

Eisenach Water Well Gas Source Investigation

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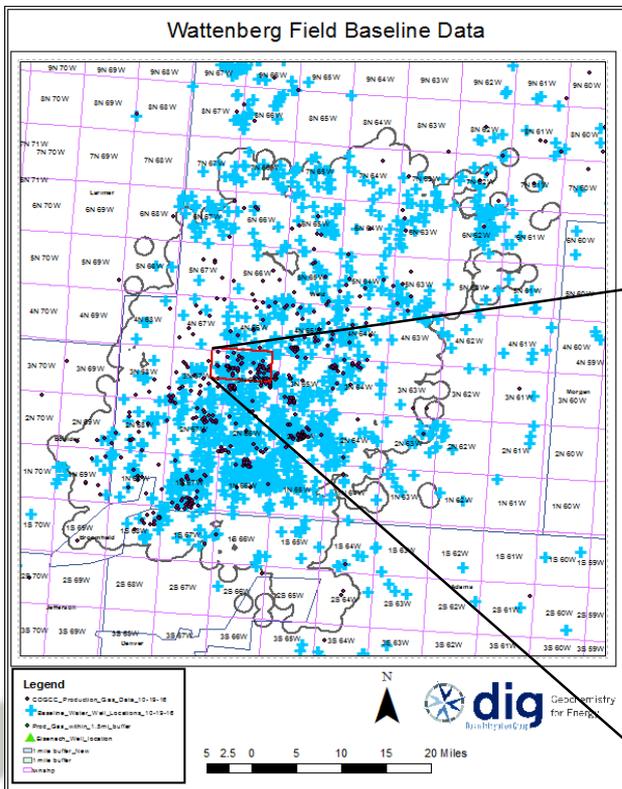


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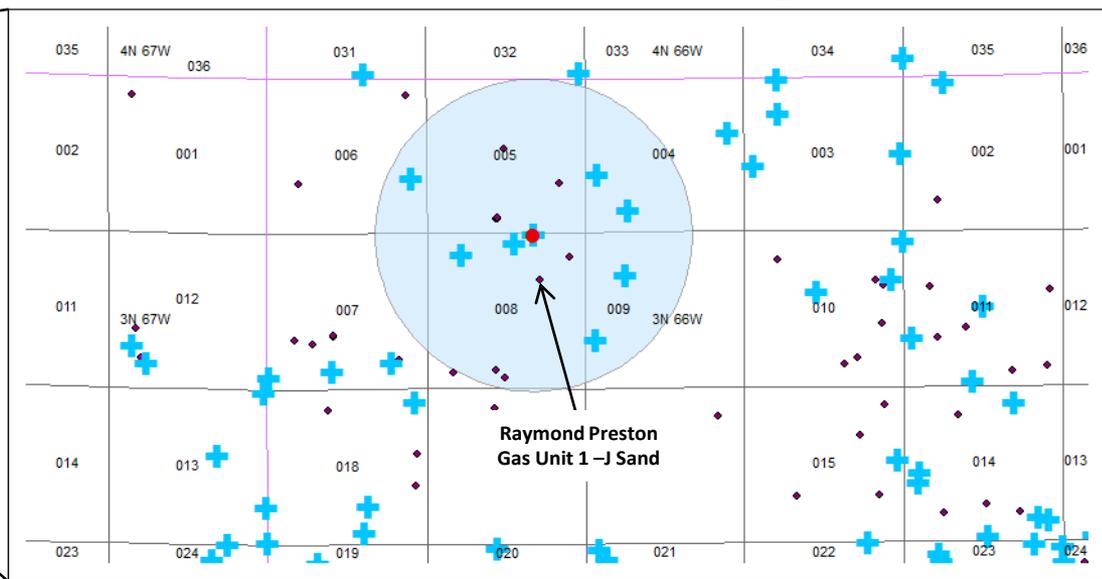
- Gas composition and stable isotopes from the Eisenach water well (WW) and produced gases in the vicinity of the well (1 mile radius) were investigated in order to evaluate possible source(s) of the gas in the Eisenach WW.
- Stable isotope composition of gases associated with the Eisenach WW reveals the gas was derived primarily from thermogenic sources.
 - Methane $\delta^{13}\text{C}$ values from 9/14/2006 and 10/13/2015 are indicative of a possible mixed thermogenic/microbial gas component, while the presence and isotopic composition of ethane and propane are consistent with a thermogenic source.
- Comparison of the geochemistry of the Eisenach WW gas and nearby production gas data suggests the thermogenic component of the Eisenach WW gas was likely sourced from the J-Sand.
- Due to the lack of C_3+ stable isotope data for the produced gas samples, as well as the variability in the NB, CD, NB-CD and J-NB-CD signatures, it may be of value to re-analyze samples from these wells or other completions in the vicinity to rule out these production zones.
- Eisenach WW ethane $\delta^{13}\text{C}$ and gas wetness values are most similar to a nearby J-Sand sourced produced gas from the Raymond Preston Gas Unit 1.
 - Bradenhead and produced gas from the Raymond Preston Gas Unit 1 J-Sand producing well are isotopically very similar to one another and the bradenhead gas has a relatively high concentration of CO_2 (9300ppm). These observations may reflect communication between the production zone and the bradenhead and therefore may indicate potential well-bore integrity issues. However, the Raymond Preston Gas Unit 1 was plugged and abandoned in December 2013.

Eisenach WW & Nearby Producing Wells

Wattenberg Field Baseline Data



Eisenach Water Well Investigation



Legend

- Eisenach_Well_location
- + Baseline_Water_Well_Locations_10-19-16
- COGCC_Production_Gas_Data_10-19-16
- 1 mile buffer
- tw nshp
- Sections



- Location of Eisenach WW and nearby producing wells. Water wells and producing wells within a 1 mile radius of the Eisenach WW were evaluated for this study.

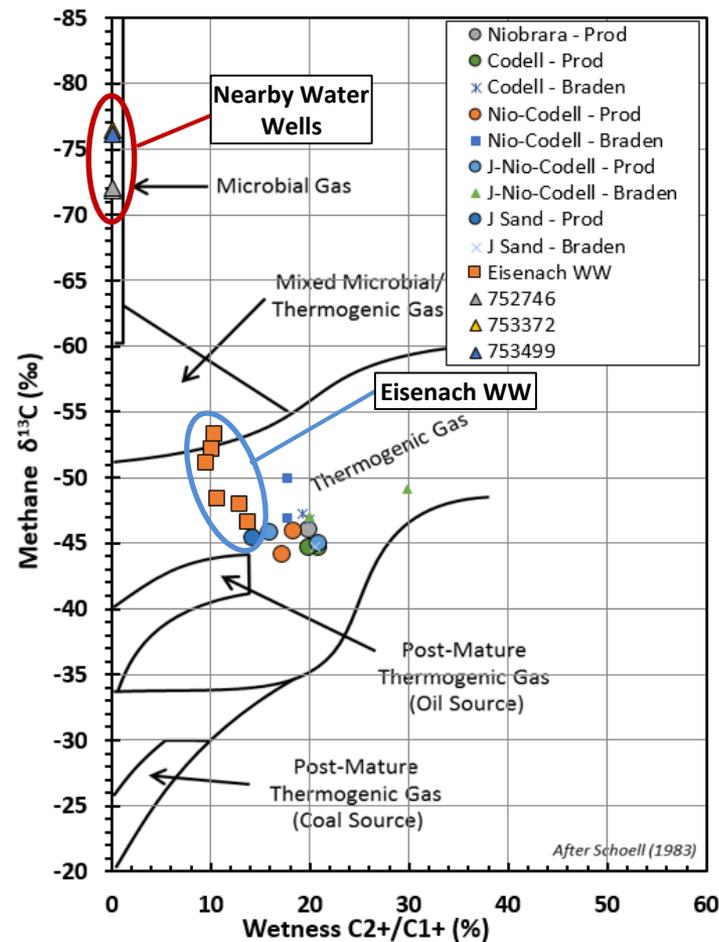
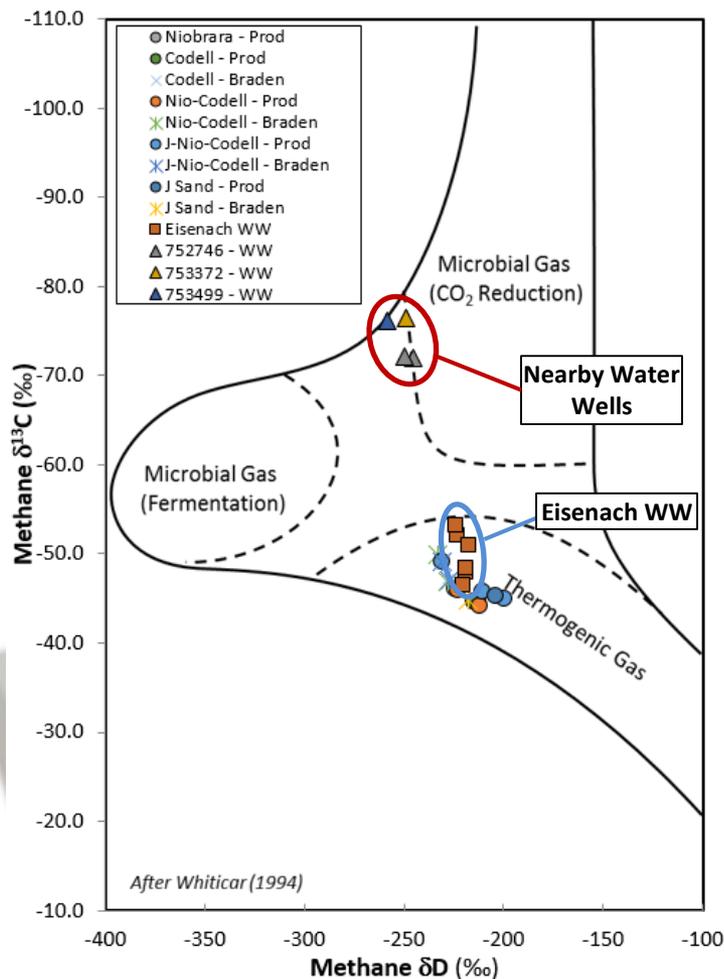
Eisenach WW & Nearby Production Gas Data



Well Name	API	Lat	Long	Fm (checked 10/20/2016)	Facility ID	Sample Date	Sample ID	Sample Type	$\delta^{13}C_1$	$\delta^{13}C_2$	$\delta^{13}C_3$	δD_1	$\delta^{13}C_{CO2}$	C1 %	C2 %	C3 %	iC4 %	nC4 %	iC5 %	nC5 %	C6+ %	N2 %	O2 %	Ar %	CO2 %
RAYMOND PRESTON GAS UNIT 1	123-08242	40.2422	-104.7978	J SAND	240454	6/7/2007	456080	Production	-45.3	-27.9		-204	3.6	81.6	9.6	2.6	0.4	0.6	0.2	0.2		0.5	0.02		3.9
RAYMOND PRESTON GAS UNIT 1	123-08242	40.2422	-104.7978	J SAND	240454	6/7/2007	456079	Bradenhead	-44.8	-27.2		-218	8.9	78.2	13.3	4.3	0.7	1.2	0.3	0.3		0.4	0.03		0.9
EISENACH & PRESTON 8-1K	123-15092	40.2443	-104.7942	CODELL	247295	6/7/2007	456472	Production	-44.6	-28.3		-213	4.0	74.7	13.8	4.8	0.8	1.4	0.4	0.3		0.3	0.02		2.9
EISENACH & PRESTON 8-1K	123-15092	40.2443	-104.7942	CODELL	247295	6/7/2007	456471	Bradenhead	-47.2	-31.5		-228	8.9	75.4	10.9	4.8	0.7	1.1	0.3	0.3		4.6	1.39	0.07	0.1
HSR-CRAWFORD 9-5	123-16401	40.2511	-104.7955	J-NIOBRARA-CODELL	248603	6/7/2007	456509	Production	-45.0	-26.5		-200	3.8	74.2	11.7	4.0	0.8	1.5	0.8	0.8		0.6	0.10	0.01	3.1
HSR-CRAWFORD 9-5	123-16401	40.2511	-104.7955	J-NIOBRARA-CODELL	248603	6/7/2007	456508	Bradenhead	-49.1	-34.4		-231		69.3	15.2	10.1	1.4	2.0	0.5	0.3		0.6	0.03		0.2
HSR-CHAKNOVA 14-5	123-16634	40.2479	-104.8030	J-NIOBRARA-CODELL	248832	6/7/2007	456512	Production	-45.7	-28.7		-211	3.2	80.2	10.6	3.0	0.5	0.8	0.3	0.2		0.4	0.02		3.6
HSR-CHAKNOVA 14-5	123-16634	40.2479	-104.8030	J-NIOBRARA-CODELL	248832	6/7/2007	456511	Bradenhead	-47.0	-32.0		-227		79.2	11.7	5.4	0.7	1.3	0.3	0.3		0.7	0.03	0.01	0.1
UPRC FEDERAL 5-6K	123-16823	40.2544	-104.8020	CODELL	249021	5/21/1997	456514	Production						77.5	12.1	4.4	0.7	1.3	0.3	0.3		0.5	0.2		2.7
UPRC FEDERAL 5-6K	123-16823	40.2544	-104.8020	CODELL	249021	9/5/1997	456515	Production						75.0	12.3	4.8	1.0	1.8	0.7	0.7	1.0	0.1			2.6
HSR-CREASON 11-5	123-18895	40.2479	-104.8028	NIOBRARA-CODELL	251092	6/7/2007	456551	Production	-44.1	-27.2		-212	3.8	71.5	10.9	2.8	0.4	0.5	0.1	0.1		8.6	2.66	0.13	2.1
HSR-CREASON 11-5	123-18895	40.2479	-104.8028	NIOBRARA-CODELL	251092	6/7/2007	456550	Bradenhead	-46.9	-32.0		-228		81.4	11.0	4.2	0.6	1.2	0.3	0.3		0.7	0.04	0.01	
HSR-BELL 12-5	123-18898	40.2480	-104.8028	CODELL	251095	6/7/2007	456553	Production	-44.7	-28.6		-215	4.1	74.9	13.8	4.8	0.8	1.4	0.5	0.4		0.3	0.03		2.7
HSR-BELL 12-5	123-18898	40.2480	-104.8028	CODELL	251095	6/7/2007	456552	Bradenhead	-46.8	-32.0		-224		79.1	11.8	5.4	0.7	1.3	0.3	0.3		0.6	0.02	0.01	0.04
BELLA FEDERAL 15N-7HZ	123-37551	40.2331	-104.8020	NIOBRARA	433223	6/4/2015	545537	Production	-46.0	-29.2	-25.9	-224		77.9	12.6	4.6	0.6	1.1	0.2	0.2	0.1	0.3	0.01	0.01	2.1
BELLA FEDERAL 15N-7HZ	123-37551	40.2331	-104.8020	NIOBRARA	433223	6/4/2015	545539	Bradenhead	-48.2	-32.0	-28.1	-230		75.4	10.7	5.1	0.8	1.4	0.5	0.4	0.4	1.2	0.01	0.01	0.01
MILLER ESTATE 8-14K	123-15349	40.2338	-104.8031	NIOBRARA-CODELL	247552	6/4/2015	545571	Production	-45.9	-29.0	-25.7	-223		79.6	12.3	4.2	0.5	0.8	0.1	0.1	0.3	0.3	0.01	0.01	1.7
MILLER ESTATE 8-14K	123-15349	40.2338	-104.8031	NIOBRARA-CODELL	247552	6/4/2015	545573	Bradenhead	-50.0	-32.5	-28.0	-233		78.8	9.1	4.9	0.9	1.3	0.5	0.3	0.5	3.5	0.12	0.02	0.01
Eisenach WW	40.24632	-104.79848			705016	5/24/2016	550848		-48.0	-27.5	-24.8	-219		60.9	6.0	2.3	0.4	0.3	0.1	0.02		25.5	3.2	0.5	0.9
Eisenach WW	40.24632	-104.79848			705016	10/13/2015	546510		-52.2	-27.8	-24.6	-224		61.3	4.6	1.7	0.3	0.2	0.0	0.01		29.5	1.0	0.5	0.7
Eisenach WW	40.24632	-104.79848			705016	4/13/2015	543742		-46.6	-27.7	-24.7	-221		78.0	8.2	3.1	0.6	0.5	0.1	0.03		8.8	0.3	0.2	0.2
Eisenach WW	40.24632	-104.79848			705016	6/19/2014	538346		-53.3	-27.8	-24.6	-224		61.9	4.4	1.8	0.4	0.3	0.1	0.03		28.6	1.4	0.5	0.4
Eisenach WW	40.24632	-104.79848			705016	6/15/2007	473647		-48.4	-27.6		-219	-21.5	73.9	5.4	2.2	0.6	0.4	0.1	0.04		16.6	0.1	0.3	0.2
Eisenach WW	40.24632	-104.79848			705016	9/14/2006	473645		-51.1	-27.4	-24.4	-218		66.7	4.1	1.9	0.6	0.3	0.1	0.03		24.5	1.1	0.4	0.2
	40.236536	-104.791225			752746	7/15/2014	539444		-71.9			-246		28.6	0.01							61.9	7.8	1.1	0.6
	40.236536	-104.791225			752746	6/27/2013	534594		-72.1			-250		40.1	0.03							55.6	3.0	1.0	0.4
	40.24449	-104.80719			753372	5/28/2014	538458		-76.5			-249		28.8	0.04							59.3	9.8	1.1	0.9
	40.24544	-104.80085			753499	7/22/2014	539274		-76.2	-48.7		-259		61.6	0.05							54.9	2.1	0.9	0.4

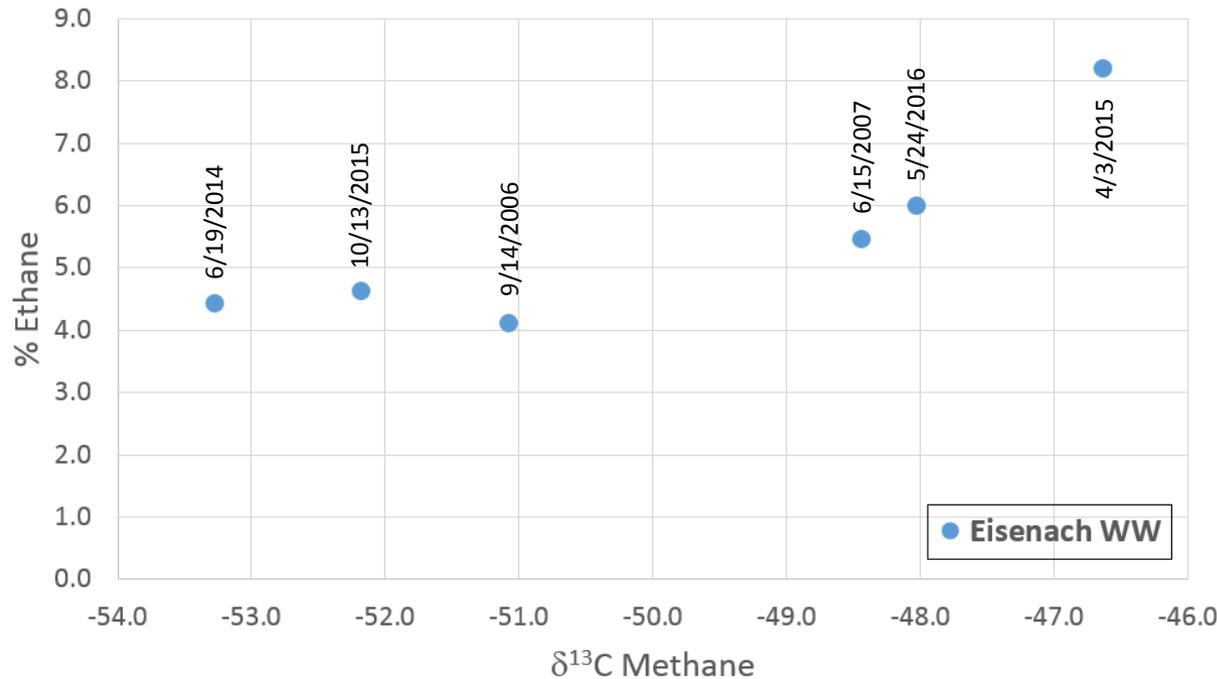
- The Eisenach WW has been analyzed for stable isotopes six times; an initial sample was taken in September 2006, with subsequent samplings in 2007, 2014, 2015, and 2016.
- Gas composition and stable isotope data was available for comparison from 9 nearby producing wells (produced and bradenhead gases) and 3 nearby water wells.

Plots of Eisenach WW and Nearby Production Gas Isotope and Composition Data



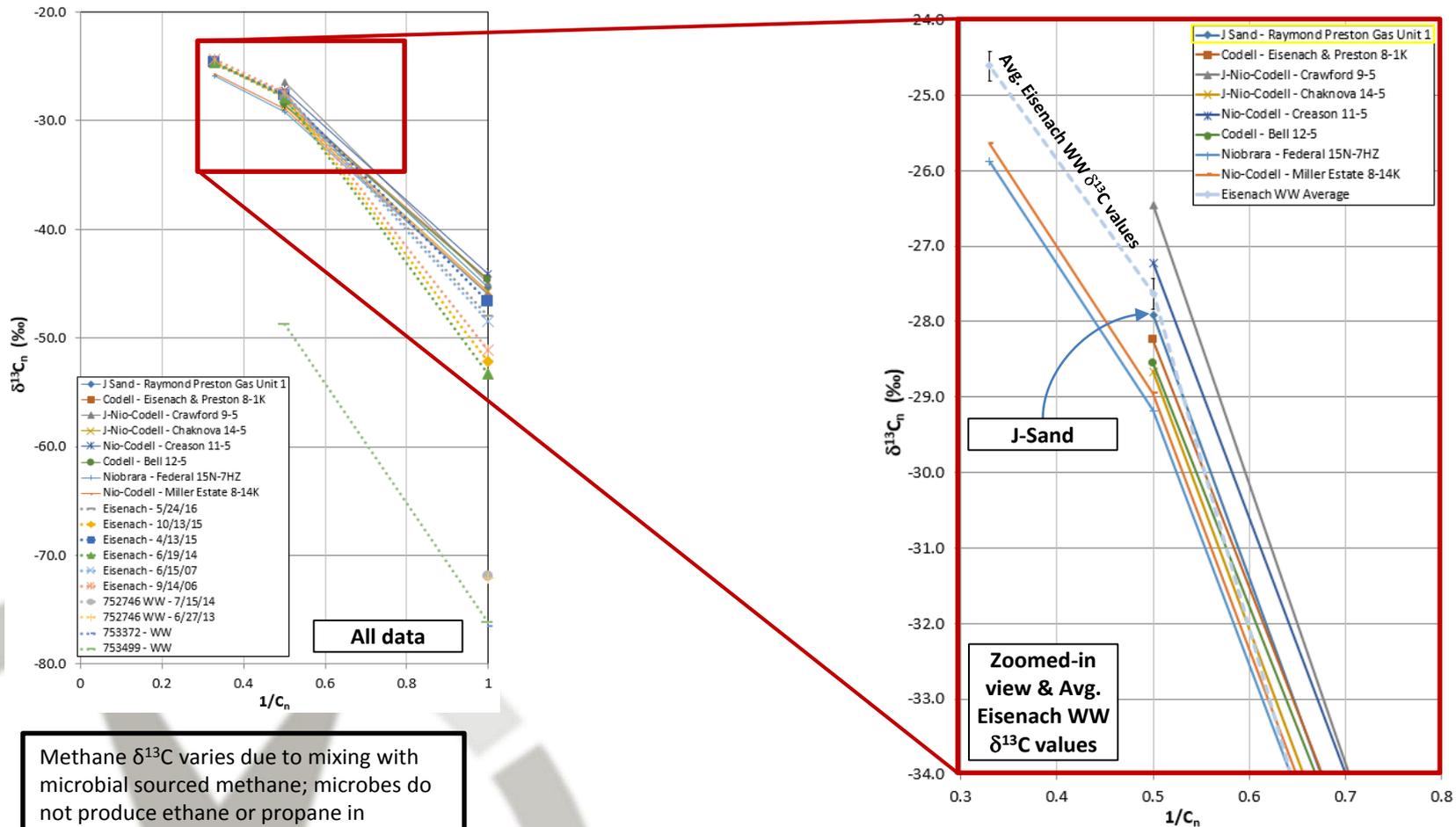
- Gas composition and stable isotopes show the Eisenach WW gas to be primarily thermogenic in origin.
- Methane gas in nearby water wells is bacterial in origin.

Evidence for Mixing of Thermogenic/Bacterial Gas



- Methane carbon isotopes and gas composition (e.g., % Ethane) in the Eisenach WW suggest various degrees of mixing with thermogenic gas over the 10 years of sampling.
- Specifically, higher concentrations (>5%) of wet gas components (e.g., ethane) correspond to more positive methane δ¹³C values, consistent with an increasing contribution from a thermogenic source.

Comparison of Eisenach WW Carbon Isotopes with Nearby Produced Gas



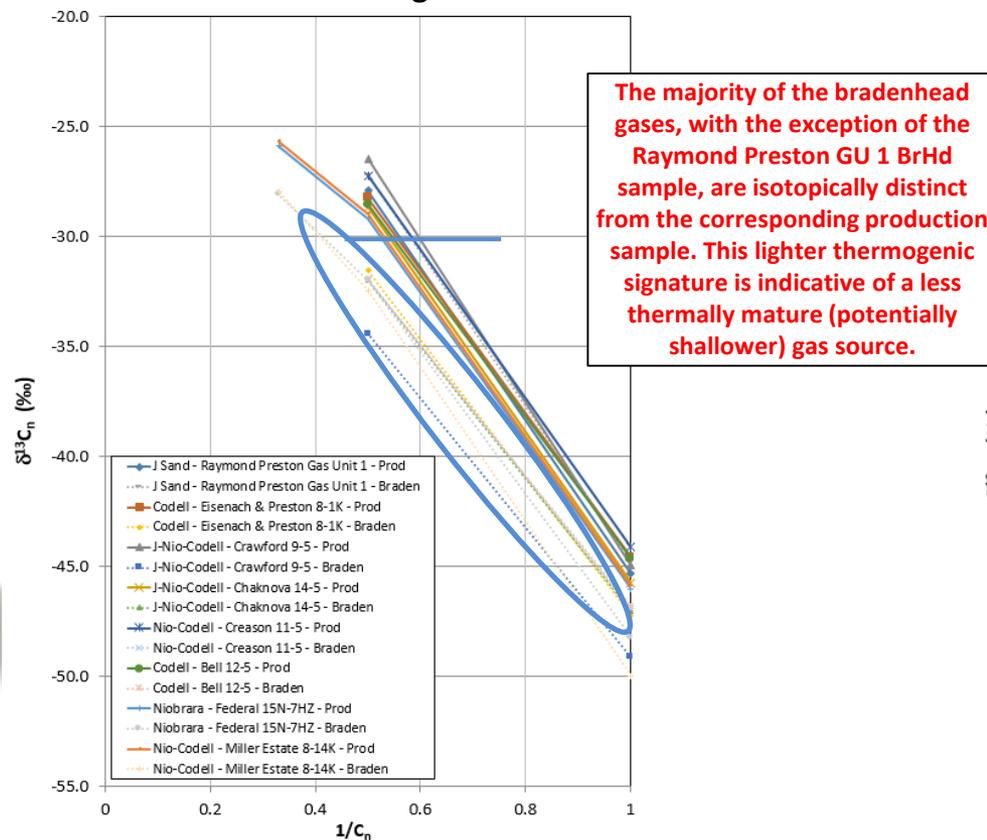
Methane $\delta^{13}C$ varies due to mixing with microbial sourced methane; microbes do not produce ethane or propane in abundance; as such those values reflect the thermogenic source.

Chung, H. M., Gormly, J. R., & Squires, R. M. (1988). Origin of gaseous hydrocarbons in subsurface environments: theoretical considerations of carbon isotope distribution. *Chemical Geology*, 71(1-3), 97-104.

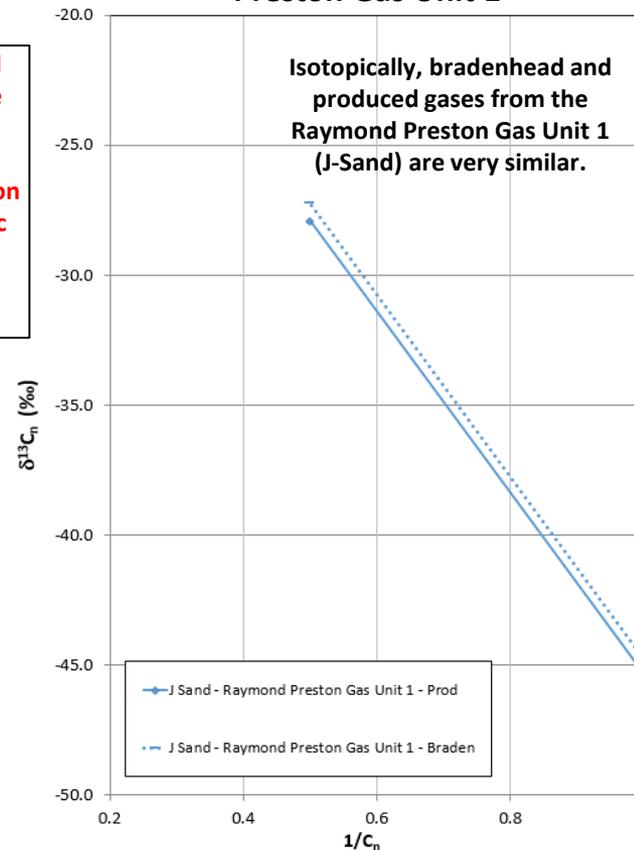
- Using a natural gas plot (Chung et al. 1988) to compare production gas stable isotopes we found that the average $\delta^{13}C$ values of ethane from the Eisenach WW most closely match J-Sand gas from the nearby Raymond Preston Gas Unit 1 well.
- Due to the lack of C_3+ stable isotope data for the produced gases, as well as the variability in the NB, CD, NB-CD and J-NB-CD signatures, it may be of value to re-analyze samples from these wells or other completions in the vicinity.

Production vs. Bradenhead Gases – Well Bore Integrity

Natural gas plot of nearby production and bradenhead gases



Natural gas plot of production-bradenhead gas pair from the Raymond Preston Gas Unit 1



- Bradenhead and produced gas stable isotopes from the Raymond Preston Gas Unit 1 well (J-Sand) are **very similar**. Other bradenhead-production gas pairs in the vicinity of the Eisenach WW do not show this high degree of similarity.
- Bradenhead gas from the Raymond Preston Gas Unit 1 well (J-Sand) has the highest concentration of CO₂ (9300ppm) compared to all other bradenhead gases in the investigated area.
- Collectively, these observations may reflect communication between the production zone and the bradenhead and therefore may indicate potential well-bore integrity issues. However, the Raymond Preston Gas Unit 1 was plugged and abandoned in December 2013.

- Gas composition and stable isotopes from the Eisenach water well (WW) and produced gases in the vicinity of the well (1 mile radius) were investigated in order to evaluate possible source(s) of the gas in the Eisenach WW.
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