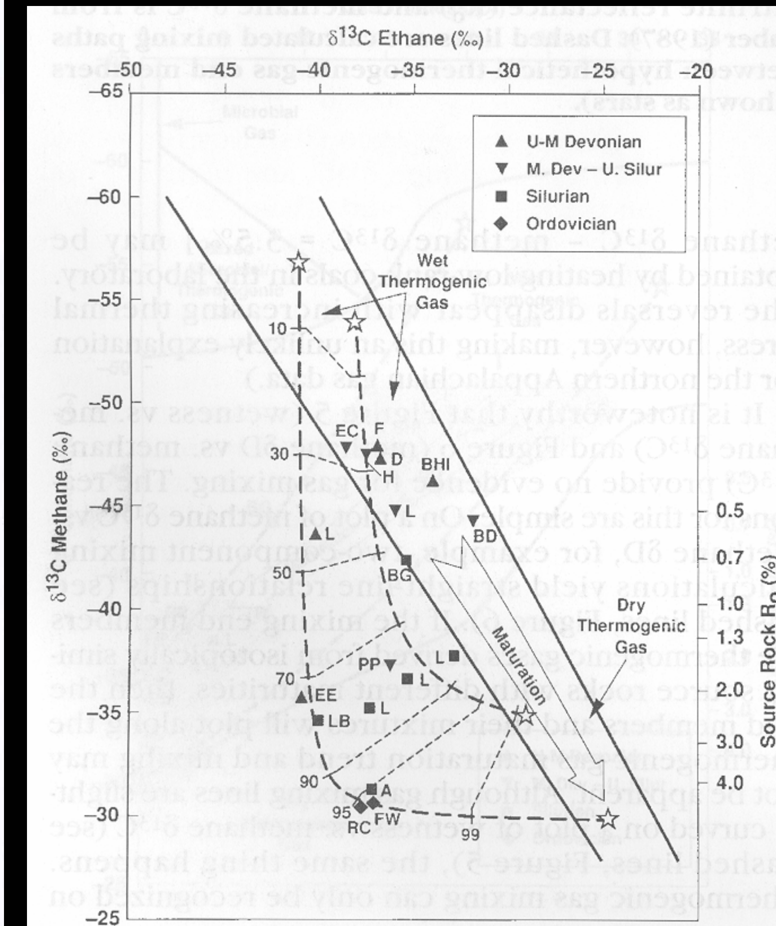


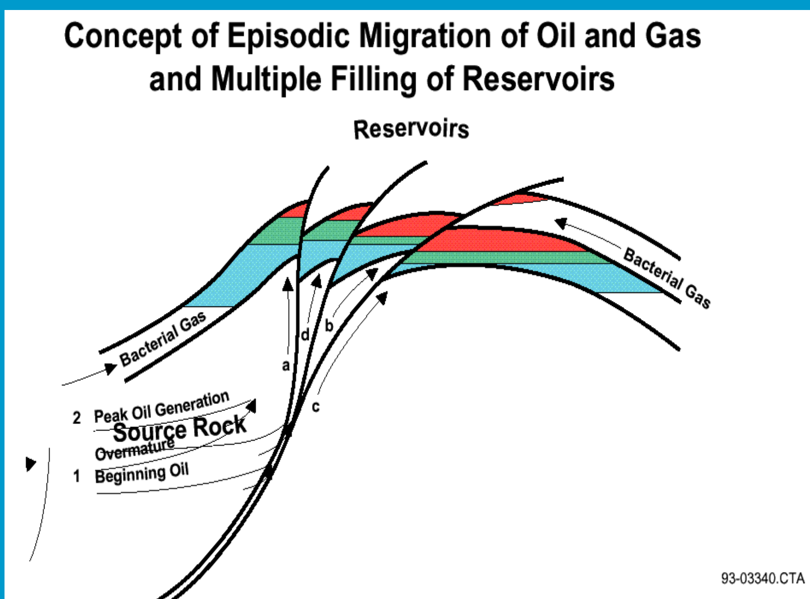


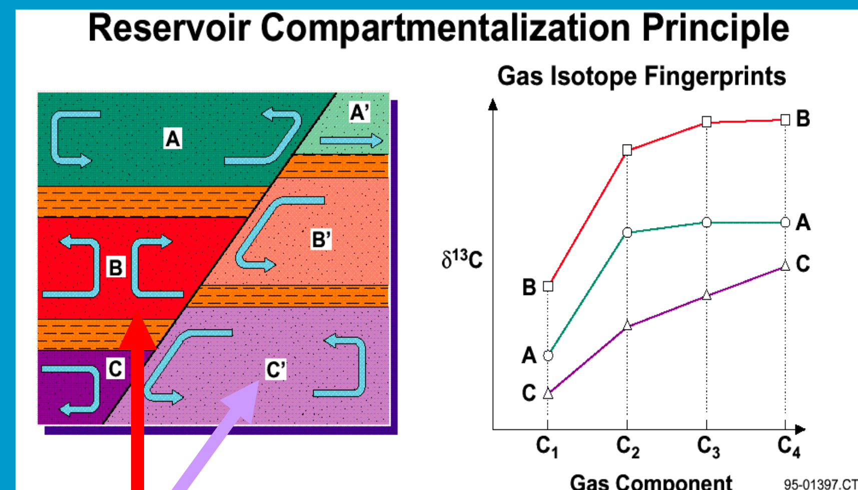
δ13C ethane, per mil
−45
−40
−35
−30
−25
−20
−70
−60
−50
−40
−30
−20
Mixing
A
B
C
80%
60%
30%
Bacteria CH4
Methane slope
Propane slope
Ro=0.5
0.7
1.0
1.2
1.5
2.0
Ro=3.0
Source maturity



δ13C Ethane (‰)
−50
−45
−40
−35
−30
−25
−20
−65
−60
−55
−50
−45
−40
−35
−30
−25
δ13C Methane (‰)
Source Rock Ro (%)
0.5
0.7
1.0
1.3
2.0
3.0
4.0
U-M Devonian
M. Dev – U. Silur
Silurian
Ordovician
Wet Thermogenic Gas
Dry Thermogenic Gas
Maturation
10
30
50
70
90
95
99
EC
F
D
H
BHI
L
BD
BG
PP
EE
LB
A
RC
FW

RESERVOIR COMPARTMENTALIZATION AND FAULT BLOCK MAPPING





Flow Units

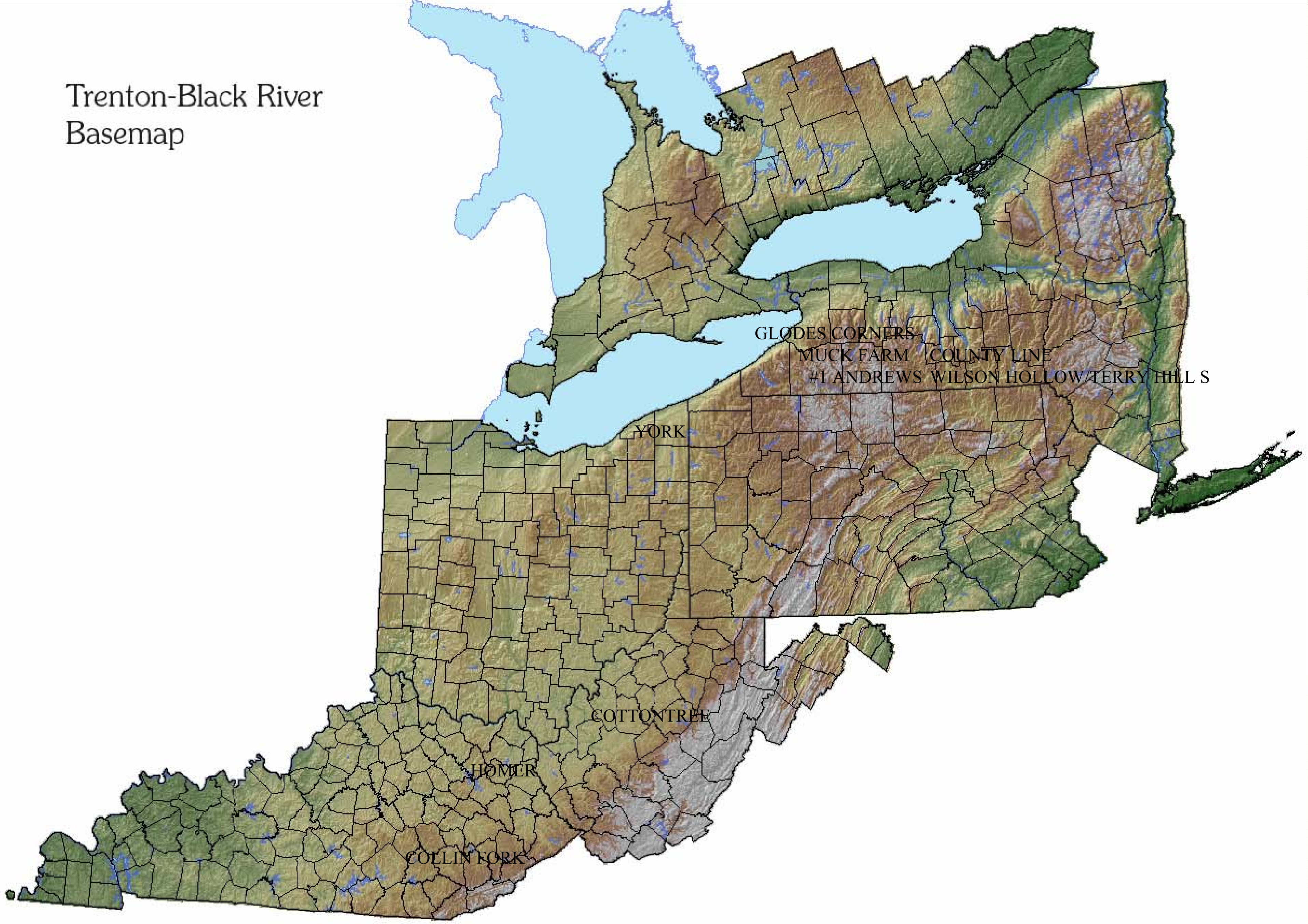
Geochemical Flow Unit Definition

Schoell, 2003 personal communication

PURPOSE OF TRENTON/BLACK RIVER NATURAL GASES STUDY

- Source Rock and Thermal Maturation Data
- Recognize and Quantify Gas Mixing
- Recognize Reservoir Compartmentalization
- Fault Block Mapping

Trenton-Black River Basemap



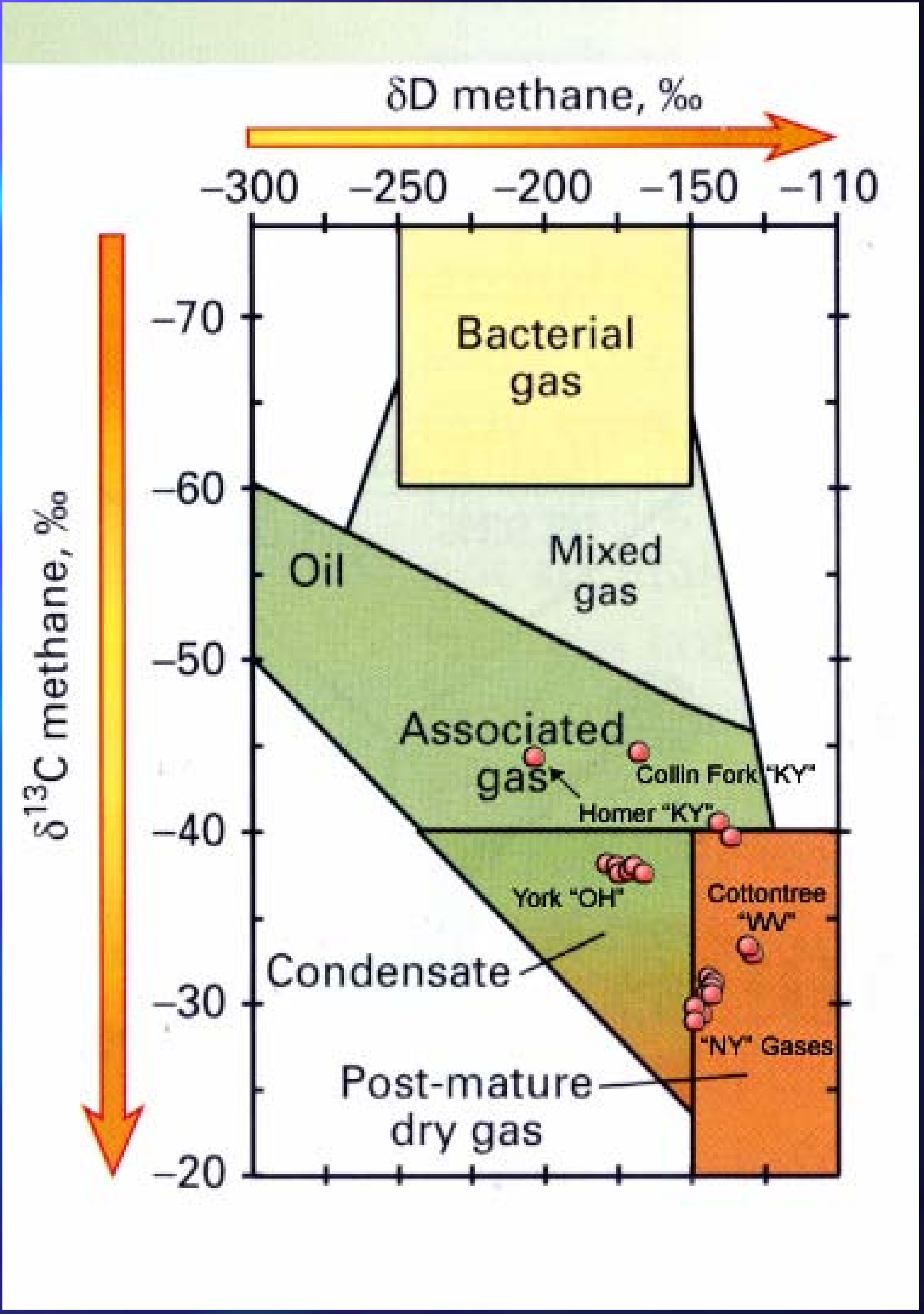
Natural Gas Sample Distribution

- Glodes Corners Field, Steuben Co., NY: 5 samples
- Muck Farm Field, Steuben Co., NY: 1 sample
- Wilson Hollow Field, Steuben and Chemung Co., NY: 1 sample
- County Line Field, Chemung Co., NY: 1 sample
- Terry Hill South Field, Chemung Co., NY: 1 sample
- #1 Andrews well, Steuben Co., NY: 1 sample

Natural Gas Sample Distribution

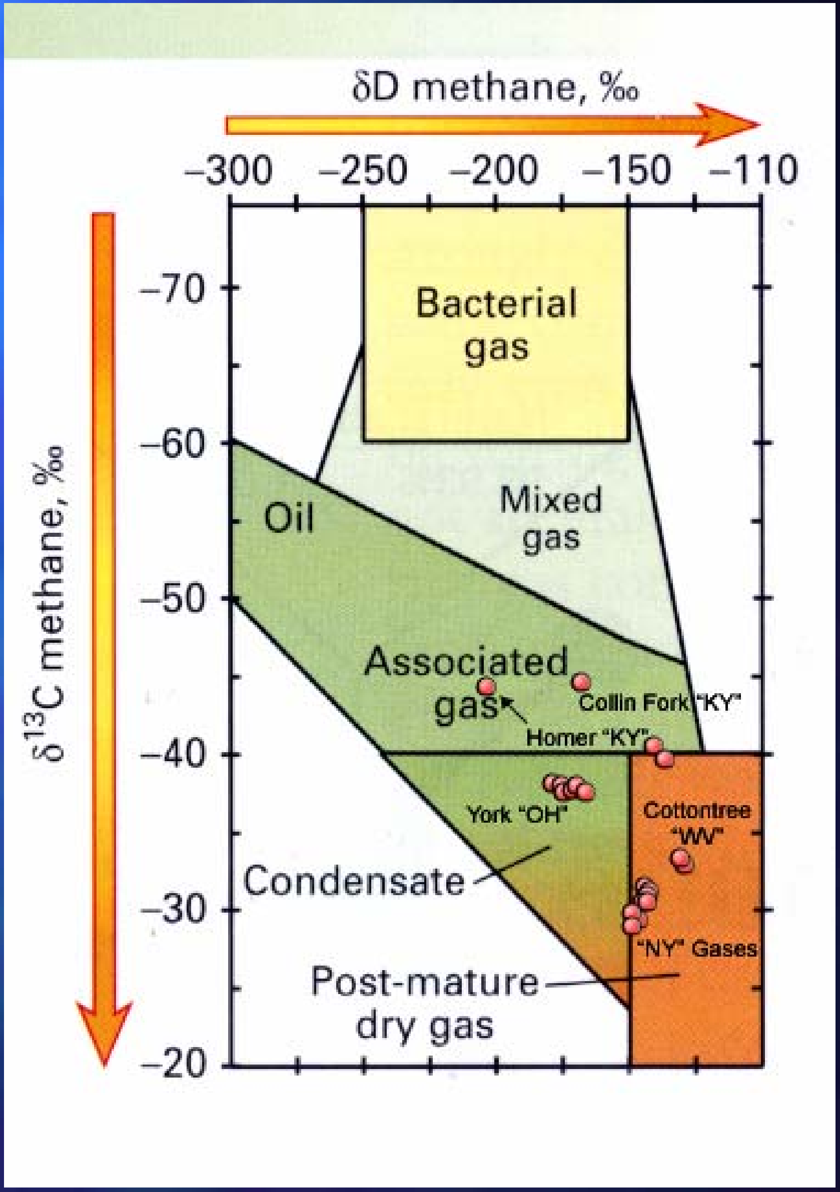
- York Field, Ashtabula Co., OH: 6 samples
- Cottontree Field, Roane CO., WV: 2 samples
- Homer Field, Elliott Co., KY: 2 samples
- Clay Co., KY: 1 sample

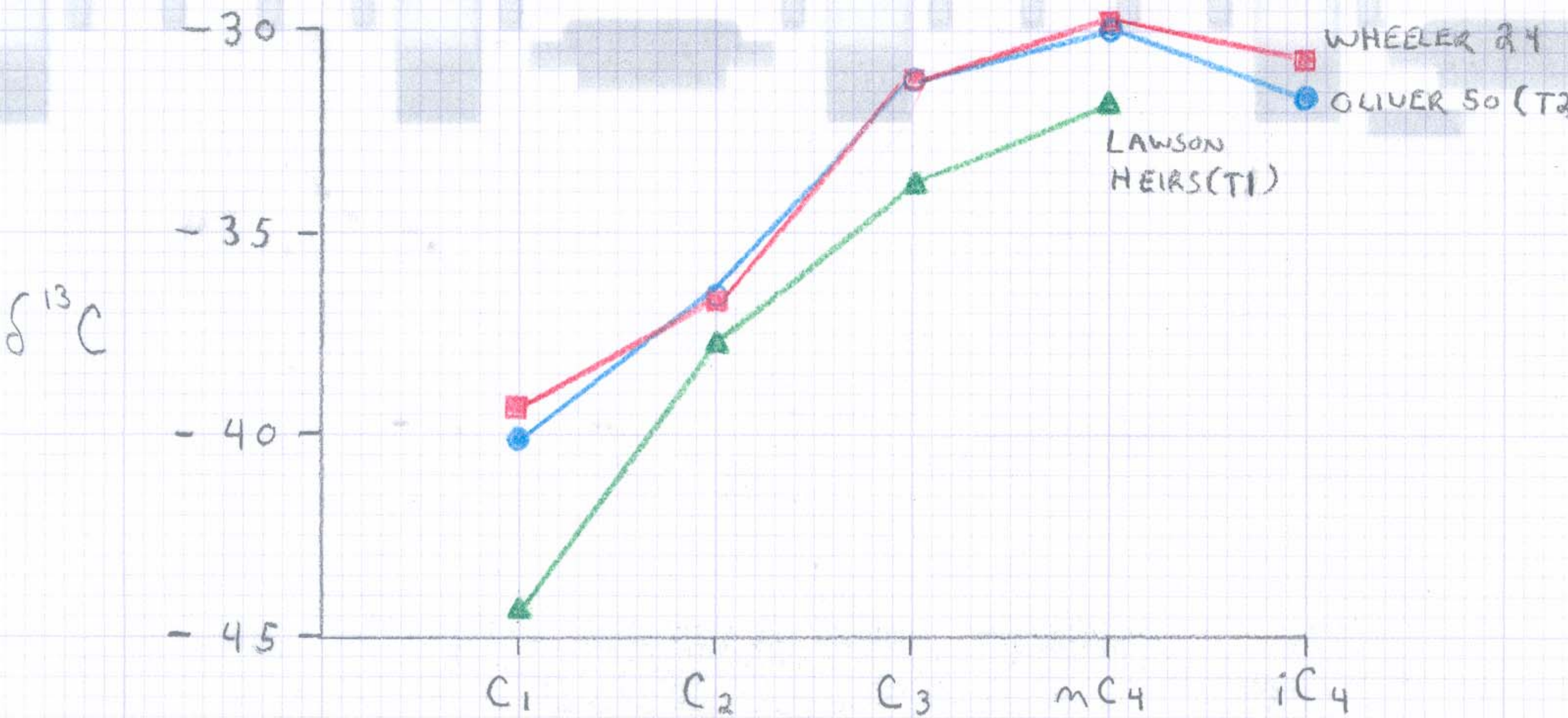
RESULTS TO DATE



RESULTS TO DATE

- Collin Fork Field, Clay Co. KY.
  - Early-mature, associated gas
  - High N_2
- Homer Field, Elliott Co. KY
  - At least two distinct natural gases:
    - Early-mature, associated gas
    - Late-mature, non-associated gas
    - Reservoir compartmentalization
  - High N_2

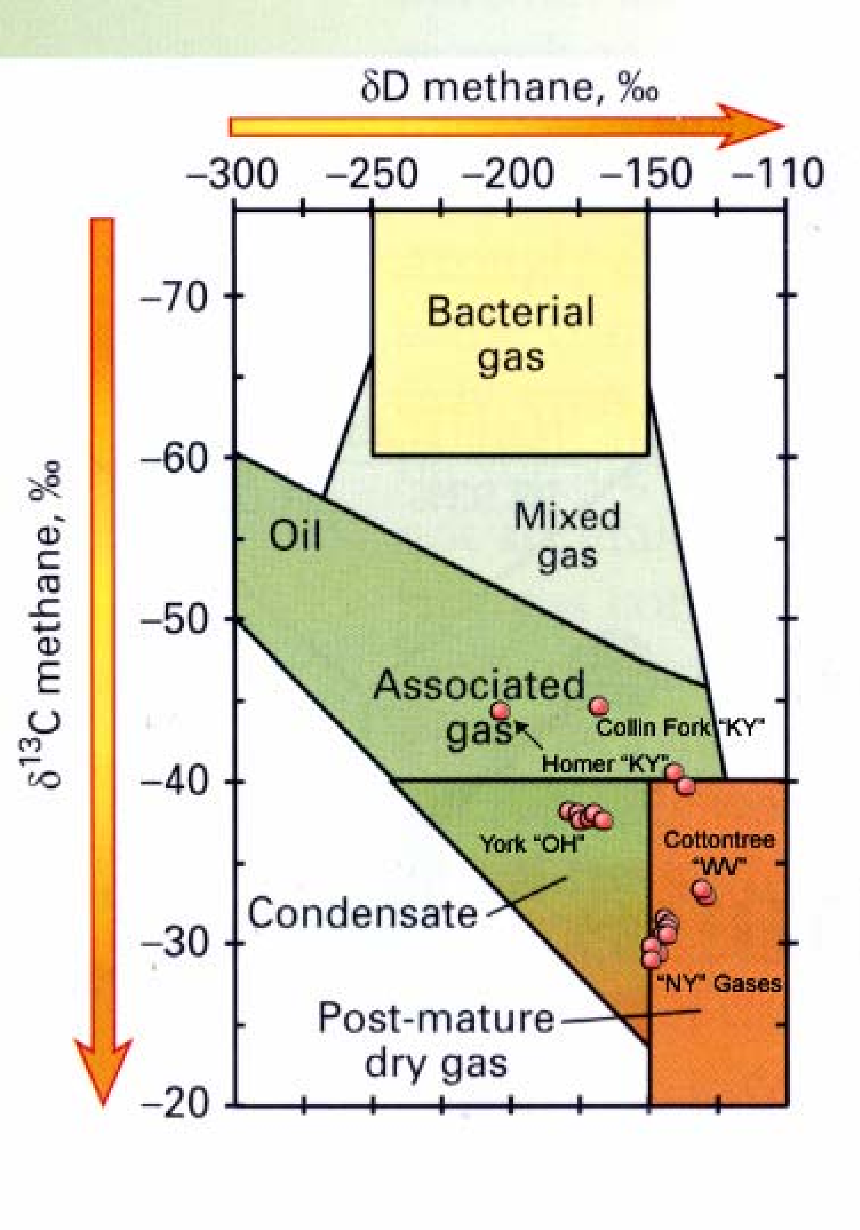


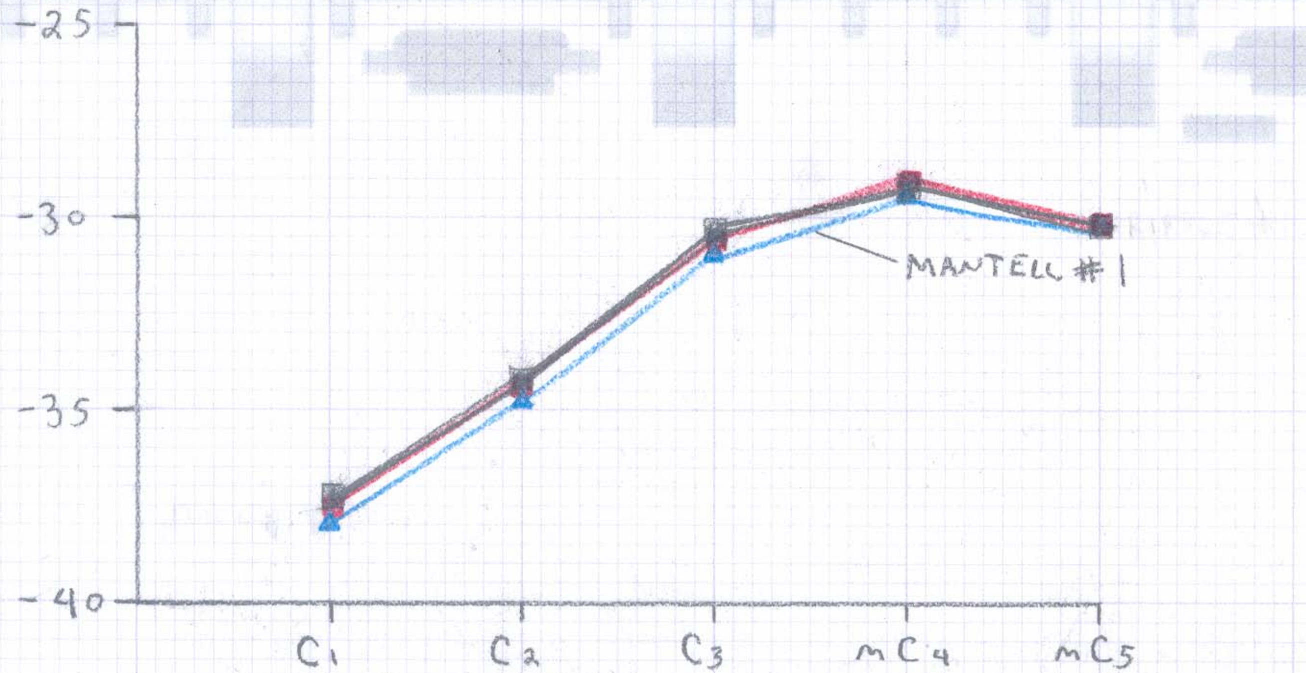


	$\delta^{13}C_1$	$\delta^{13}C_2$	$\delta^{13}C_3$	$\delta^{13}{}_nC_4$	$\delta^{13}{}_iC_4$ ‰
OLIVER 50 (T2)	-40.30	-36.67	-31.45	-30.22	-31.59
WHEELER 24	-39.50	-36.83	-31.36	-29.93	-30.95
LAWSON HEIRS (T1)	-44.41	-37.71	-33.92	-31.57	nm

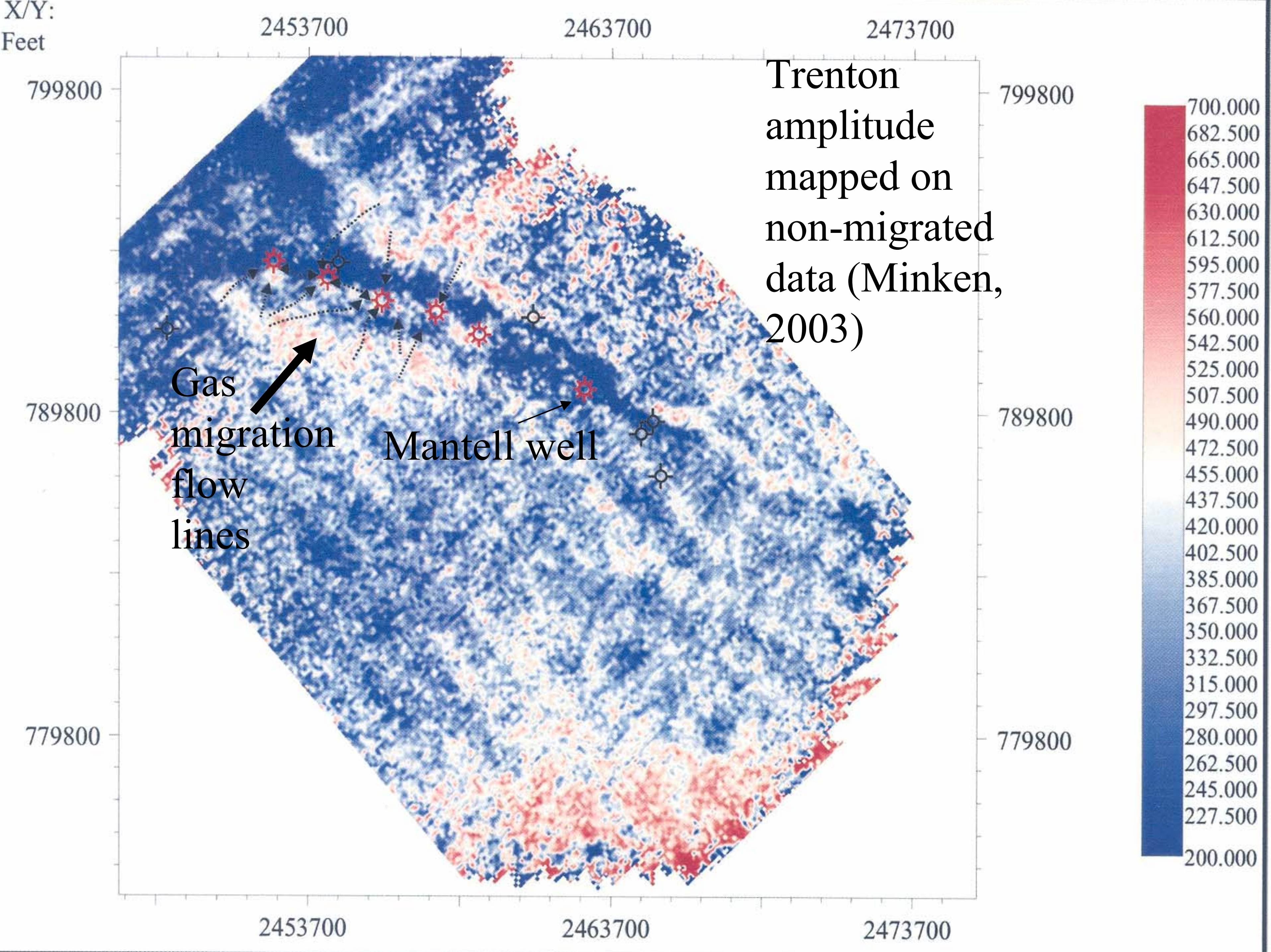
RESULTS TO DATE

- York Field, Ashtabula Co. OH
  - Condensate-associated gases
  - Late-mature
  - High N_2
  - Same source rocks
  - Compartmentalization?





	$\delta^{13}C_1$	$\delta^{13}C_2$	$\delta^{13}C_3$	$\delta^{13}{}_mC_4$	$\delta^{13}iC_4$ ‰
RIFFLE#1	-37.41	-34.36	-30.48	-29.36	-30.32
DALIN#1	-37.50	-34.48	-30.59	-29.33	-30.31
YORK #1	-37.44	-34.44	-30.50	-29.34	-30.31
DOWNES#3	-37.37	-34.38	-30.50	-29.21	-30.30
DOWNES #1	-37.38	-34.37	-30.44	-29.25	-30.26
MANTELL#1	-38.04	-34.75	-30.83	-29.45	-30.40



X/Y:
Feet
2453700
2463700
2473700
799800
789800
779800
Trenton amplitude mapped on non-migrated data (Minken, 2003)
Gas migration flow lines
Mantell well
700.000
682.500
665.000
647.500
630.000
612.500
595.000
577.500
560.000
542.500
525.000
507.500
490.000
472.500
455.000
437.500
420.000
402.500
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350.000
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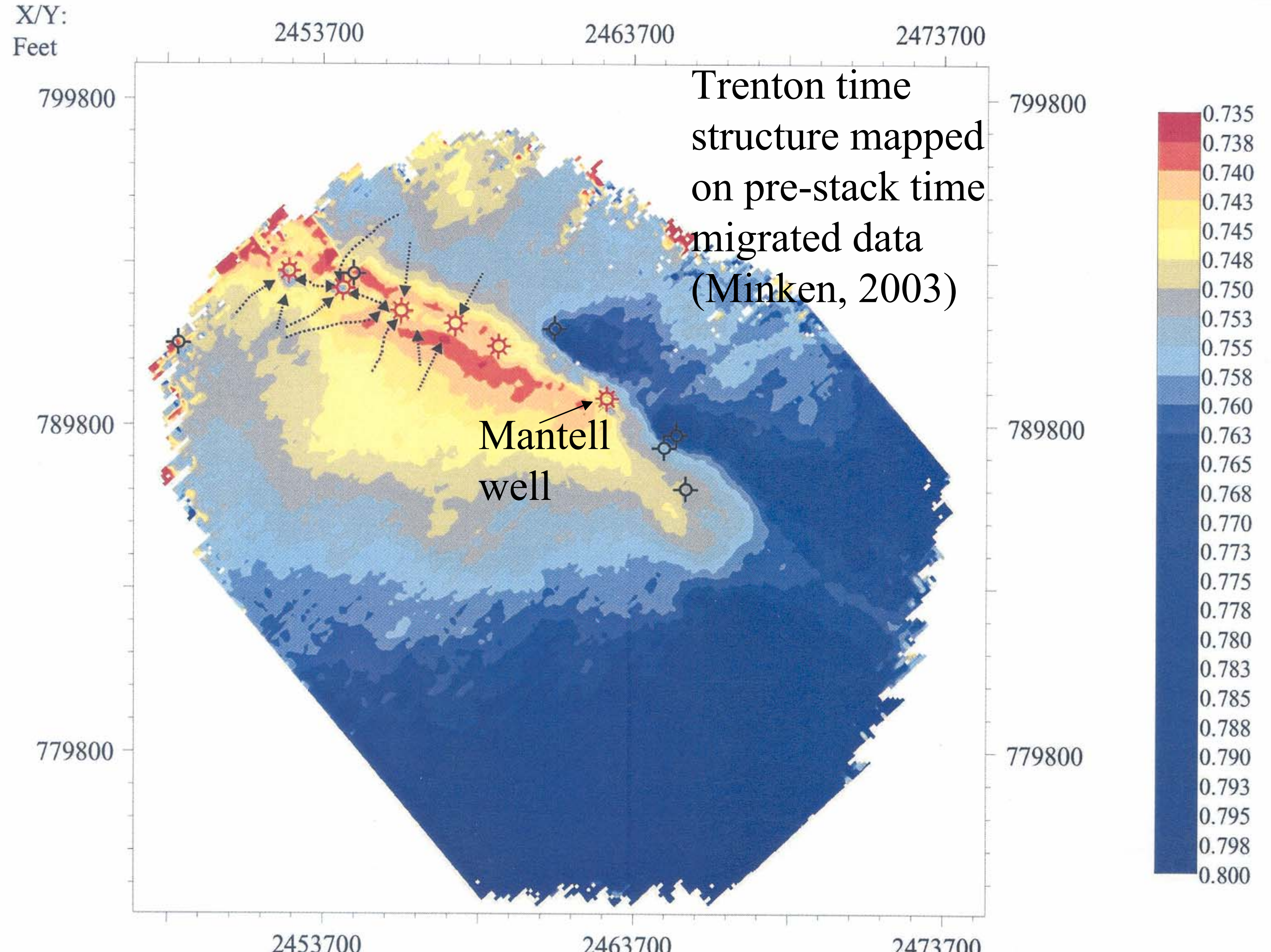
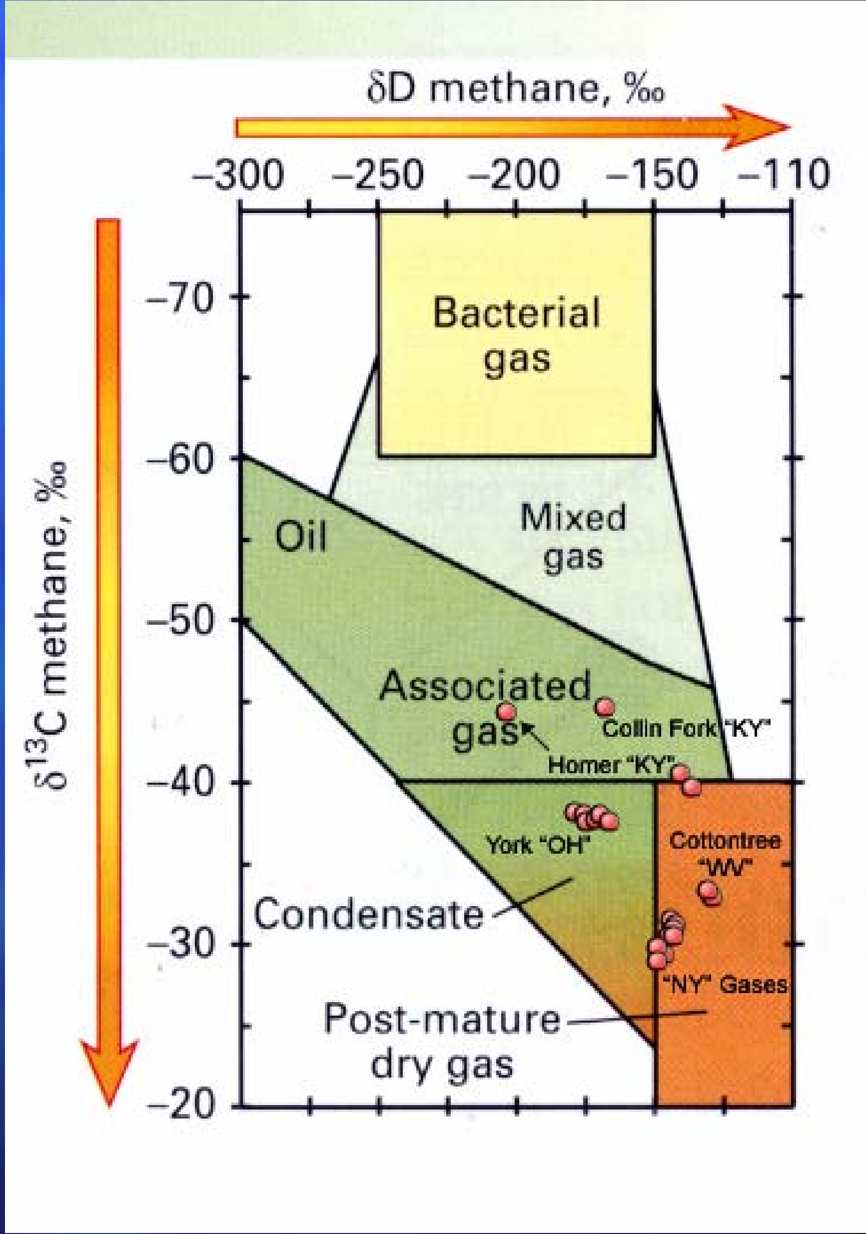
315.000
297.500
280.000
262.500
245.000
227.500
200.000


X/Y:
Feet
2453700
2463700
2473700
799800
789800
779800
Trenton time structure mapped on pre-stack time migrated data (Minken, 2003)
Mantell well
0.735
0.738
0.740
0.743
0.745
0.748
0.750
0.753
0.755
0.758
0.760
0.763
0.765
0.768
0.770
0.773
0.775
0.778
0.780
0.783
0.785
0.788
0.790
0.793
0.795
0.798
0.800

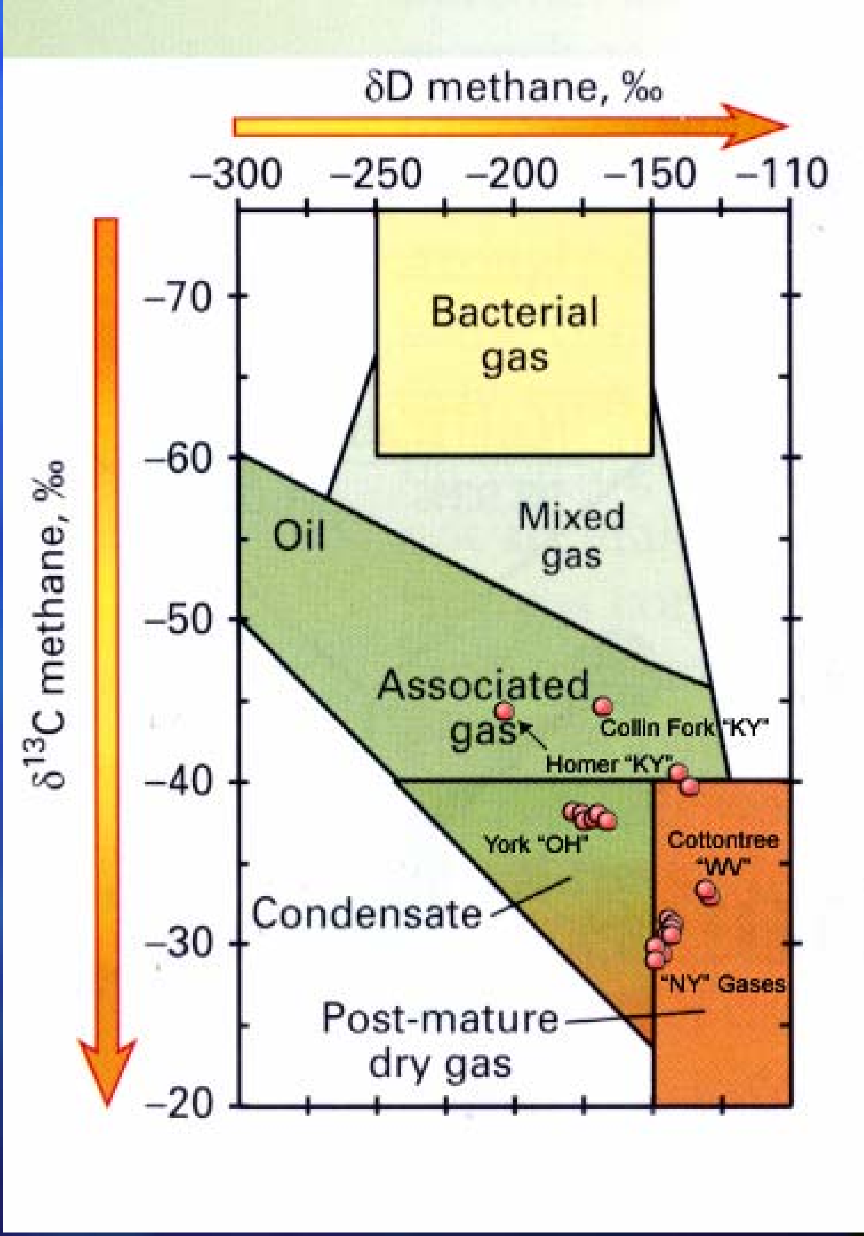
RESULTS TO DATE

- Cottontree Field, Roane Co. WV
  - Post-mature dry gas
  - Late-mature



RESULTS TO DATE

- New York Gases
  - Post-mature dry gases
  - Late-mature (source rock R_o > 4.0)
  - Very dry (≥ 95% CH_4)
  - Isotopic reversals between methane and ethane
  - Notable N_2 at Glodes Corners and Muck Farm fields (1.18 – 2.41%)



NITROGEN IN NATURAL GASES

- Origin of N_2 in natural gases poorly understood
- Magmatic gas component?
- Mantle outgassing?
- Oxidation of ammonia in the pore waters of sedimentary basins (maturation of organic matter)
- Atmosphere

"Integrated Hydrothermal Dolomite gas Conceptual Exploration Model and The Identification Of An Unrecognized Major Mg-Hydrocarbon Source", S. Keith and others, 2003.

- Proposed a model to explain the generation, transport, and deposition and anomalous amounts of Mg and hydrocarbons that characterize HTD and MVT zinc deposits
- Based on surface geochemistry at Glodes Corners Field

"Integrated Hydrothermal Dolomite gas Conceptual Exploration Model and The Identification Of An Unrecognized Major Mg-Hydrocarbon Source", S. Keith and others, 2003.

- Proposed Reaction Sequence:
  - Generation of methane and hydrocarbon-stable metagenic fluids from serpentinization of peridotite in intracratonic failed rifts or collision sutures in the basement
  - Initial low temperature dolomitization of shelf carbonates in overlying strata
  - Early HTD near depositional site
  - Late HTD, anhydrite formation, and CO_2 effervescence, H_2 loss, and CH_4 unmixing
  - Sulfide and hydrocarbon deposition
  - Deposition of late $CaCO_3$ and clay minerals
  - Gas-charged fluids may continue to ascend to higher stratigraphic levels where they deposit gas charge in shallower sandstones

Analytical Criteria for Identifying Mantle-Derived Hydrocarbons in Oil and Gas Fields (Jenden and others, 1993)

- Methane $\delta^{13}C$ > -25 permil
- Isotopic reversals of the form methane $\delta^{13}C$ > ethane $\delta^{13}C$ > propane $\delta^{13}C$
- $^{3}He/^{4}He$ > 0.1 Ra

NY Gases

- Methane $\delta^{13}C$ = -29.56 to 32.77 permil
- Methane $\delta^{13}C$ consistently > than ethane $\delta^{13}C$ (gas mixing?)
- $^{3}He/^{4}He$ = 0.109 to 0.196 Ra: suggests a dominantly crustal source of He in the gases, with a possible minor (1.2 – 2.3%) component of mantle-derived He

- Noble Gas Geochemistry:
  - $^{4}He/^{40}Ar$
  - $^{40}Ar/^{36}Ar$
  - He/Ne
  - $^{20}Ne/^{36}Ar$
  - N_2/Ar
  - $^{84}Kr/^{36}Ar$
  - $CH_4/^{3}He$

PRELIMINARY CONCLUSIONS AND FUTURE WORK

- Gases produced from Trenton/Black River reservoirs in the Appalachian basin are early-mature to post-mature. Maturity appears to correlate with burial and tectonic history.
- Gases produced at the Homer Field in Elliott County, KY are compartmentalized and originated from at least two different sources.
- Gases produced at York Field in Ashtabula County, OH also come from at least two discrete reservoir compartments; isotope geochemistry may reflect reserve potential.

PRELIMINARY CONCLUSIONS AND FUTURE WORK

- Gases produced from Trenton/Black River reservoirs in New York are post-mature, and exhibit isotopic reversals
  - Mixing?
  - Hydrothermal gases?
- Noble gas geochemistry of the NY gases indicates a predominantly crustal origin, with a minor ^{3}He component derived from the mantle

PRELIMINARY CONCLUSIONS AND FUTURE WORK

- Trenton/Black River gases produced in KY, OH, and NY contain notable N_2 (1.18 – 5.17%)
  - Magmatic component?
  - Future Work:
    - Interpret noble gas data
    - Construct plots to quantify gas mixing in the reservoirs
    - Compartmentalization and fault block mapping?
    - PA samples/data???
    - Look at H_2S and CO_2 in Trenton/Black River reservoirs