

Formation	Source Ref	Sample Name	Age	Cl ppm	Br ppm	SO4 ppm	Ca ppm	Mg ppm	Sr ppm	Na ppm	Ba ppm	Ra-226 pCi/L	Ra-228 pCi/L	⁸⁷ Sr/ ⁸⁶ Sr	δ ² H ‰	δ ¹⁸ O ‰	TDS ppm
Berea Ss.	22,24	M1	L. Miss.	32,579	228	88	4,520	972	221	11,381				0.710800	-33.5	-4.9	
Berea Ss.	22,24	M4	L. Miss.	87,881	894	412	15,320	3,281	609	30,457					-35.4	-2.7	
Berea Ss.	this study ¹	M1	L. Miss.	32,579	228	88	4,548	1,092	173	12,279	12			0.710886			
Berea Ss.	this study ¹	M4	L. Miss.	87,881	894	412	16,078	3,293	476	32,101	8			0.711479			
Organic-rich Sh.	22,24	D6	U. Dev.	60,903	602	194	9,560	1,604	123	25,327				0.718300	-42.4	-5.7	
Organic-rich Sh.	22,24	D7	U. Dev.	80,542	783	127	12,360	2,066	180	30,503					-38.9	-4.7	
Organic-rich Sh.	22,24	D14	U. Dev.	60,655	675	184	10,000	1,920	104	23,289				0.715800	-37.9	-4.6	
Organic-rich Sh.	22,24	D17	U. Dev.	60,655	675	184	10,000	1,920	104	23,289					-47.2	-5.5	
Venango Grp. Ss.	22,24	D24	U. Dev.	70,581	642	483	10,920	1,798	171	27,457							
Venango Grp. Ss.	22,24	D33	U. Dev.	99,792	918	564	18,720	2,333	128	34,510					-39.7	-3.1	
Bradford Grp. Ss.	22,24	D10	U. Dev.	61,399	653	-	8,640	1,823	85	23,198				0.719000	-39.3	-5.1	
Bradford Grp. Ss.	22,24	D27	U. Dev.	62,108	631	119	11,160	1,458	84	24,411					-41.2	-4.6	
Bradford Grp. Ss.	22,24	D29	U. Dev.	131,697	944	62	24,760	2,430	2,317	44,586					-43.5	-5.8	
Bradford Grp. Ss.	22,24	D30	U. Dev.	148,784	1,037	-	30,760	2,965	3,601	57,548					-39.2	-4.7	
Bradford Grp. Ss.	22,24	D31	U. Dev.	81,003	692	706	12,680	1,823	74	29,770					-40.9	-5.1	
Bradford Grp. Ss.	22,24	D32	U. Dev.	83,095	734	314	12,760	1,944	77	32,701					-46.7	-4.7	
Bradford Grp. Ss.	22,24	D34	U. Dev.	91,213	804	110	15,800	2,138	325	30,114					-39.8	-4.5	
Bradford Grp. Ss.	22,24	D37	U. Dev.	45,376	463	1,182	8,440	1,191	47	19,305					-55.6	-7.1	
Bradford Grp. Ss.	22,24	D38	U. Dev.	96,424	984	657	16,080	2,430	126	34,739					-40.4	-4.3	
Bradford Grp. Ss.	22,24	D39	U. Dev.	72,070	723	286	10,880	1,774	62	29,060				0.720500	-42.9	-5.1	
Bradford Grp. Ss.	22,24	D40	U. Dev.	72,566	730	249	10,960	1,677	52	27,343				0.721000	-40.0	-5.1	
Upper Devonian	6	ED-82-01	U. Dev.	122,000	1,170	4	18,000	2,520	691	56,700	171				-39.0	-2.5	
Upper Devonian	6	ED-82-02	U. Dev.	123,000	1,180	1	18,800	2,500	1,490	58,300	843						
Upper Devonian	6	ED-82-03	U. Dev.	123,000	1,100		19,000	2,520	1,470	58,500	815						
Upper Devonian	6	ED-82-04	U. Dev.	111,000	1,070	8	17,100	2,410	1,290	52,100	1020						
Upper Devonian	6	ED-82-05	U. Dev.	151,000	1,340	2	24,700	2,880	2,340	63,500	1840						
Upper Devonian	6	ED-82-06	U. Dev.	155,000	1,350	11	25,100	2,850	2,420	63,700	2010	1900					
Upper Devonian	6	ED-82-07	U. Dev.	181,000	1,250	18	34,400	3,140	6,080	71,900	698						
Upper Devonian	6	ED-82-08	U. Dev.	70,600	622	5	11,000	1,650	404	30,600	174						
Upper Devonian	6	ED-82-09	U. Dev.	151,000	1,210	140	24,500	2,970	1,420	61,900	7	200			-35.0	-1.9	
Upper Devonian	6	ED-82-10	U. Dev.	105,000	983	50	14,900	2,150	578	47,400	623				-39.0	-3.0	
Upper Devonian	6	ED-82-11	U. Dev.	123,000	1,190	1	17,700	2,600	936	58,900	668				-39.0	-2.0	
Venango Second	6	ED-82-13	U. Dev.	57,400	586	270	8,150	1,570	129	25,000	2						
Venango First and Third	6	ED-82-15	U. Dev.	35,400	365	8	3,930	910	124	15,200	355						
Venango Second and Third	6	ED-82-23	U. Dev.	50,000	472	17	6,490	1,400	137	21,800	52				-39.0	-5.6	
Red Valley	6	ED-82-12	U. Dev.	6,780	94	2	1,580	195	22	3,400	17						
Glade	6	ED-82-14	U. Dev.	80,500	800	570	12,700	2,110	117	35,000	1						
Glade	6	ED-82-16	U. Dev.	63,200	792	390	11,800	2,050	152	30,000	3						
Glade	6	ED-82-17	U. Dev.	55,800	609	350	8,680	1,510	141	24,000	ND						
Glade	6	ED-82-18	U. Dev.	67,800	835	850	12,600	2,180	151	31,000	ND				-41.0	-4.4	
Cooper	6	ED-82-19	U. Dev.	5,760	99	4	920	100	5	3,000	7						
Kane	6	ED-82-20	U. Dev.	44,000	436	14	5,780	1,150	191	19,800	ND						
Cooper	6	ED-82-21	U. Dev.	41,200	437	310	6,110	1,040	39	17,400	ND						
Upper Devonian SS	this study	PAGB-3a	U. Dev.	87,000	780	93	13,677	1,740	160	37,054	69						
Upper Devonian SS	this study	PAGB-4a	U. Dev.	90,000	826	36	14,786	1,777	216	36,350	165						
Organic-rich Sh.	this study ¹	D6	U. Dev.	60,903	602	194	9,419	1,692	107	27,883	10			0.718347			
Organic-rich Sh.	this study ¹	D14	U. Dev.	60,655	675	184	10,375	2,050	96	25,402	13			0.715800			
Bradford Grp. Ss.	this study ¹	D27	U. Dev.	62,108	631	119	10,693	1,535	82	26,187	22			0.719459			
Bradford Grp. Ss.	this study ¹	D31	U. Dev.	81,003	692	706	12,639	1,912	72	31,107	7			0.719670			
Bradford Grp. Ss.	this study ¹	D32	U. Dev.	83,095	734	314	13,098	2,004	72	32,771	8			0.720131			
Venango Grp. Ss.	this study ¹	D33	U. Dev.	99,792	918	564	18,243	2,504	115	39,383	8			0.719725			
Bradford Grp. Ss.	this study ¹	D34	U. Dev.	91,213	804	110	14,707	2,083	266	35,642	13			0.716113			
Bradford Grp. Ss.	this study ¹	D37	U. Dev.	45,376	463	1,182	7,937	1,308	47	20,517	7			0.722000			
Bradford Grp. Ss.	this study ¹	D40	U. Dev.	72,566	730	249	10,770	1,718	61	28,950	10			0.721026			
Marcellus Sh.	21	BR-A1	M. Dev.	77,000			6,120	538	1,970	30,400	5490			0.710653			
Marcellus Sh.	21	BR-A2	M. Dev.	159,000			20,800	1,750	5,230	49,400	12000			0.710270			

Marcellus Sh.	21	BR-A3	M. Dev.	68,000			11,300	1,110	3,340	41,900	7820			0.710742		
Marcellus Sh.	21	BR-A4	M. Dev.	77,000			7,930	840	2,870	34,000	6470			0.710757		
Marcellus Sh.	21	BR-A5	M. Dev.	73,000			7,050	726	2,600	27,600	5860			0.710733		
Marcellus Sh.	21	WE-A1.5	M. Dev.				349		46		70			0.711992		
Marcellus Sh.	21	WE-A2	M. Dev.	10,300			624	43	88	2,792	179			0.712013		
Marcellus Sh.	21	WE-A4	M. Dev.	29,000			2,278	217	381	11,747	740			0.712036		
Marcellus Sh.	21	WE-A5	M. Dev.	32,200			2,880	254	450	14,216	888			0.712027		
Marcellus Sh.	21	WE-A7	M. Dev.	42,000			3,938	381	651	18,288	1405			0.712044		
Marcellus Sh.	21	WE-A12	M. Dev.	47,900			5,603	518	934	23,928	2193			0.712013		
Marcellus Sh.	21	WE-A15	M. Dev.	53,500			6,292	629	1,127	24,820	2687			0.712019		
Marcellus Sh.	21	WE-A29	M. Dev.	76,600			6,236	671	1,215	26,297	2987			0.712091		
Marcellus Sh.	21	WE-B3	M. Dev.	19,000			1,239	694	214	9,901	333			0.712076		
Marcellus Sh.	21	WE-B5	M. Dev.	30,600			2,782	376	533	16,704	1058			0.712108		
Marcellus Sh.	21	WE-B7	M. Dev.	40,700			3,900	490	738	18,288	1490			0.712088		
Marcellus Sh.	21	WE-B9	M. Dev.	46,800			4,627	559	900	18,510	1892			0.712108		
Marcellus Sh.	21	WE-B13	M. Dev.	71,100			5,749	211	1,063	22,437	2306			0.712117		
Marcellus Sh.	21	WE-B18	M. Dev.				6,278		1,380		2700			0.712113		
Marcellus Sh.	21	WA-A11	M. Dev.	88,500			12,278	1,267	1,393	32,500	151			0.711129		
Marcellus Sh.	21	WA-A13	M. Dev.	102,100			14,028	1,478	1,694	35,070	194			0.710988		
Marcellus Sh.	21	WA-A15	M. Dev.	107,300			15,269	1,632	1,832	37,100	253					
Marcellus Sh.	21	WA-A17	M. Dev.	102,600			15,875	1,671	1,872	38,530	296			0.711056		
Marcellus Sh.	21	WA-A20	M. Dev.	115,300			16,509	1,820	1,888	40,350	328			0.711088		
Marcellus Sh.	21	WA-A25	M. Dev.	116,100			17,612	1,896	2,045	46,260	349			0.711021		
Marcellus Sh.	21	WA-A30	M. Dev.				18,080	1,992	2,151	47,881	379			0.711076		
Marcellus Sh.	21	WA-B1-8	M. Dev.	59,600			8,682	880	1,192	20,310	176			0.710880		
Marcellus Sh.	21	WA-B1-4	M. Dev.	65,300			8,796	890	1,205	20,440	191			0.710905		
Marcellus Sh.	21	WA-B2-9	M. Dev.	59,400			8,779	859	1,277	20,510	389			0.710969		
Marcellus Sh.	21	WA-B2-6	M. Dev.	58,700			8,818	866	1,296	20,910	339			0.710954		
Marcellus Sh.	21	WA-B3-10	M. Dev.	36,700			5,674	570	795	12,890	11			0.710737		
Marcellus Sh.	21	WA-B3-5	M. Dev.	36,800			5,733	589	803	12,940	10			0.710722		
Marcellus Sh.	21	GR-AF	M. Dev.	41,900			4,377	567	1,389	20,923	393			0.710084		
Marcellus Sh.	21	GR-A1	M. Dev.	63,700			6,532	776	1,397	26,020	1108			0.710988		
Marcellus Sh.	21	GR-A2	M. Dev.	65,000			7,903	828	1,823	30,100	1560			0.710976		
Marcellus Sh.	21	GR-A3	M. Dev.	67,300			7,372	866	1,721	26,840	1487			0.710957		
Marcellus Sh.	21	GR-A4	M. Dev.	70,200			8,874	755	2,009	30,910	1756			0.710961		
Marcellus Sh.	21	GR-A5	M. Dev.	71,200			7,952	762	1,868	28,270	1638			0.710975		
Marcellus Sh.	21	GR-A7	M. Dev.	81,900			8,786	841	2,415	32,800	962			0.710148		
Marcellus Sh.	21	GR-A15	M. Dev.	86,500			9,634	953	2,275	32,380	2273			0.711160		
Marcellus Sh.	21	GR-A20	M. Dev.	87,700			10,390	976	2,484	34,520	2525			0.711173		
Marcellus Sh.	22,24	D60	M. Dev.	132,087	1,213	-	22,840	3,038	4,788	41,335				0.710000	-47.2	-5.9
Marcellus Sh.	22,24	D61	M. Dev.	105,854	1,081	-	21,160	2,187	1,975	37,785					-30.2	-0.4
Marcellus Sh.	22,24	D62	M. Dev.	112,377	1,142	-	22,720	2,819	1,844	37,304						
Marcellus Sh.	this study	PAGB-1a	M. Dev.	88,000	815	5	13,215	1,342	2,305	34,371	2655					
Marcellus Sh.	this study ²	PAGB-2a	M. Dev.	94,000	819	3	13,625	1,333	2,421	36,019	3100					
Marcellus Sh.	this study ¹	D61	M. Dev.	105,854	1,081	-	21,741	2,183	1,624	36,222	240			0.711432		
Marcellus Sh.	this study ¹	D62	M. Dev.	112,377	1,142	-	22,334	2,261	1,532	38,407	268			0.711605		
Marcellus Sh.	7	127	M. Dev.									2,653	318			122,527
Marcellus Sh.	7	128	M. Dev.									3,082	935			250,112
Marcellus Sh.	7	129	M. Dev.									1,958	572			134,880
Marcellus Sh.	7	130	M. Dev.									1,486	472			222,681
Marcellus Sh.	7	131	M. Dev.									1,756	377			117,259
Marcellus Sh.	7	3	M. Dev.									50	37			333,000
Marcellus Sh.	this study ²	4-0	M. Dev.	46,000	451	55	6,522	660	1,229	21,300	472	1277		0.710115		
Marcellus Sh.	this study ²	4-1	M. Dev.	59,000	583	18	7,898	972	1,047	26,224	899	2780				
Marcellus Sh.	this study ²	4-2	M. Dev.	59,000	581	30	8,390	1,023	1,198	27,246	1104	4044		0.711016		
Marcellus Sh.	this study ²	4-3	M. Dev.	56,000	543	26	7,956	965	1,170	25,175	1073	4835		0.710998		
Marcellus Sh.	this study ²	4-4	M. Dev.	54,000	531	37	8,186	983	1,236	25,993	1135	4988		0.710995		
Marcellus Sh.	this study ²	4-5	M. Dev.	62,000	608	27	8,310	1,009	1,256	26,703	1199	4769		0.710997		

Marcellus Sh.	this study ²	4-7	M. Dev.	75,000	733	34	10,308	1,134	1,732	32,622	771	3548	0.710185		
Marcellus Sh.	this study ²	4-15	M. Dev.	68,000	668	29	10,884	1,235	1,611	31,628	1746	5863	0.711197		
Marcellus Sh.	this study ²	4-20	M. Dev.	66,000	655	32	9,138	1,178	1,321	24,735	1388	5383	0.711220		
Ridgeley	6	ED-82-37	L. Dev.	58,900	349	2	8,930	797	4,400	24,400	1510			-41.0	-0.5
Ridgeley	6	ED-82-38	L. Dev.	133,000	763		17,600	1,580	8,930	61,300	3890			-51.0	-1.7
Ridgeley	6	ED-82-39	L. Dev.	174,000	1,010	1	23,800	2,050	13,100	79,900	4370	5000			
Ridgeley	6	ED-82-40	L. Dev.	207,000	1,130		28,400	2,390	12,800	83,300	3680			-42.0	2.0
Medina Ss.	6	ED-82-22	L Sil.	93,000	943	400	16,600	2,050	477	37,600	ND				
Medina Ss.	6	ED-82-27	L Sil.	159,000	2,240	280	41,600	4,150	1,610	42,400		500			
Medina Ss.	6	ED-82-28	L Sil.	151,000	1,860	360	26,900	2,750	1,030	59,900	4				
Medina Ss.	6	ED-82-29	L Sil.	187,000		270	36,300	3,790	1,430	78,900	4			-38.0	-3.1
Medina Ss.	6	ED-82-30	L Sil.	130,000	1,490	260	22,000	2,160	893	51,100	3			-39.0	-3.6
Medina Ss.	6	ED-82-31	L Sil.	159,000	1,990	300	30,100	3,120	1,160	65,300	4				
Tuscarora	6	ED-82-36	L Sil.	152,000	1,540	3	25,500	1,370	3,810	70,700	919	5300		-40.0	-2.3
Medina Ss.	22,24	S70	L Sil.	159,383	1,609	262	27,800	2,989	747	60,639					
Medina Ss.	22,24	S73	L Sil.	141,623	1,311	164	25,040	3,353	705	54,571			0.711900	-32.3	-3.9
Medina Ss.	this study ¹	S73	L Sil.	141,623	1,311	164	22,201	2,836	520	45,253	7		0.711954		
Utica	this study	RW-1	Ord.	43,866	440	363	3,717	516	747	19,113	578	157	0.710505		

Table S2. Analytical results for produced water and flowback samples collected during this and previous studies (4, 6, 7, 21, 22, 24). ¹ Results from analysis of cation and strontium isotope samples analyzed at Duke University. Data presented for anions of these samples are originally reported in (22, 24). ² Split samples of GR samples published in (21). If blank, no value reported/recorded. Ss.=sandstones; Sh.=shales; L. Miss.=Lower Mississippian; U. Dev.=Upper Devonian; M. Dev.=Middle Devonian; Sil.=Silurian; Ord. = Ordovician, ppm = part per million, pCi/L = pico Curie per liter.