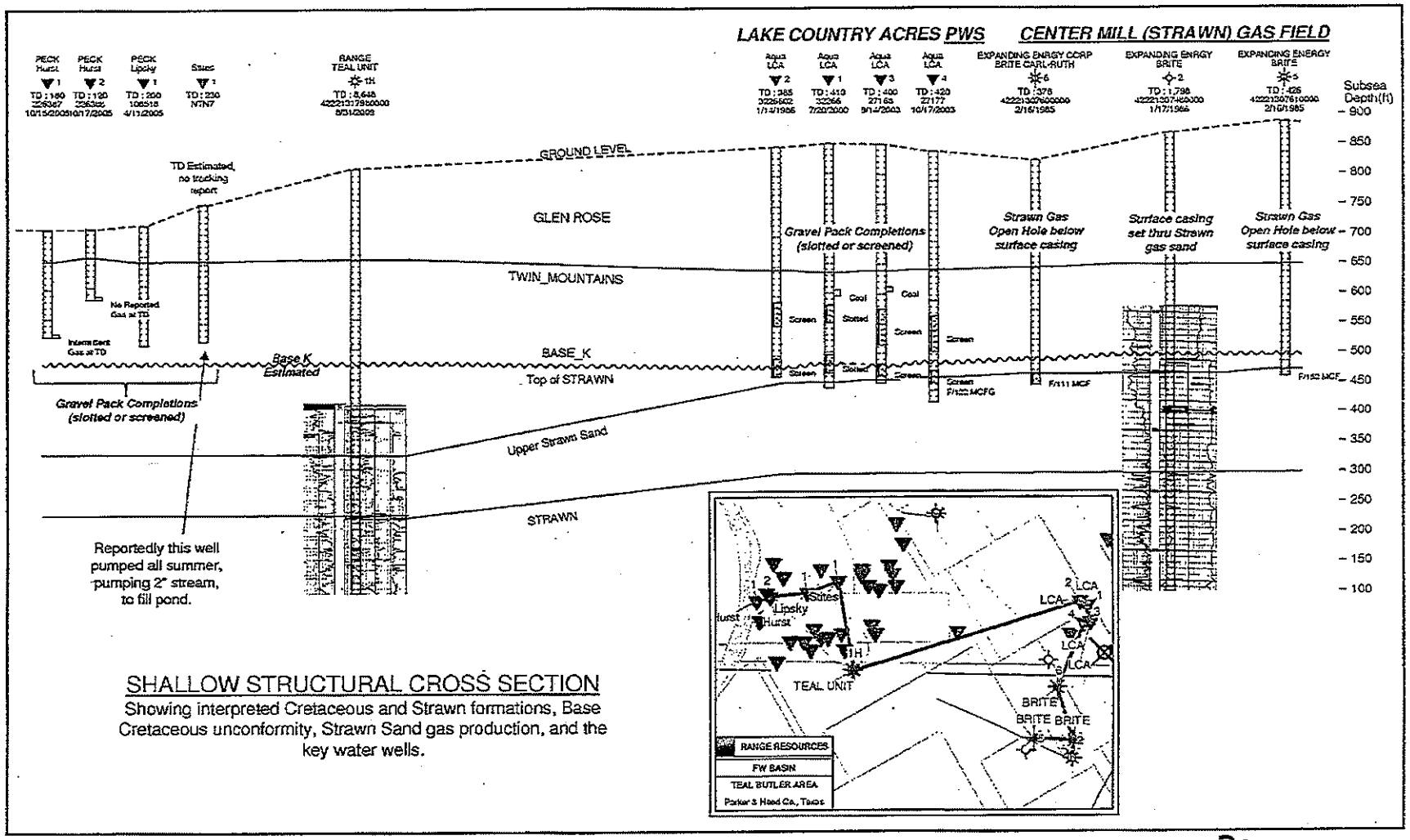
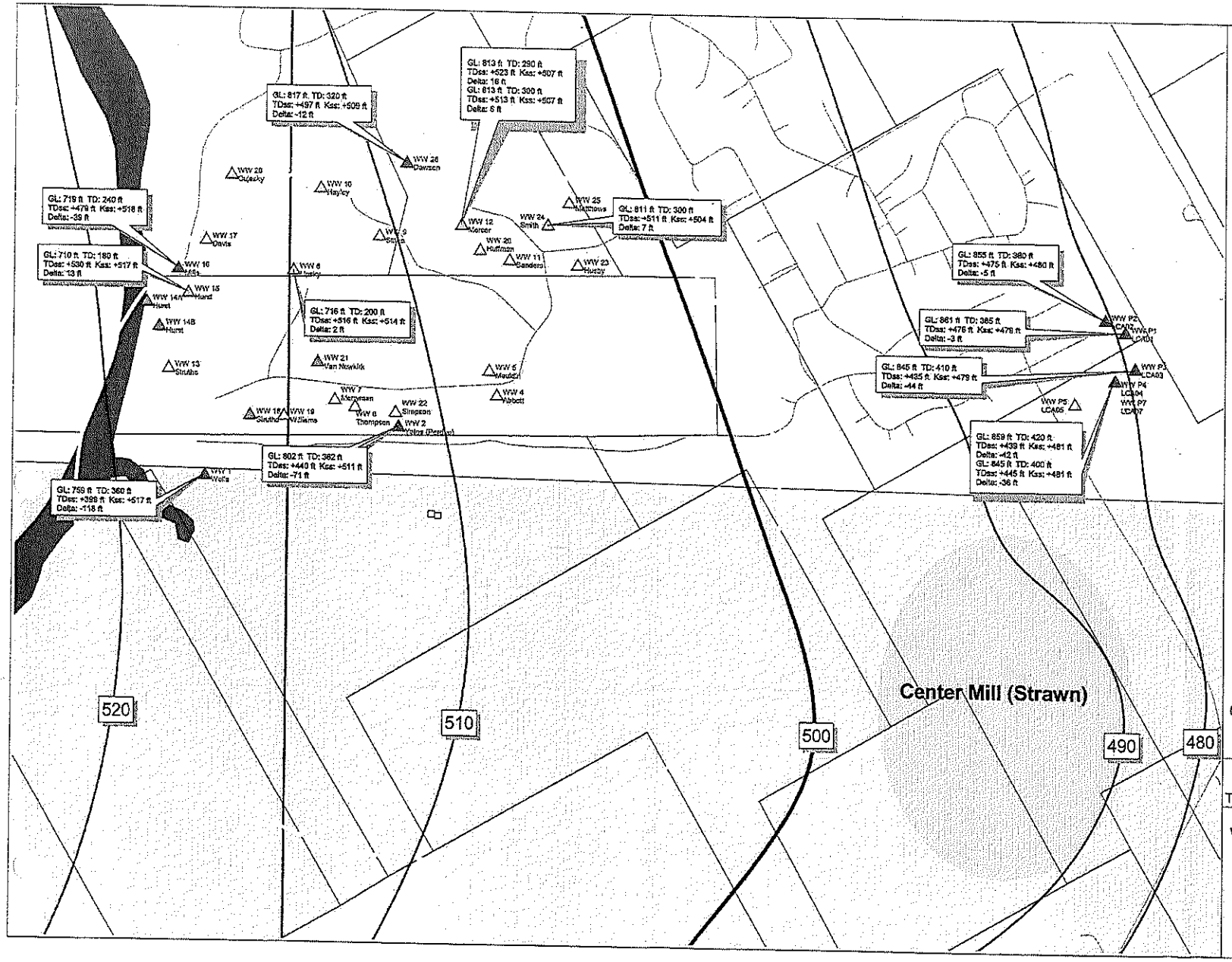


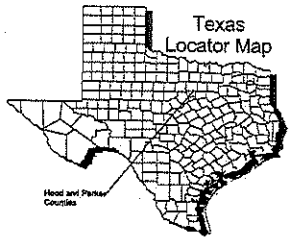
SHALLOW STRUCTURAL CROSS SECTION

Showing interpreted Cretaceous and Strawn formations, Base Cretaceous unconformity, Strawn Sand gas production, and the key water wells.

Exhibit No. 33
Operator: Range Resources
Docket No. 7B-0268629
Date: January 19, 2011

From RRC





Legend

Area Water Wells

- Wells below base of K
- Wells within 25 ft of K
- Wells within 50 ft of K
- Wells > 50 ft from base of K
- Unknown Total Depth

Exhibit No. Corrected 32A
Operator: Range Resources
Docket No. 7B-0268629
Date: January 19, 2011

Scale

0 750 1500 Feet

Platt, Sparks & Associates
Consulting Petroleum Engineers, Inc.
Texas Registered Engineering Firm F-1493

Water Wells Completed Below
Base of Cretaceous
Hood and Parker Counties

Composition, Nature, and Origin of Produced Gas, Well Headspace Gas, and Water Solution Gas Samples; Parker County and Hood County, Texas

Dr. Alan S. Kornacki[1] and
Dr. Mark A. McCaffrey[2]

[1]Weatherford Laboratories, Inc.
Houston, Texas
[2]Weatherford Laboratories, Inc.
Dallas, Texas

Exhibit No. 22
Operator: Range Resources
Docket No. 7B-0268629
Date: January 19, 2011

Inventory of Gas Samples Collected and Analyzed for This Study

Type of Sample	25 Water Wells	Butler Gas Well	Teal Gas Well
Solution Gas	29 (Including 3 duplicates)		
Headspace Gas	30 (Including 2 duplicates)		
Tubing Gas Produced from Barnett		2 (One duplicate)	2 (One duplicate)
Injected Barnett Gas		2 (One duplicate)	1
Bradenhead Gas		2 (One duplicate)	1

Key Observations

- The geochemical parameter used by the EPA to determine a thermogenic origin of the (b) (6) gas (e.g., the C isotopic composition of methane) does not differentiate gas in the Barnett Formation from gas in Pennsylvanian reservoirs.

- The (b) (6) water well (the same well that flared gas in 2005, four years before the Range wells were drilled) contains methane that has the same carbon isotopic composition as the (b) (6) headspace gas.

- N_2 and CO_2 concentrations can be used to distinguish Barnett Formation reservoir gas from Pennsylvanian Strawn reservoir gas – specifically, high N_2/low CO_2 samples are characteristic of gases produced from Pennsylvanian reservoirs.

- The natural gas component of the most recent (b) (6) well headspace gas samples contains higher N_2 than is encountered in Barnett gas.

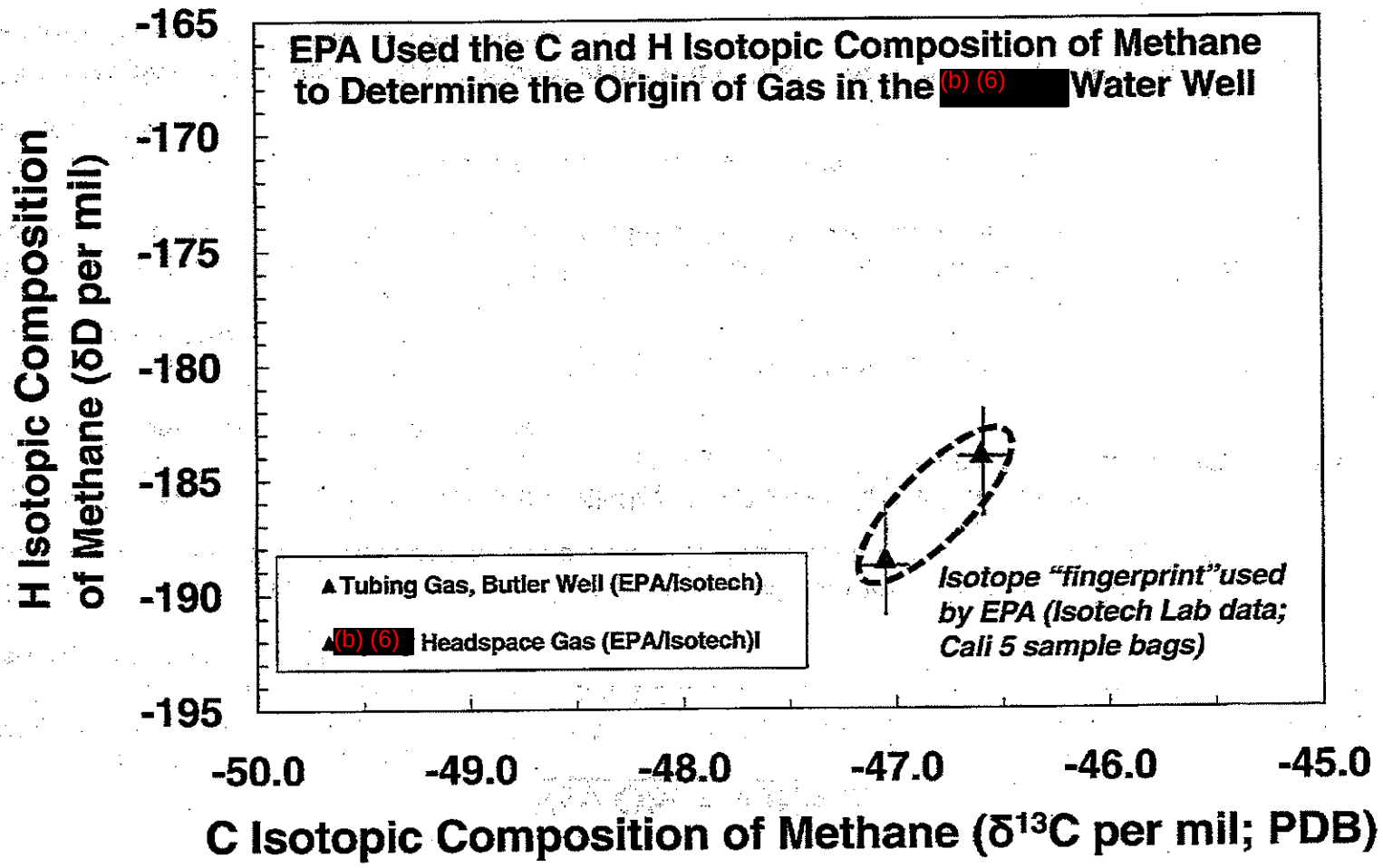
- The natural gas in the headspace sample from the (b) (6) well (the water well nearest the surface location of the Range gas wells) also contains higher N_2 than is encountered in Barnett gas.

- The natural gas component of the Butler bradenhead gas sample contains higher N_2 than is encountered in Barnett gas.

- The isotopic composition of N_2 is different in the Butler bradenhead gas sample than in tubing gas samples produced from the Barnett Formation.

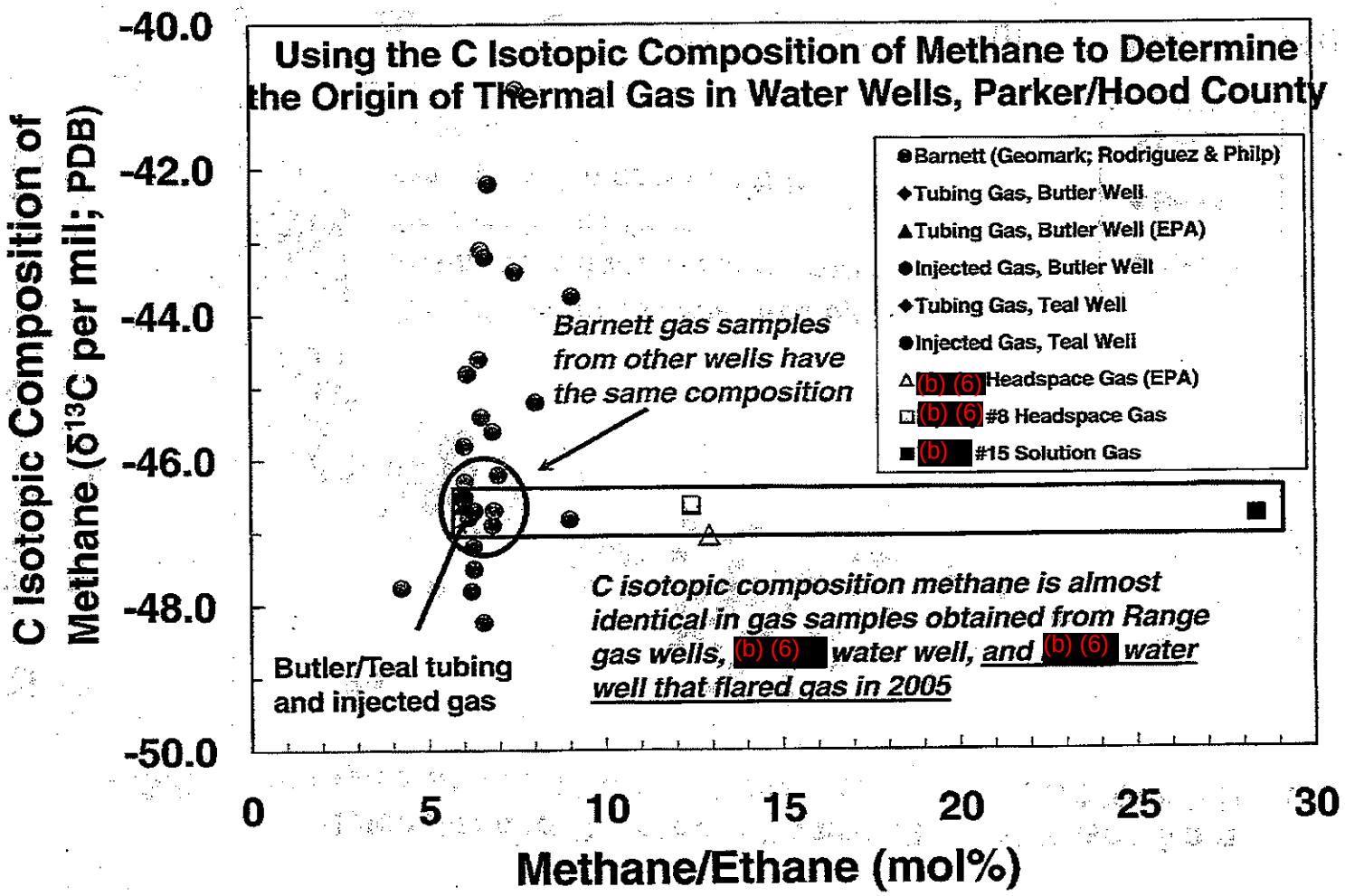
- All aquifer water samples in the study area contain at least trace amounts of thermal natural gas.

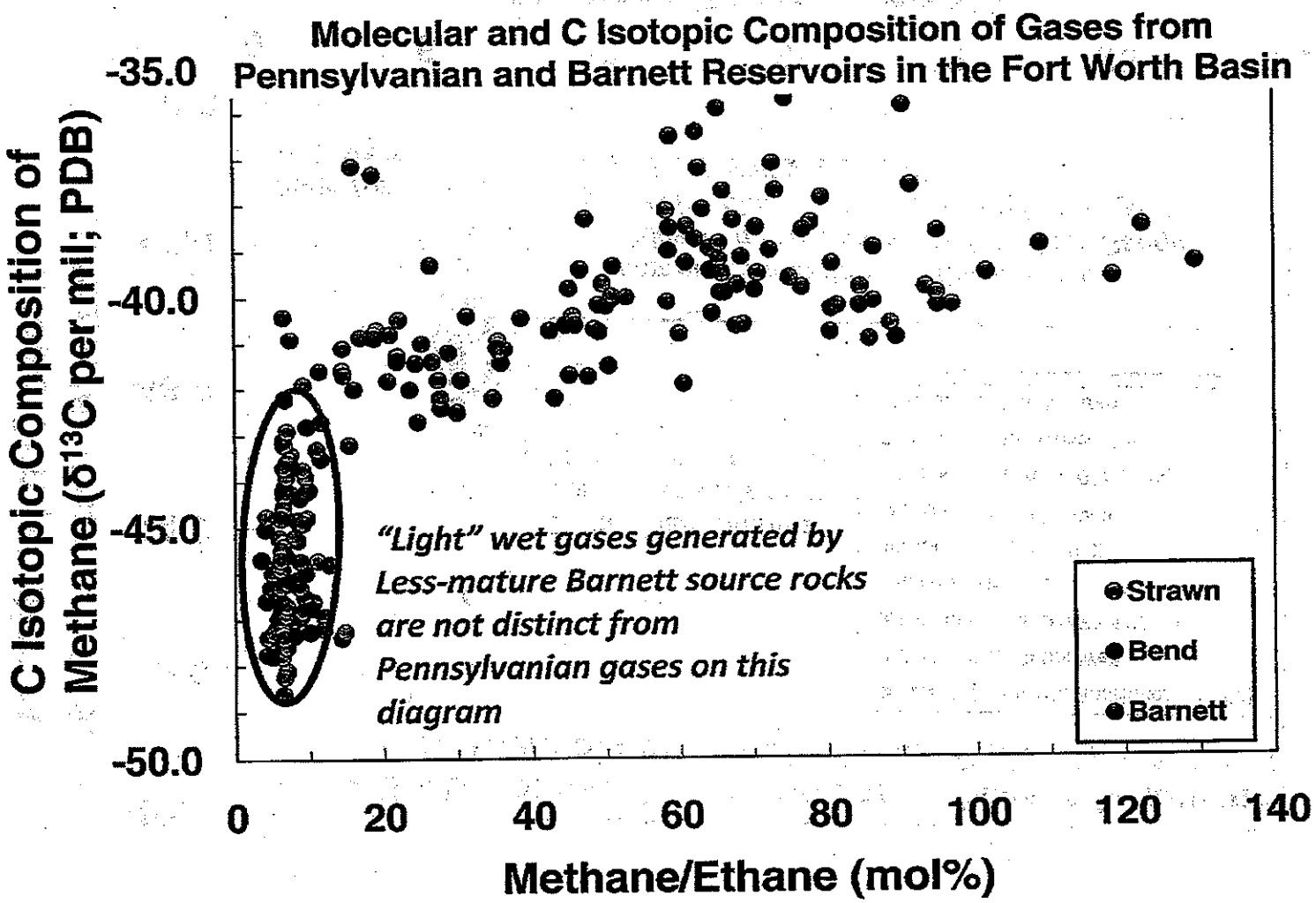
- The natural gas in most of the aquifer samples has an isotopic signature indicative of partial microbial degradation.

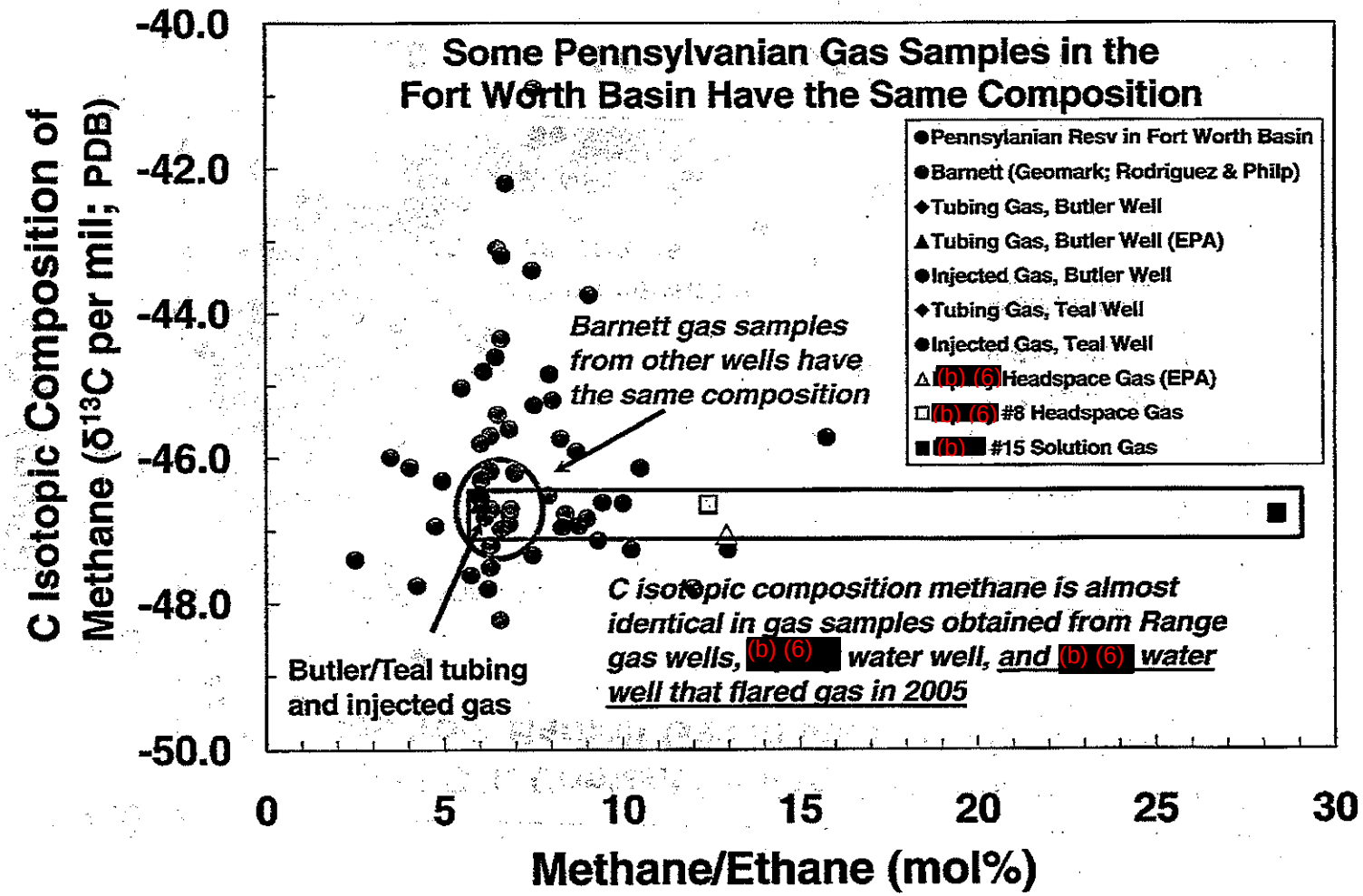


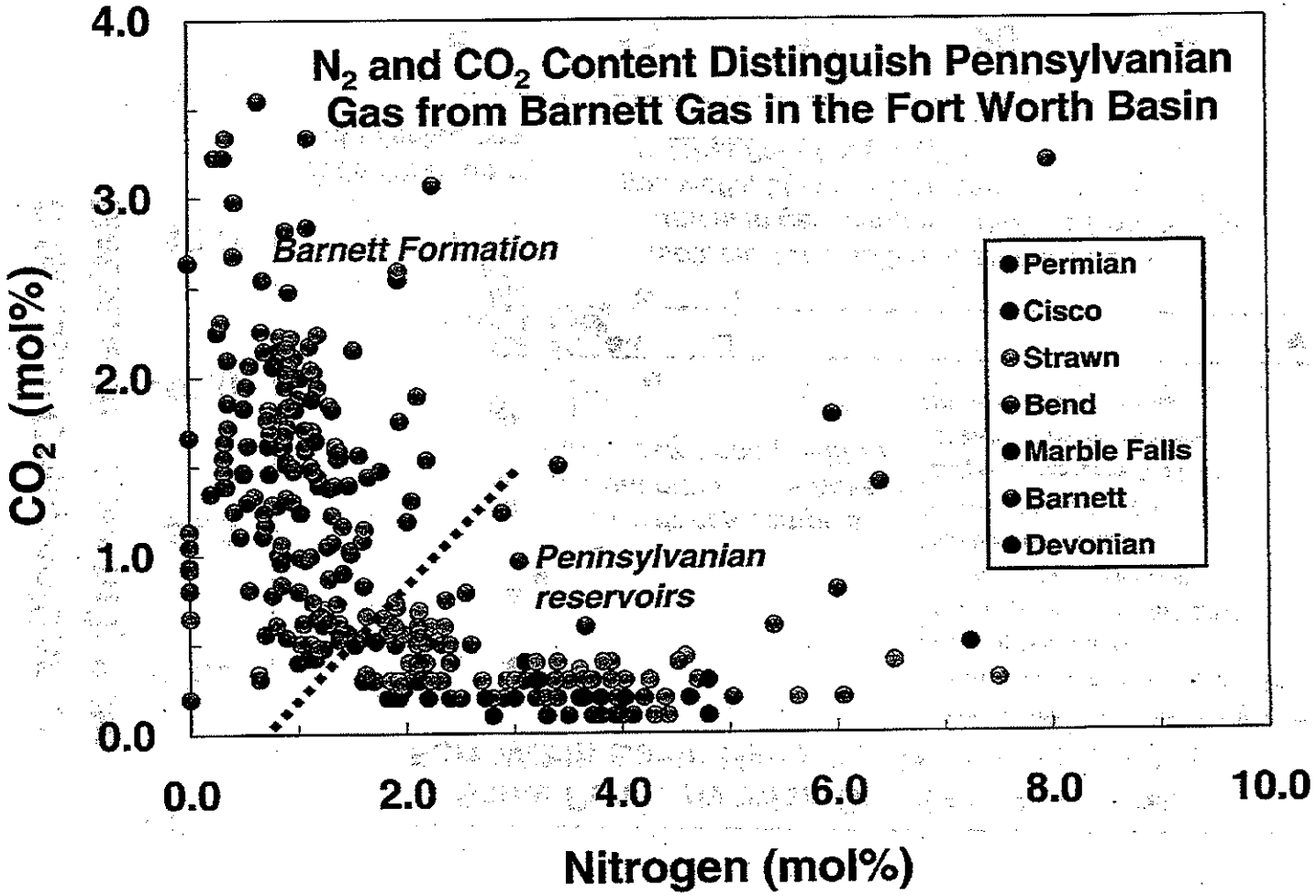
carbon

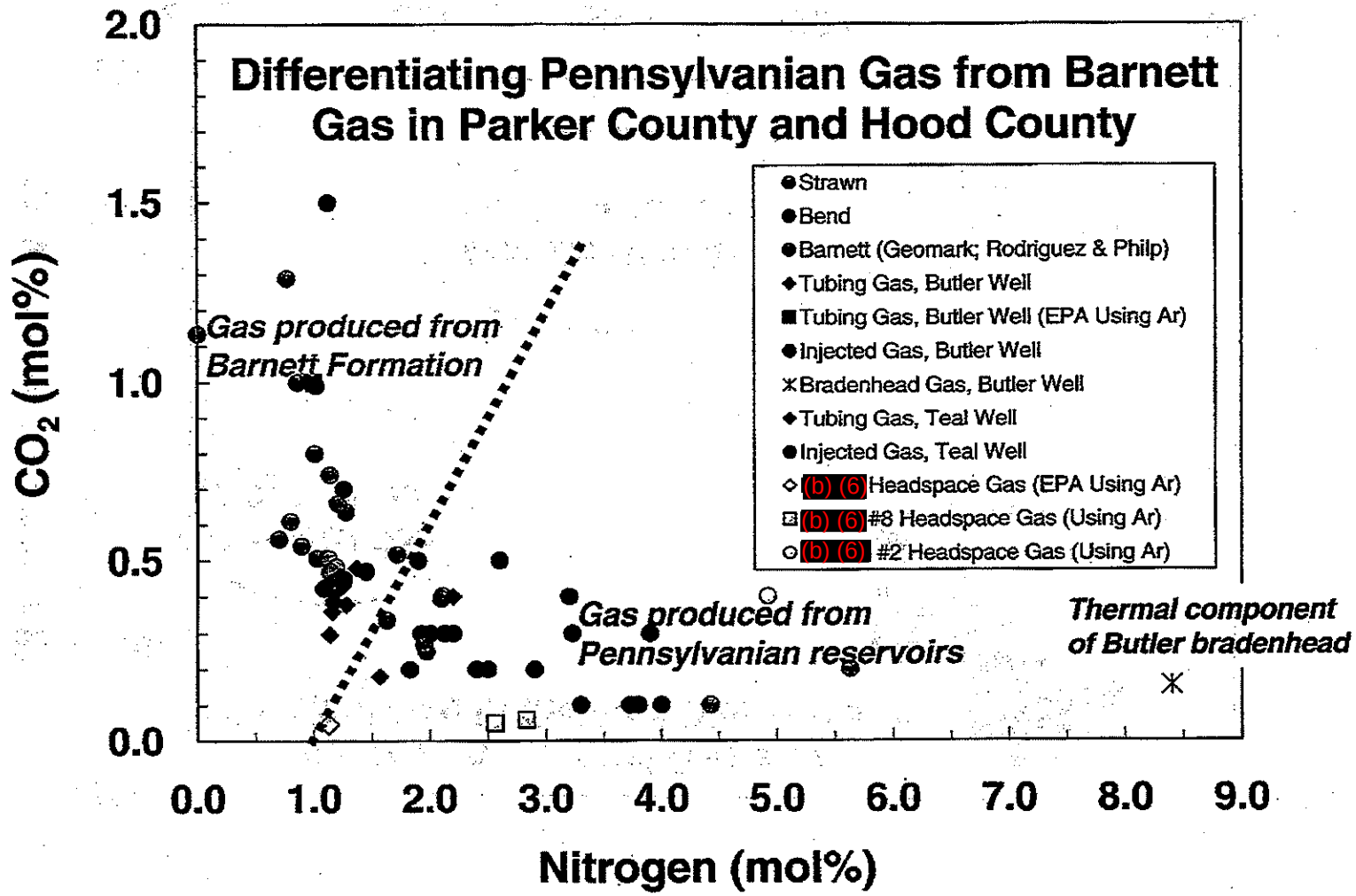
46.5-47

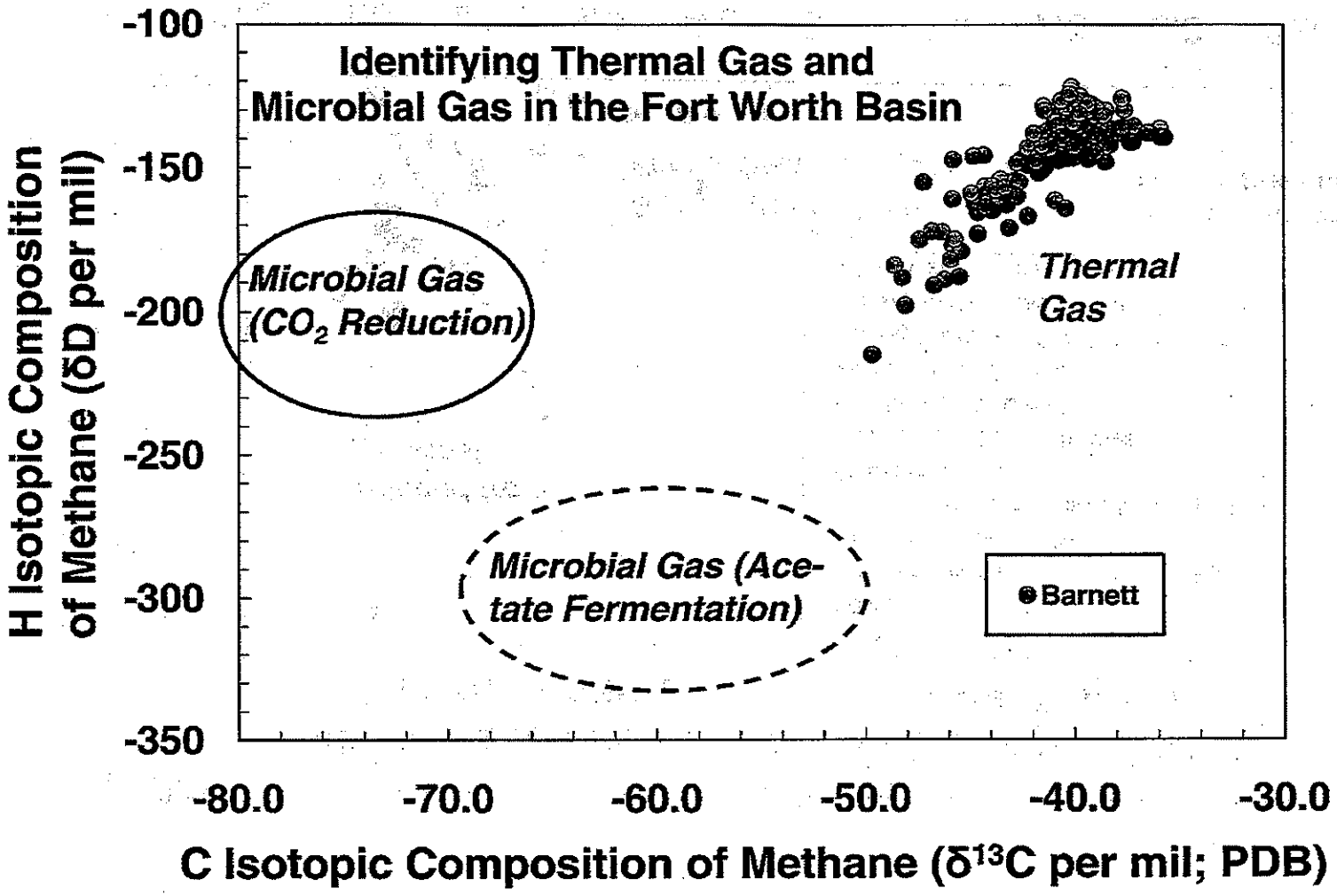

Using the C Isotopic Composition of Methane to Determine the Origin of Thermal Gas in Water Wells, Parker/Hood County
C Isotopic Composition of Methane ($\delta^{13}C$ per mil; PDB)
-40.0
-42.0
-44.0
-46.0
-48.0
-50.0
0
5
10
15
20
25
30
Methane/Ethane (mol%)
Barnett (Geomark; Rodriguez & Philp)
Tubing Gas, Butler Well
Tubing Gas, Butler Well (EPA)
Injected Gas, Butler Well
Tubing Gas, Teal Well
Injected Gas, Teal Well
(b) (6) Headspace Gas (EPA)
(b) (6) #8 Headspace Gas
(b) #15 Solution Gas
Barnett gas samples from other wells have the same composition
Butler/Teal tubing and injected gas
C isotopic composition methane is almost identical in gas samples obtained from Range gas wells, (b) (6) water well, and (b) (6) water well that flared gas in 2005

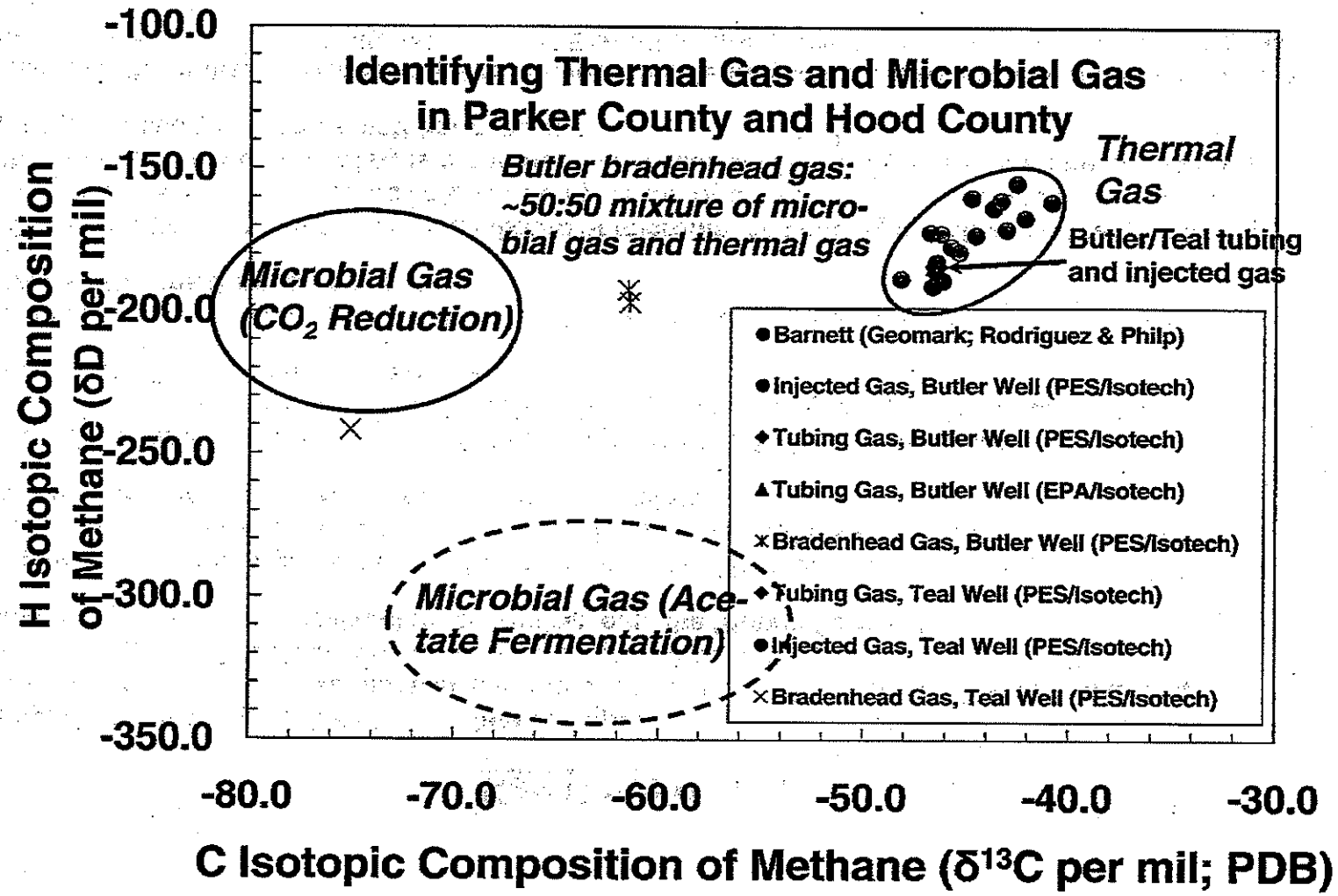

Molecular and C Isotopic Composition of Gases from
Pennsylvanian and Barnett Reservoirs in the Fort Worth Basin
C Isotopic Composition of
Methane (δ13C per mil; PDB)
-35.0
-40.0
-45.0
-50.0
0
20
40
60
80
100
120
140
Methane/Ethane (mol%)
"Light" wet gases generated by
Less-mature Barnett source rocks
are not distinct from
Pennsylvanian gases on this
diagram
Strawn
Bend
Barnett


Some Pennsylvanian Gas Samples in the Fort Worth Basin Have the Same Composition
Pennsylvanian Resv in Fort Worth Basin
Barnett (Geomark; Rodriguez & Philp)
Tubing Gas, Butler Well
Tubing Gas, Butler Well (EPA)
Injected Gas, Butler Well
Tubing Gas, Teal Well
Injected Gas, Teal Well
(b) (6) Headspace Gas (EPA)
(b) (6) #8 Headspace Gas
(b) #15 Solution Gas
Barnett gas samples from other wells have the same composition
C isotopic composition methane is almost identical in gas samples obtained from Range gas wells, (b) (6) water well, and (b) (6) water well that flared gas in 2005
Butler/Teal tubing and injected gas
C Isotopic Composition of Methane (δ13C per mil; PDB)
-40.0
-42.0
-44.0
-46.0
-48.0
-50.0
0
5
10
15
20
25
30
Methane/Ethane (mol%)


N2 and CO2 Content Distinguish Pennsylvanian Gas from Barnett Gas in the Fort Worth Basin
Barnett Formation
Pennsylvanian reservoirs
Permian
Cisco
Strawn
Bend
Marble Falls
Barnett
Devonian
CO2 (mol%)
Nitrogen (mol%)
0.0
1.0
2.0
3.0
4.0
0.0
2.0
4.0
6.0
8.0
10.0


Differentiating Pennsylvanian Gas from Barnett Gas in Parker County and Hood County
Strawn
Bend
Barnett (Geomark; Rodriguez & Philp)
Tubing Gas, Butler Well
Tubing Gas, Butler Well (EPA Using Ar)
Injected Gas, Butler Well
Bradenhead Gas, Butler Well
Tubing Gas, Teal Well
Injected Gas, Teal Well
(b) (6) Headspace Gas (EPA Using Ar)
(b) (6) #8 Headspace Gas (Using Ar)
(b) (6) #2 Headspace Gas (Using Ar)
Gas produced from Barnett Formation
Gas produced from Pennsylvanian reservoirs
Thermal component of Butler bradenhead
CO2 (mol%)
Nitrogen (mol%)
0.0
0.5
1.0
1.5
2.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


Identifying Thermal Gas and
Microbial Gas in the Fort Worth Basin
Microbial Gas
(CO_2 Reduction)
Thermal
Gas
Microbial Gas (Ace-
tate Fermentation)
Barnett
-100
-150
-200
-250
-300
-350
H Isotopic Composition
of Methane (δD per mil)
-80.0
-70.0
-60.0
-50.0
-40.0
-30.0
C Isotopic Composition of Methane ($\delta^{13}C$ per mil; PDB)


Identifying Thermal Gas and Microbial Gas in Parker County and Hood County
Butler bradenhead gas: ~50:50 mixture of microbial gas and thermal gas
Thermal Gas
Butler/Teal tubing and injected gas
Microbial Gas (CO_2 Reduction)
Microbial Gas (Acetate Fermentation)
Barnett (Geomark; Rodriguez & Philp)
Injected Gas, Butler Well (PES/Isotech)
Tubing Gas, Butler Well (PES/Isotech)
Tubing Gas, Butler Well (EPA/Isotech)
Bradenhead Gas, Butler Well (PES/Isotech)
Tubing Gas, Teal Well (PES/Isotech)
Injected Gas, Teal Well (PES/Isotech)
Bradenhead Gas, Teal Well (PES/Isotech)
H Isotopic Composition of Methane (δD per mil)
-100.0
-150.0
-200.0
-250.0
-300.0
-350.0
-80.0
-70.0
-60.0
-50.0
-40.0
-30.0
C Isotopic Composition of Methane ($\delta^{13}C$ per mil; PDB)

Key Conclusions

• The approach used by the EPA to correlate the (b) (6) gas sample to Range Resources production was fundamentally flawed: the geochemical parameter used by the EPA to determine a thermal origin of the (b) (6) gas (e.g., the C isotopic composition of methane) does not differentiate gas in the Barnett Formation from gas in Pennsylvanian reservoirs: e.g., the Strawn Formation.

• Using the EPA reasoning, methane carbon isotopes would lead one to erroneously conclude that the Range Resources wells are the source of the gas in the (b) (6) water well – a well that flared gas in 2005, four years before the Range Resources wells were drilled.

• N_2 and CO_2 concentrations can be used to distinguish Barnett Formation reservoir gas from Pennsylvanian Strawn reservoir gas – specifically, high N_2/low CO_2 samples are characteristic of gases produced from Pennsylvanian reservoirs.

• Elevated N_2 in a headspace gas sample from the (b) (6) well indicates derivation from Pennsylvanian reservoirs, NOT the Barnett Formation.

•The Butler bradenhead gas sample is a mixture of microbial gas and N_2-enriched thermal gas from a Pennsylvanian reservoir (a fact indicated not only by the N_2 concentrations, but also by the observation that the isotopic composition of N_2 is different in the Butler bradenhead gas sample than in tubing gas samples produced from the Barnett Formation).

•The fact that the Butler bradenhead gas is derived from Pennsylvanian reservoirs (and not the Barnett Formation) is NOT consistent with migration of Barnett reservoir gas to shallower reservoirs along the well path.

• Gas migration into the aquifer is not a single event, but rather seepage has occurred over a long period of time, as indicated by the observation that the most of the aquifer water samples contain thermal gas that has been incompletely metabolized by microbes.