Cuttings Analysis - Branine 1-3 (15-093-21222)

Notes- The following RVS data were used for the preparation of the AAPG Midcontinent Section 2023 talk - Demonstrating the Utility of CO2 Entrained in Legacy Drill Cuttings as a Proxy for Pressure Compared to Drill Stem Tests Measurements in Oil Fields from Kearny County Kansas.
The cuttings data for all wells listed except the KGS 5025 Patterson were generated from cuttings available through the KGS' sample repository - Branine 1-3 through Patters 1-31 were analyzed specifically for this presentation with only the sections that corresponded to past DST analyese beign run, not the entire well.

Data are transmitted as is.

See headers of data for approariate units relating to the RVS measurements

Sulfate Proxy and Organic Acids Data are not calibrated and are reported in instrumental counts, comparisons of these data are best made between the same instrumental runs - there are three such runs, the Branine 1-3 through Patterson 1-31 data, with the Gatos O Patterson 1-23, and Patterson KGS 5-25 each representing their own run.

Water is the volume of water contained in the rock sample, while this is not the same as SW, it has been shown to quantiatively relate to the volume of water in the subsurface

Aliquot 1 (Aq1) referst to the volatiles extracted from the rock samples after crushing at 20 mbar vacuum pressure, Aliquot 2 (Aq2) refers to the volatiles extracted from the same rock sample as Aq1 but at a subsequent 2 mbar vacuum pressure, sum is the sum of both extractions;

In the event of questions please reach out to Advanced Hydrocarbon Stratigraphy in Tulsa, OK (advancedhydrocarbon.com). Christopher Smith - Senior Chemist - was responsible for the perparation of this file and can be reached at christopher@advancedhydrocarbon.com

Well	API	Field	Formation	Year	Pressure	Formation	Depth	CO2 Aq1 (nanomoles)	SO Aq1 (Sulfate Proxy, counts)	Formic Acid Aq1 (counts)	Acetic Acid Aq1 (counts)	Water Aq1 (counts)	CO2/Water Aq1 (Ratio)	CO2 Aq2 (nanomoles)	SO Aq2 (Sulfate Proxy, counts)	Formic Acid Aq2 (counts)	Acetic Acid Aq2 (counts)
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3930	26.85624012	1098233.069	166.5842263	53.73614999	189.5858304	0.141657423	109.8472039	2706738.323	160.4051956	48.94254763
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3940	273.7837614	1286767.459	234.6043254	68.14337148	154.2165932	1.775319735	105.7205838	2859501.125	134.8639447	41.81558626
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3950	78.06622456	1284410.014	102.2293268	31.53844513	175.3483552	0.445206483	110.523239	3363006.196	213.1269499	63.95228998
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3960	220.3318143	856776.044	209.4790763	62.89487922	147.0934324	1.49790382	141.3829782	3881808.892	181.2473486	53.2688691
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3970	472.5789356	2327238.363	236.3337411	73.82921774	158.8212584	2.975539549	128.1679557	4033882.8	190.4225128	52.73060833
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3980	206.8940911	669031.2166	185.1994359	45.99884175	151.2534596	1.36786353	124.2414409	3588862.875	196.4770556	51.57061274
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3990	301.2714986	1032275.356	229.0116884	72.66843502	210.097098	1.43396316	130.2711916	3542723.47	214.8235144	60.78317174
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3992	245.7290879	761041.2343	152.94573	46.37068594	156.4165424	1.570991687	130.7413005	3900984.349	199.1084606	55.53188776
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4000	831.9338064	2360570.758	236.052807	69.53001419	191.9699124	4.333667688	121.0823786	3832821.388	163.9723844	40.77382831
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4008	129.7213641	872070.1621	84.83033885	22.55504364	209.657172	0.618730869	124.9360862	3792367.913	153.1835894	45.55659517
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4010	62.03962329	1405604.204	78.61654824	21.6443702	187.4726124	0.330926328	120.6867382	3812335.399	198.3418747	49.79394119
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4020	165.1244972	1796790.428	237.9150832	65.77399945	175.7637712	0.939468333	136.6122364	4164724.682	206.4516962	54.85479033
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4030	236.9898669	915544.3483	173.6984332	40.75033256	164.9533564	1.436708365	122.7554947	4037703.726	200.5056139	45.51843105
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4040	202.7997088	2162187.226	183.9206373	58.24138481	163.868274	1.237577622	112.5209439	3750318.387	167.2236193	40.20482221
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4050	457.5826074	2517706.413	199.5099453	53.82501307	167.99382	2.723806194	108.063846	3783394.706	149.3748252	33.37997567
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4060	38.10375591	2462669.899	104.9146113	28.49018445	202.1081528	0.188531513	105.0981002	3537089.656	128.812467	31.10725829
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4070	23.51803595	2486996.878	104.4083113	27.47899473	189.9301712	0.123824645	117.3032931	4036088.656	148.277482	33.9895194
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4080	151.7695884	2353003.533	212.2494326	61.85175855	180.5841472	0.840436942	115.6751613	3679284.443	129.2358762	27.57883653
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4090	442.2557663	2918749.705	177.8109434	44.95741249	192.7859016	2.294025459	99.97412755	5776192.271	153.579699	30.0158797
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4100	272.2395874	3165948.58	206.7756344	52.07997225	194.408874	1.400345477	104.6017992	3444019.849	150.8405616	29.91498955
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4110	58.24895216	3186441.462	97.41223878	24.43703594	202.7851	0.287244734	117.0312328	3768357.981	165.1831213	26.71028036
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4112	198.3631447	2543634.206	187.1887351	41.32815005	176.9065148	1.121287958	118.242448	4307072.08	186.867802	38.28153938
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4120	587.91425	3628044.592	219.3363793	56.06847403	220.4428108	2.666969487	137.1887027	4417958.153	194.9079662	39.63850267
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4130	110.1146696	3425080.394	95.26514641	16.54563927	194.2397664	0.566900752	120.0566333	4451595.534	190.7696004	39.93184904
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4140	212.3609665	2178240.506	149.2621453	37.80172718	170.7350716	1.243804009	111.2961062	3728582.381	156.4721001	26.18662207
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4150	533.9537951	2657232.287	156.1964363	37.90669419	191.129512	2.793675291	149.1618355	3741831.919	186.3696748	34.49740303
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4330	174.5230102	2931871.651	187.6961805	34.97215847	171.722988	1.016305459	129.7086031	4601023.407	224.9612117	39.6180577
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4340	102.5994035	2797672.88	114.2478593	25.87215907	182.9253424	0.560881298	111.5993591	3950201.493	221.1122941	34.69971554
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4350	405.2589096	3574485.616	223.4085939	52.39643127	221.8704708	1.826556315	128.2033728	4134167.7	160.1580283	20.60076099
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4360	133.1110206	3008461.041	160.2320848	32.19676493	186.2969532	0.714509917	106.3605095	3661386.366	144.3328228	30.9712928
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4370	107.0075961	2297124.364	114.8378403	28.94624049	167.2922412	0.639644704	106.6353296	3986262.287	186.4913208	33.49981852
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4380	65.23667428	3625183.807	126.8375467	21.57331139	199.2205936	0.327459492	109.8299774	4090031.914	204.3658419	48.31604796
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4390	157.6196574	3588859.484	190.5909739	40.28559309	186.139922	0.846780507	103.3439829	3952451.626	152.0726225	24.03082193
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4397	19.26876496	3077760.085	97.74373731	17.44893097	191.7529856	0.100487431	98.80825089	3571977.639	156.9449786	21.67563061
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4400	196.2333528	3643781.297	188.2334302	41.15328047	200.9030436	0.976756496	99.73788623	3316729.322	142.330345	21.483707
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4407	178.0567422	3638961.626	197.6088475	41.52612822	184.8808072	0.963089381	106.9132359	3995868.388	238.955645	33.39436502
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4410	77.56367869	3829232.854	127.8091824	20.18767979	227.4230764	0.341054566	103.0740697	4049049.445	173.2759074	25.25481857
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4420	62.21209095	3003014.037	77.02673743	12.76550183	196.7653832	0.316173963	98.57500132	3557912.119	151.0559868	21.63527635
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4430	697.7295533	3165860.567	196.8697861	37.32707727	218.7404184	3.189760532	74.74835137	3830939.708	200.2978356	25.93306695
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4440	369.17259	3706944.396	200.3586835	43.50849507	209.1225424	1.765340961	83.44766333	4117881.171	206.0561679	33.34080302
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4446	121.9956042	2473778.293	134.976119	18.51127562	173.7340696	0.702197355	74.53897258	3833322.526	175.6143594	29.43019433
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4450	113.5830847	2750024.493	138.0738189	22.24472362	170.2453884	0.667172754	84.17041687	3958928.216	206.5228483	25.92798763

Well	API	Field	Formation	Year	Pressure	Formation	Depth	Water Aq2 (counts)	CO2/Water Aq2 (ratio)	CO2 Sum (nanomoles)	SO Sum (Sulfate Proxy, counts)	Formic Acid Sum (counts)	Acetic Acid Sum (counts)	Water Sum (counts)	CO2/Water Sum (counts)	SO/Water Sum (counts)
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3930	102.2299864	1.074510599	136.703444	3804971.392	326.989422	102.6786976	291.8158168	0.468457966	13038.94845
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3940	91.920708	1.150128041	379.5043451	4146268.584	369.4682701	109.9589577	246.1373012	1.541840035	16845.34836
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3950	83.3335972	1.326274668	188.5894635	4647416.21	315.3562767	95.49073511	258.6819524	0.729039895	17965.75357
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3960	86.7472208	1.62982718	361.7147925	4738584.936	390.7264249	116.1637483	233.8406532	1.546843064	20264.16224
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3970	85.5778316	1.497677065	600.7468913	6361121.163	426.7562538	126.5598261	244.39909	2.458056989	26027.59758
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3980	86.5656112	1.435228599	331.135532	4257894.092	381.6764915	97.56945449	237.8190708	1.392384265	17903.92199
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3990	116.2482928	1.120628858	431.5426902	4574998.827	443.8352028	133.4516068	326.3453908	1.322349579	14018.88599
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	3992	97.607066	1.339465531	376.4703883	4662025.584	352.0541906	101.9025737	254.0236084	1.482029134	18352.72561
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4000	105.7292316	1.145211942	953.016185	6193392.145	400.0251914	110.3038425	297.699144	3.201272843	20804.1987
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4008	114.440116	1.09171583	254.6574504	4664438.075	238.0139282	68.11163881	324.097288	0.785743849	14392.09228
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4010	90.6461728	1.331404675	182.7263615	5217939.603	276.9584229	71.43831138	278.1187852	0.65700834	18761.55039
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4020	87.412958	1.562837359	301.7367336	5961515.11	444.3667794	120.6287898	263.1767292	1.14651753	22652.13618
Branine 1-3	15-093-21222	Hartland	Lansing "E"	1992	829	Lansing "E"	4030	89.4060808	1.373010578	359.7453616	4953248.074	374.2040471	86.26876362	254.3594372	1.414318908	19473.4197
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4040	96.0111116	1.171957516	315.3206527	5912505.613	351.1442565	98.44620702	259.8793856	1.213334609	22750.96041
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4050	92.3695716	1.169907407	565.6464534	6301101.119	348.8847705	87.20498875	260.3633916	2.172526829	24201.17928
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4060	108.1804368	0.97150745	143.2018562	5999759.554	233.7270783	59.59744273	310.2885896	0.461511834	19336.06248
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4070	95.3193748	1.23063431	140.821329	6523085.534	252.6857933	61.46851413	285.249546	0.493677662	22867.9962
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4080	106.4923096	1.086230186	267.4447497	6032287.976	341.4853088	89.43059508	287.0764568	0.931615057	21012.82719
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4090	55.727684	1.793975999	542.2298939	8694941.976	331.3906424	74.97329219	248.5135856	2.18189236	34987.79334
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4100	105.8856852	0.987874791	376.8413866	6609968.43	357.6161961	81.9949618	300.2945592	1.254905808	22011.61569
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4110	105.754608	1.106630104	175.280185	6954799.442	262.5953601	51.14731631	308.539708	0.568096036	22541.01907
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4112	91.0925056	1.298048036	316.6055928	6850706.286	374.0565371	79.60968943	267.9990204	1.18136847	25562.43032
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4120	107.1828	1.279950726	725.1029527	8046002.745	414.2443455	95.7069767	327.6256108	2.213205955	24558.52803
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4130	95.7647424	1.253662155	230.1713029	7876675.927	286.0347468	56.4774883	290.0045088	0.793681808	27160.52919
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4140	108.349286	1.027197412	323.6570727	5906822.887	305.7342454	63.98834924	279.0843576	1.159710546	21165.00881
Branine 1-3	15-093-21222	Hartland	Lansing "I"	1992	909	Lansing "I"	4150	89.2552208	1.671183312	683.1156306	6399064.206	342.5661111	72.40409722	280.3847328	2.436351023	22822.44166
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4330	79.4481276	1.632620013	304.2316133	7532895.058	412.6573922	74.59021618	251.1711156	1.211252387	29991.08811
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4340	87.46308	1.275959629	214.1987626	6747874.373	335.3601534	60.57187461	270.3884224	0.792189106	24956.22525
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4350	128.9623708	0.994114578	533.4622824	7708653.316	383.5666222	72.99719225	350.8328416	1.520559706	21972.4393
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4360	104.6638104	1.016210943	239.4715301	6669847.406	304.5649076	63.16805773	290.9607636	0.823037193	22923.52867
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4370	89.370528	1.193182272	213.6429258	6283386.652	301.3291611	62.44605901	256.6627692	0.832387675	24481.09896
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4380	115.1071528	0.954154236	175.0666517	7715215.72	331.2033886	69.88935935	314.3277464	0.556955769	24545.13103
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4390	103.823638	0.995380098	260.9636404	7541311.11	342.6635964	64.31641503	289.96356	0.89998771	26007.78908
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4397	103.9727956	0.950327923	118.0770159	6649737.725	254.6887159	39.12456158	295.7257812	0.399278735	22486.16167
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4400	119.1693224	0.836942631	295.971239	6960510.619	330.5637753	62.63698747	320.072366	0.924701007	21746.67781
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4407	72.8783	1.467010563	284.9699781	7634830.014	436.5644924	74.92049324	257.7591072	1.105567059	29620.0204
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4410	133.2812988	0.773357333	180.6377484	7878282.3	301.0850898	45.44249835	360.7043752	0.500791675	21841.3827
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4420	112.2614088	0.878084485	160.7870923	6560926.155	228.0827242	34.40077819	309.026792	0.520301464	21230.92989
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4430	112.1705812	0.666381065	772.4779047	6996800.275	397.1676217	63.26014422	330.9109996	2.334397786	21144.0547
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4440	110.4362384	0.755618487	452.6202533	7824825.567	406.4148514	76.84929809	319.5587808	1.416391226	24486.34191
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4446	98.7850584	0.754557155	196.5345768	6307100.819	310.5904784	47.94146995	272.519128	0.721177182	23143.69955
Branine 1-3	15-093-21222	Hartland	Marmaton	1992	405	Marmaton	4450	103.6349832	0.812181507	197.7535015	6708952.709	344.5966672	48.17271124	273.8803716	0.722043352	24495.92379

Well	API	Field	Formation	Year	Pressure	Formation	Depth	CO2 Aq1 (nanomoles)	SO Aq1 (Sulfate Proxy, counts)	Formic Acid Aq1 (counts)	Acetic Acid Aq1 (counts)	Water Aq1 (counts)	CO2/Water Aq1 (Ratio)	CO2 Aq2 (nanomoles)	SO Aq2 (Sulfate Proxy, counts)	Formic Acid Aq2 (counts)	Acetic Acid Aq2 (counts)
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4890	256.6296069	3467270.284	188.7193754	37.37448756	191.0794964	1.343051514	77.58855407	4018327.024	211.5571146	30.69028764
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4900	9.92080304	3214376.496	45.03892163	7.947013763	205.7791732	0.048210919	79.79777662	4057803.248	231.7726734	26.7043401
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4910	78.76051272	2812033.394	70.70443632	12.76384332	181.046326	0.435029611	73.10852277	3895903.163	175.6435384	25.39713239
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4920	169.924644	2663185.058	137.1972564	27.10141295	174.1292468	0.975853552	65.76839999	3347903.26	180.0584334	20.34359733
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4930	62.03766753	3616778.685	83.50484291	14.21786887	198.0838996	0.313188844	71.67044878	3737005.71	162.9679487	17.30787899
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4940	106.142418	3034230.996	145.7700516	18.88511231	184.620378	0.574922547	69.35151727	3446435.99	180.040927	22.76435416
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4950	8.675926203	3851549.458	78.04393376	18.18220252	245.0360384	0.035406736	74.17974304	3993151.705	219.8072921	50.32136966
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4956	300.3302486	4677676.255	197.285761	60.76717831	160.9641696	1.865820507	14.25258148	816782.1958	4.767591808	0.749259946
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4960	265.0783427	3981835.949	200.9920178	48.28927365	244.5417268	1.083980007	93.21657035	3284718.002	164.2239152	17.45292711
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4970	24.69860732	2804191.21	71.64918223	16.11717724	186.606182	0.132356855	84.07194476	2681909.93	126.8621411	14.41141206
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4980	345.401357	3843963.291	183.6699169	33.24582513	184.338152	1.873737765	81.5497603	2915174.742	136.7144865	17.42124223
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4990	209.4905203	4640537.013	186.1571313	39.51925432	211.7746536	0.989214322	80.71532649	3310361.885	139.8015218	15.78201177
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	5000	212.7088422	4253192.629	177.4079731	32.37595419	205.9653428	1.032740942	71.59637424	3003761.9	123.1799227	23.07187326

Well	API	Field	Formation	Year	Pressure	Formation	Depth	Water Aq2 (counts)	CO2/Water Aq2 (ratio)	CO2 Sum (nanomoles)	SO Sum (Sulfate Proxy, counts)	Formic Acid Sum (counts)	Acetic Acid Sum (counts)	Water Sum (counts)	CO2/Water Sum (counts)	SO/Water Sum (counts)
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4890	101.2528164	0.766285392	334.218161	7485597.308	400.27649	68.06477521	292.3323128	1.143281623	25606.46559
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4900	90.14949	0.885171692	89.71857966	7272179.744	276.811595	34.65135386	295.9286632	0.303176376	24574.09723
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4910	108.0149848	0.676836857	151.8690355	6707936.557	246.3479748	38.16097571	289.0613108	0.525386933	23205.93004
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4920	97.8581852	0.672078681	235.693044	6011088.318	317.2556898	47.44501028	271.987432	0.866558584	22100.61058
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4930	118.6865476	0.603863287	133.7081163	7353784.395	246.4727916	31.52574787	316.7704472	0.422097823	23214.86887
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4940	105.3380976	0.658370702	175.4939353	6480666.985	325.8109785	41.64946647	289.9584756	0.605238164	22350.32783
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4950	124.3459636	0.596559316	82.85566925	7844701.163	297.8512259	68.50357218	369.382002	0.224308896	21237.36706
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4956	145.671062	0.097840857	314.5828301	5494458.45	202.0533528	61.51643825	306.6352316	1.025918739	17918.54909
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4960	117.3344544	0.794451816	358.294913	7266553.951	365.215933	65.74220076	361.8761812	0.990103609	20080.22171
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4970	104.2045576	0.806797195	108.7705521	5486101.14	198.5113233	30.52858929	290.8107396	0.374025224	18864.85055
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4980	102.4645528	0.795882655	426.9511173	6759138.032	320.3844034	50.66706736	286.8027048	1.488657918	23567.20463
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	4990	113.8166956	0.709169477	290.2058468	7950898.898	325.9586532	55.30126609	325.5913492	0.891319279	24419.87146
Branine 1-3	15-093-21222	Hartland	St. Louis	1992	549	St. Louis	5000	119.7915344	0.597674741	284.3052164	7256954.529	300.5878958	55.44782745	325.7568772	0.872752768	22277.21051

ADVANCED HYDROCARBON STRATIGRAPHY (AHS)

Demonstrating the Utility of CO2 Entrained in Legacy Drill Cuttings as a Proxy for Pressure Compared to Drill Stem Tests Measurements in Oil Fields from Kearny County Kansas

Christopher Smith (PhD)

Senior Chemist – AHS

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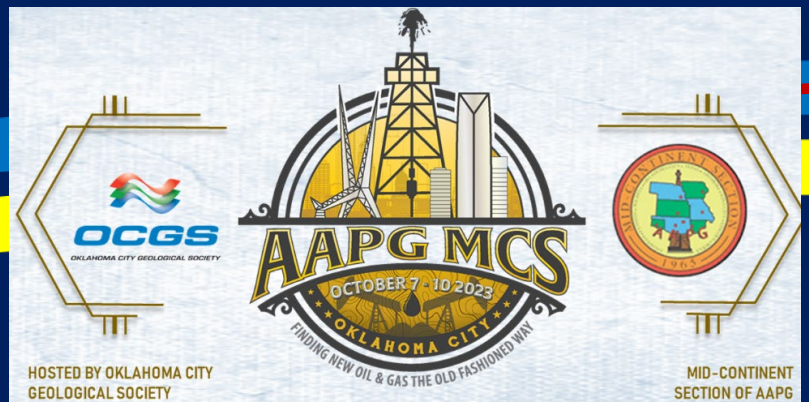

AHS

Advanced Hydrocarbon Stratigraphy
AdvancedHydrocarbon.com

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

Acknowledgements

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Timothy Smith – AHS

A special thank you to Doug Louis and Jonelle Stevens at the Kansas Geological Sample Repository

Many thanks to OCGS, especially Molly Turko, Troy Johnson, the conference committee/organizers for the opportunity to present today

Rock Volatiles Stratigraphy (RVS)

ADVANCED HYDROCARBON STRATIGRAPHY

Compounds Measured by RVS

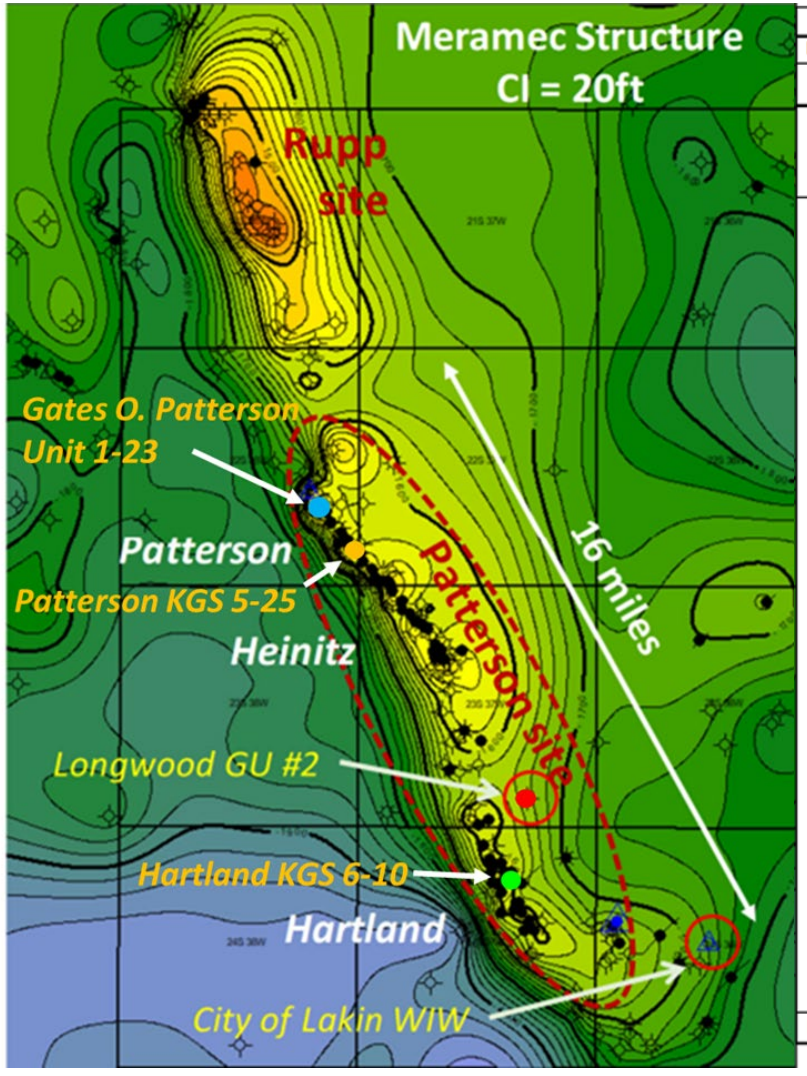
Hydrocarbons	**Small Molecules**	**Sulfur Species**
C1-4 Gases	Water	Hydrogen Sulfide
C5-10 Paraffins	Carbon Dioxide	Carbonyl Sulfide
C6-10 Naphthenes	Hydrogen	Carbon Disulfide
C6-9 Aromatics	Nitrogen	SO- (Sulfate Proxy)
	Oxygen	Sulfur Dioxide
Nobel Gases	Ammonia	
Helium	Carbon Monoxide	**Biological Compounds**
Argon		Formic Acid
Xenon	**Stimulation Chemicals**	Acetic Acid
Bit Burn	Trichloroethylene	Methyl Ethyl Ketone
Ethene	Methanol	
2-Transbutene	Ethanol	

- 40+ volatile compounds are analyzed via gentle extraction, identification, and quantification on a novel cryo trap-mass spectrometry system developed by AHS
- Capabilities for isomers and isotopes
- Any type of rock samples as well as produced fluids and muds can be analyzed regardless of mud system or age of samples
- Technology is used in oil and gas, geothermal, helium, carbon capture, and hydrogen

Background

ADVANCED HYDROCARBON STRATIGRAPHY

- Since 2020 KGS and AHS have been using RVS to assist in Patterson site as part of the KGS's Phase II CarbonSAFE program.
- This involved the RVS analyses of two wells drilled in 2020 as part of the CarbonSAFE program and subsequently the 1941 discovery well
- The Patterson site consists of shallow oil fields with KGS attention focused on deeper carbonate saline aquifers to serve as CO_2 injection zones



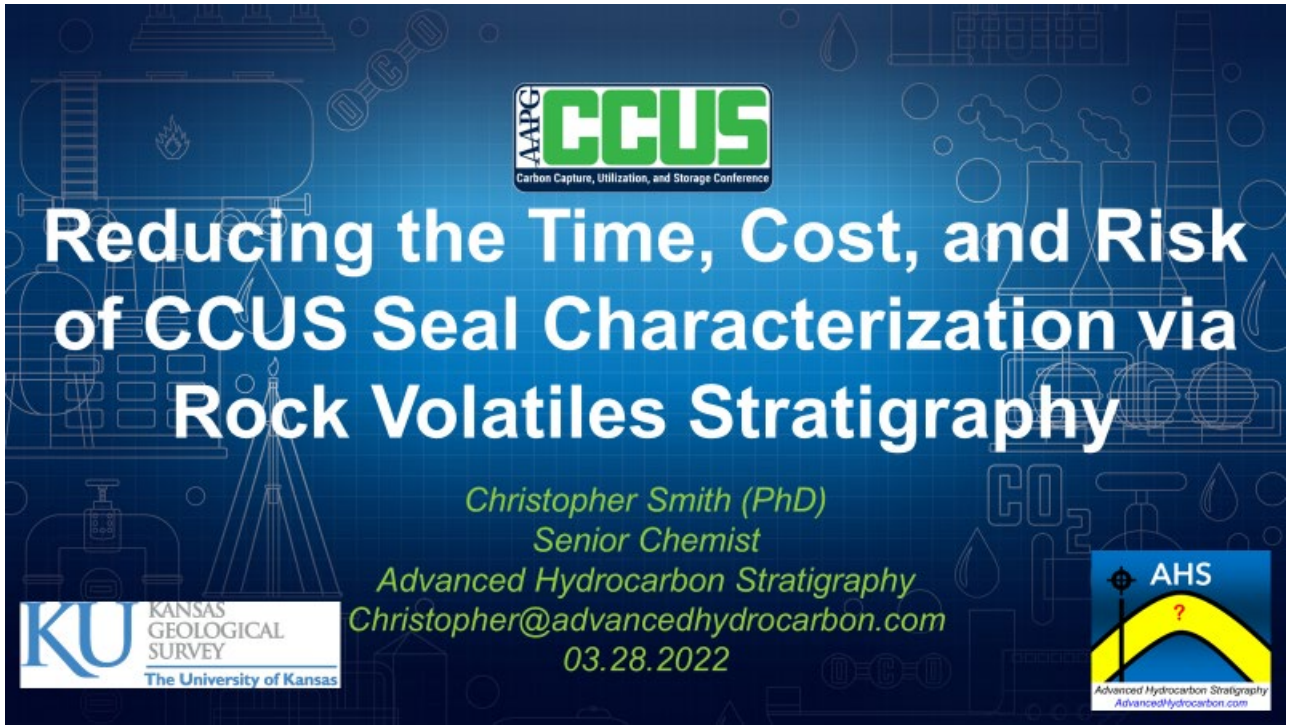
STRATIGRAPHY*

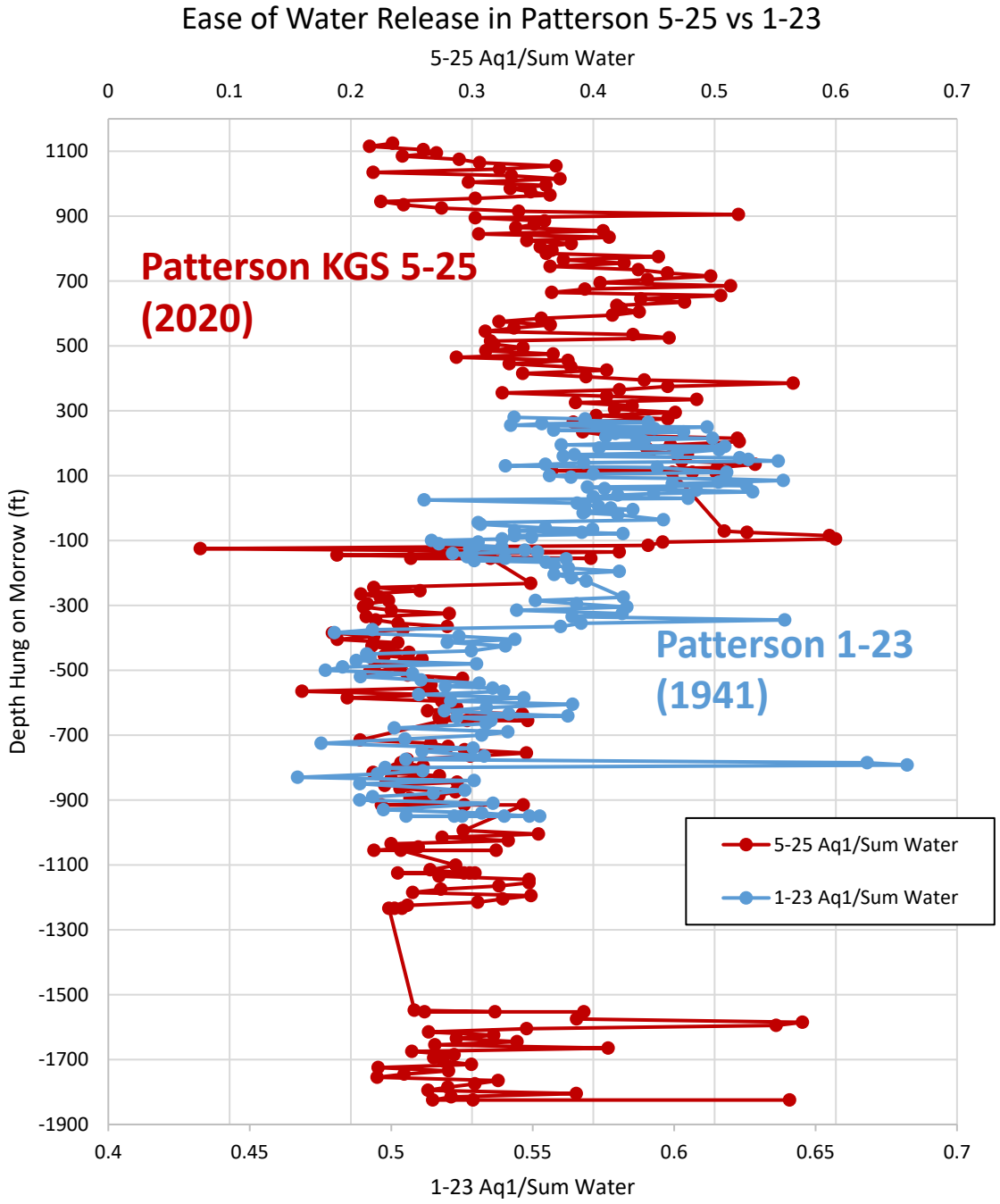
Era	Period	Group/Stage	Comment
	Neogene	Ogallala	USDW
Mesozoic	Cretaceous	Montana	caprock
		Colorado	baffle
		Kiowa	baffle
Paleozoic	Permian	Nippewalla	caprock
		Sumner	
		Chase	gas-bearing
		Council Grove	
	Pennsylvanian	Admire	baffle
		Wabaunsee	
		Shawnee	
		Douglas	
		Lansing-Kansas City	oil-bearing
		Pleasanton	baffle
		Marmaton	
		Cherokee	caprock
		Atoka	
		Morrow	oil-bearing
	Mississippian		
		Chester	oil-bearing
		Meramec	baffle
		Osage	deep saline
		Kinderhook	baffle
	Devonian		
	Silurian		
	Ordovician	Viola	deep saline
		Simpson	
		Arbuckle	
	Cambrian	Reagan	bottom barrier
Precambrian			

LEGEND:
- shale + limestone
- shale + sandstone + limestone
- shale + limestone ± evaporite
- shale + sandstone
- limestone ± shale
- sandstone + limestone ± shale
- sandstone
- dolomite
- igneous and metamorphic rocks
- major unconformity

Comparing legacy samples

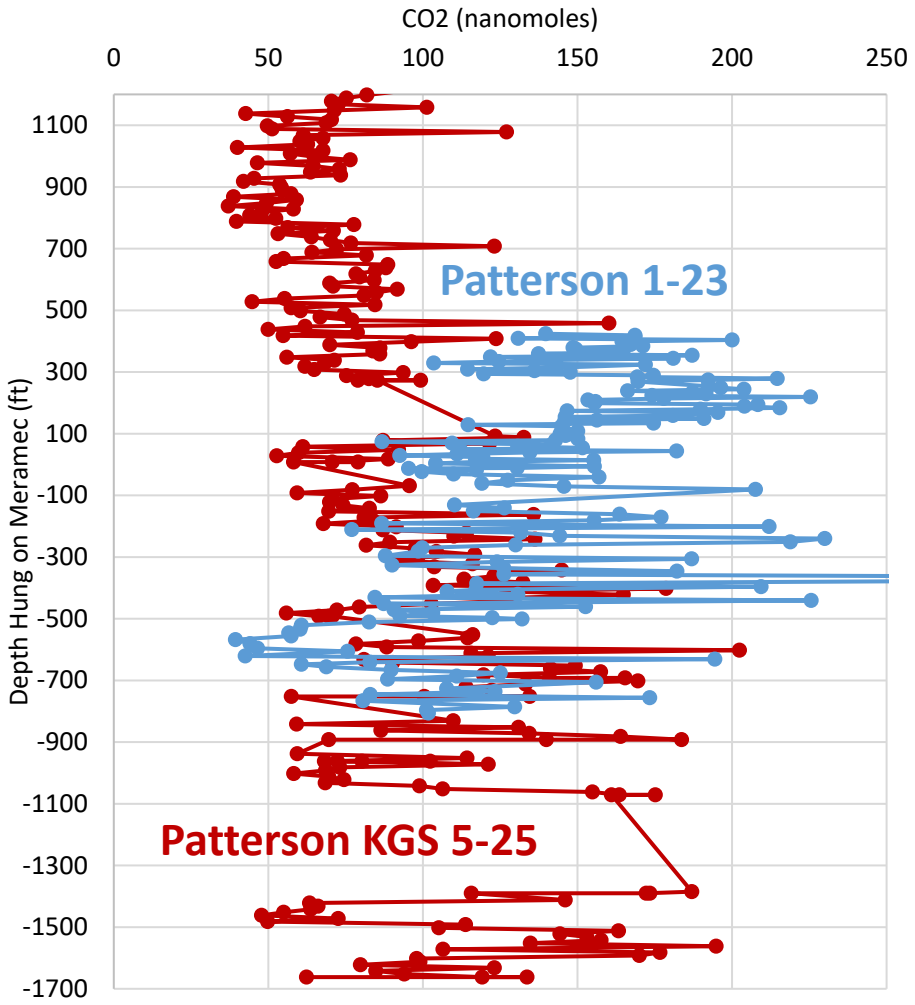
Since 2020 KGS and AHS have been using RVS to assist in evaluating the Patterson site as part of the KGS's Phase II CarbonSAFE program using fresh and legacy cuttings – several rock properties show good correlation across wells in these fields that are separated by decades of age

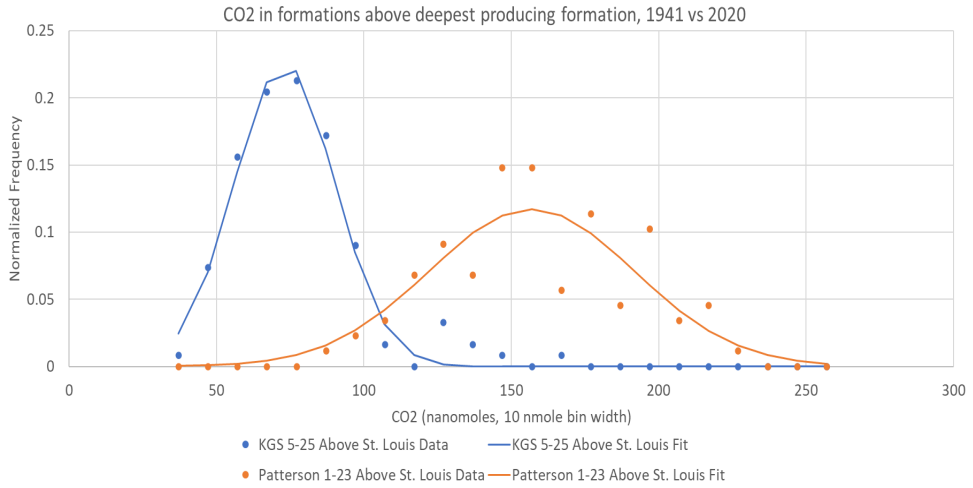


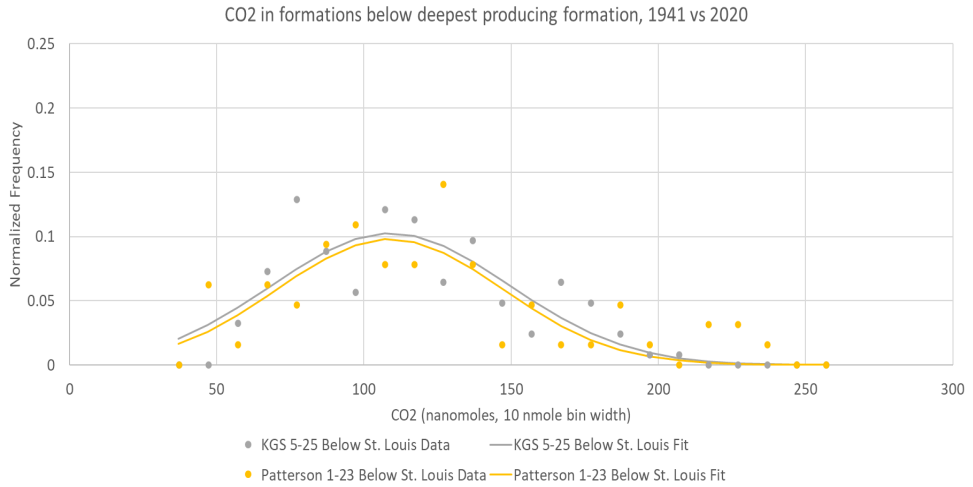


Broader Comparison of CO_2 Content in Produced vs Non-Produced Formations, 1941 vs 2020

ADVANCED HYDROCARBON STRATIGRAPHY



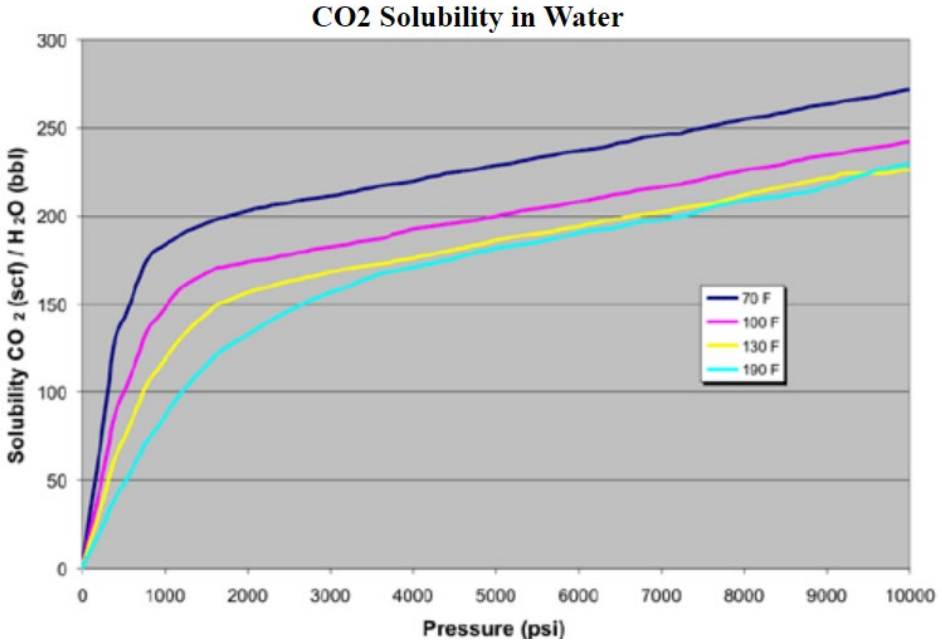


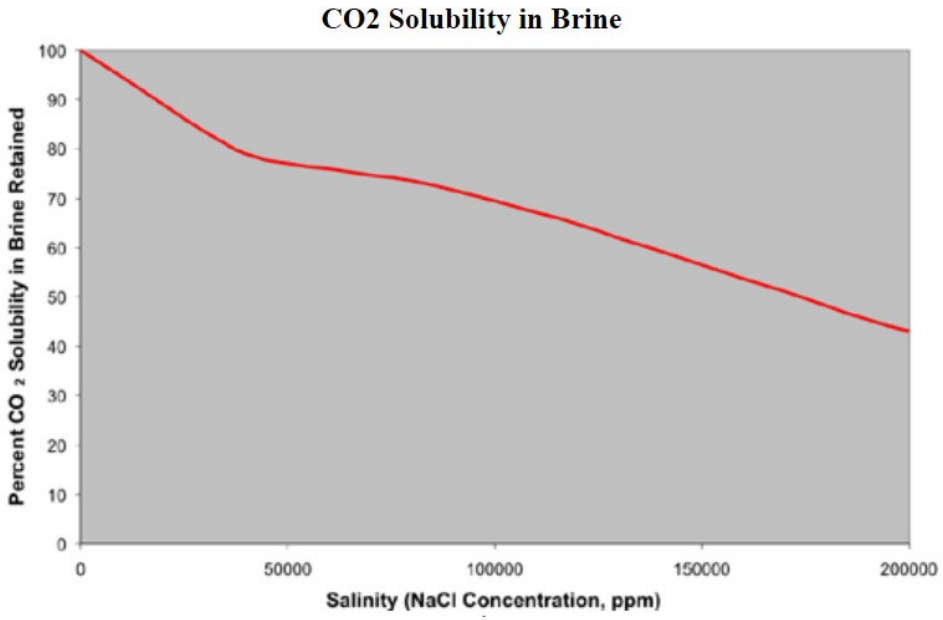


When considering the broader trends of the 1941 vs 2020 well, the shallow produced formation contain roughly 1/3 of the original CO_2 where statistically it can be argued the deeper saline aquifers that have never been produced remain unchanged -> **CO_2 is responding to field history**

Drivers of CO_2 Solubility

ADVANCED HYDROCARBON STRATIGRAPHY





- CO_2 solubility in water is driven by pressure – increasing temperature and salinity work against solubility
- CO_2 solubility in oil has similar dependencies as well as the composition of the oil
- Past RVS work has strongly suggested that entrained CO_2 content responds to changes in pressure regimes that can be due to artificial or natural events/features -> **Can a fuller investigation utilizing legacy samples and DSTs allow the formal establishment of a linkage and between CO_2 and subsurface pressure and provide insights into a model that could be further utilized in subsurface applications in oil and gas and CCS?**

KGS Oil & Gas Reports MIDCARB Online Tools to Evaluate Saline Aquifers for CO2 Sequestration

Kansas Geological Survey
Open-file Report 2003-33

Available Data

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- Historical DST data from Patterson and Hartland fields in addition to pressure tests from Phase II CarbonSAFE program
- Three brine measurements in productive shallow portion of Patterson field, one in the deep granite section of Hartland
- Temperature regimes/measurements
- RVS analyses of 5 Patterson and 1 Hartland wells with 12 zones with pressure data for direct comparison
  - Hartland Branine 1-3 has 4 DSTs in different formations -> **can we establish a stratigraphic relationship across multiple formations?**
  - The Morrow in the Patterson field with 5 wells drilled at different points in the field's life cycle with 4 of them having pressure measurements -> **can we establish a relationship in the same formation that responds to changes in recent time?**
  - Expand to whole Patterson field by including 4 deeper pressure tests in the saline aquifers -> **is a field wide relationship across formations and field history is possible?**
  - Expand to Hartland -> **is a broader model across fields is possible?**

Field History - Patterson

AHS

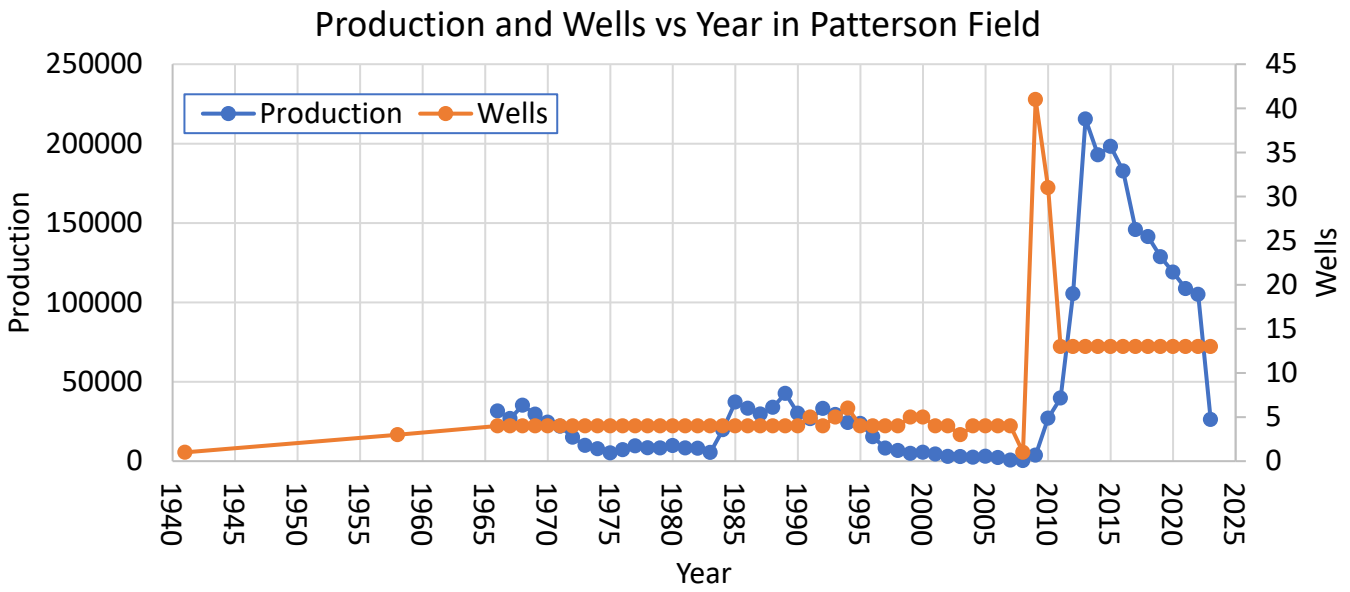
Patterson was discovered in 1941 a month before Pearl Harbor

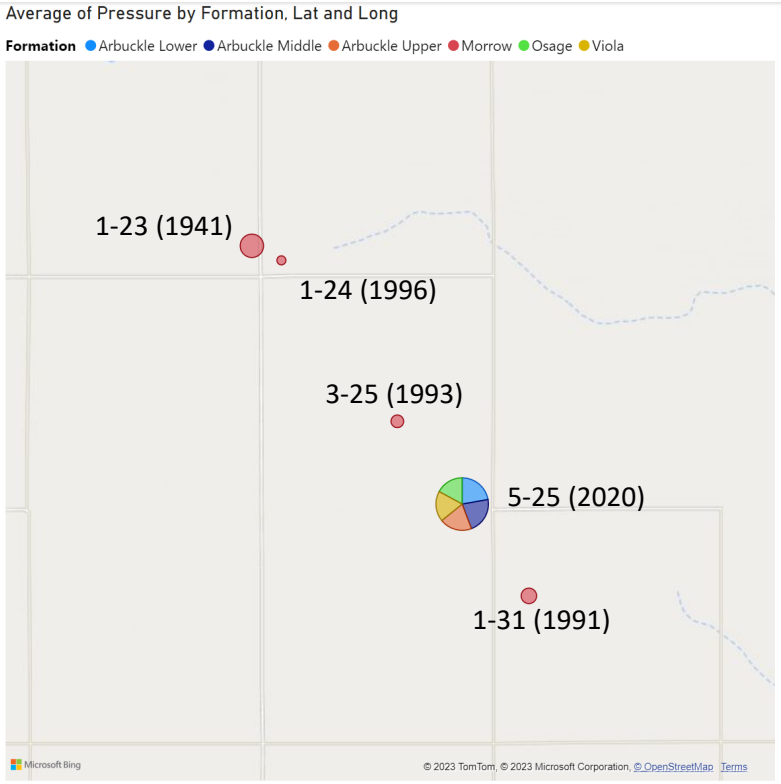
Field produces from the Morrow sandstone with discovery well having a reported pressure of 1125 psi – field is under pressured

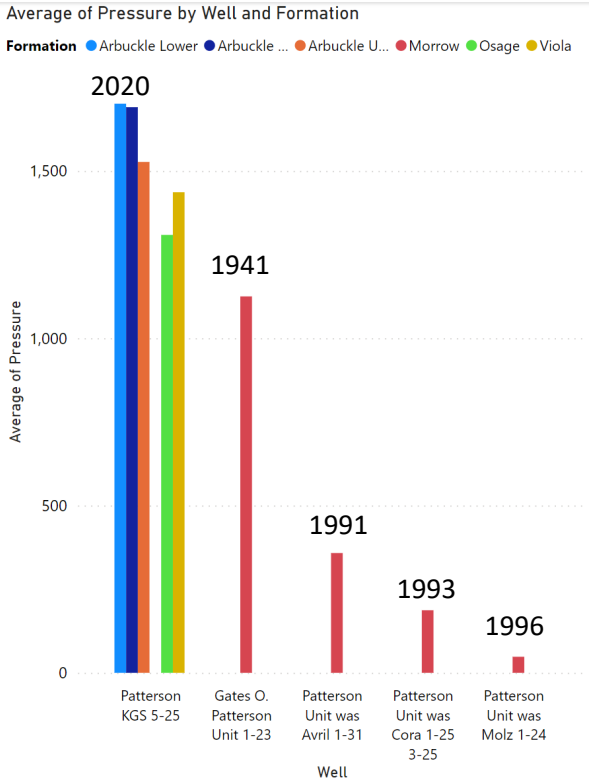
Several DSTs have been run in the area on the Morrow showing a clear decrease in pressure as production continued

In 2010 water flooding via injection wells began to be used

There have been a small number of penetrations into and below the Meramec but no noted production from the horizons tested as part of the CarbonSAFE Phase II project







Field History - Hartland

AHS

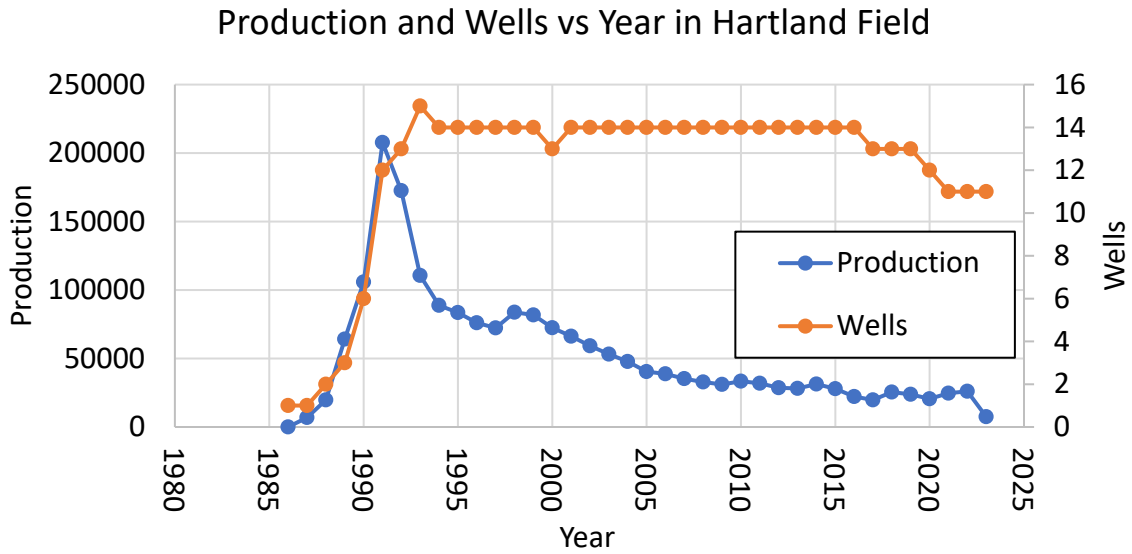
Discovered in 1986 with oil in the Mississippian lime with subsequent discoveries in the Morrow (1989), Lansing/Kansas City (1990) and Marmaton (1990)

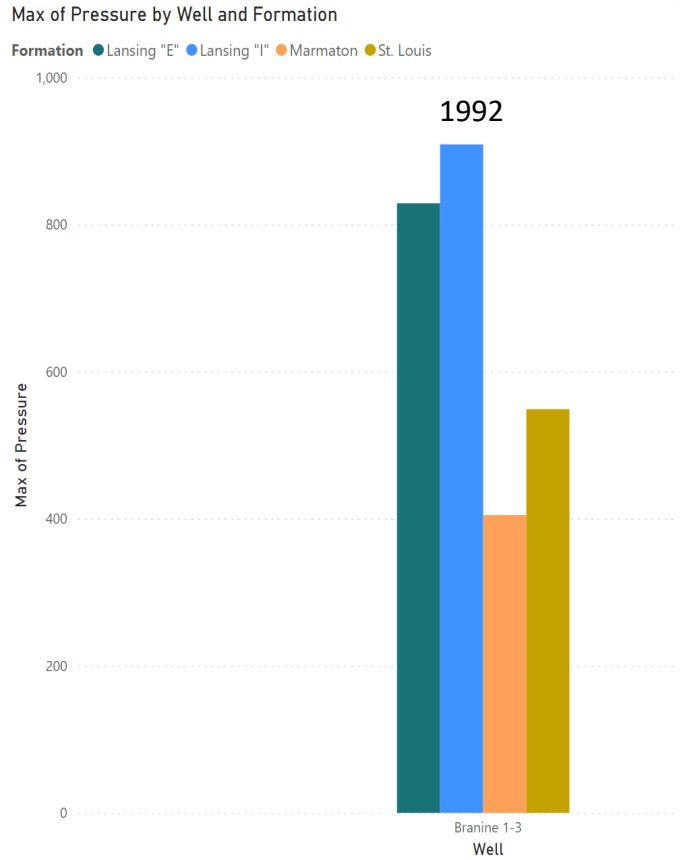
Same deep carbonate saline aquifers targeted for CO_2 injection as in Patterson

Unlike Patterson there are no EOR activities

The nature of the producing lime formations means large scale field wide trends overtime are difficult to observe

Offers an opportunity to evaluate stratigraphic trends and translate learnings to another field from Patterson





Pressure vs CO2 in the Same Well – Branine 1-3

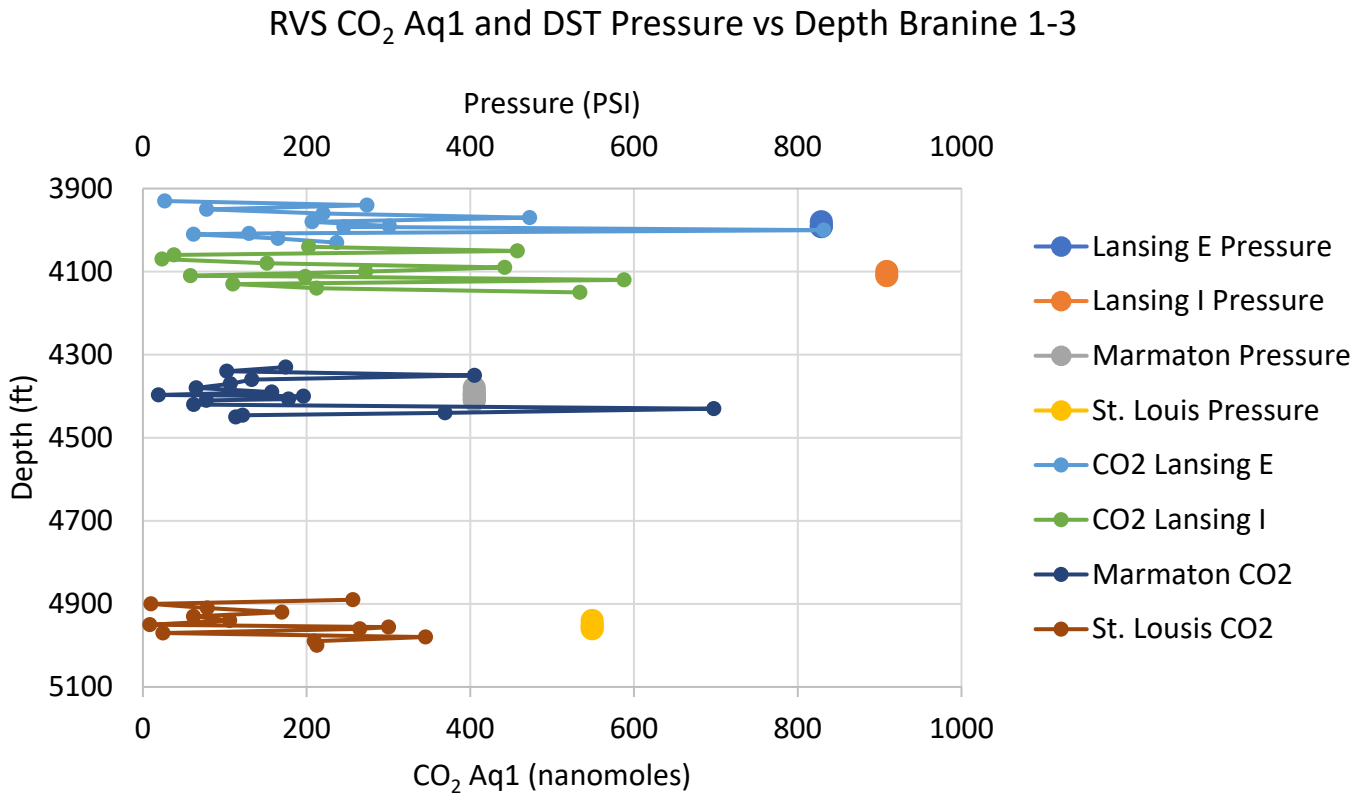
Branine 1-3 was drilled in 1992 with 4 DSTs in the Lansing (2), Marmaton (1), and St. Louis (1)

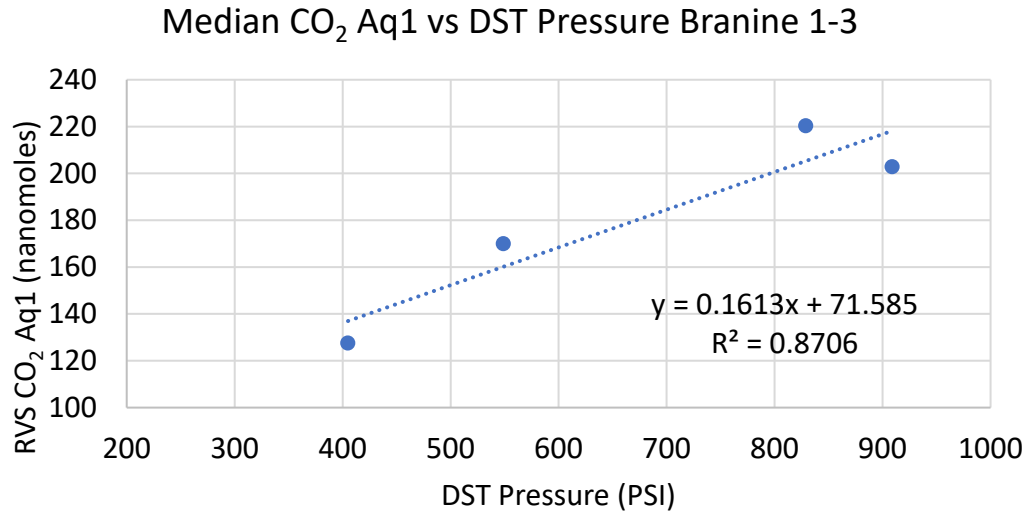
In addition to having 4 in the same well the trend is inverted to depth, greater pressure shallow

DSTs were typically 20-40 ft in coverage, cuttings as available in the test zone ±50 ft were used for RVS

Both median and mean values for first extraction of CO_2 (20 mbar extraction) show a strong correlation with DST pressures

Within the same well evidence of relationship between CO_2 and pressure across different formations





Pressure vs CO_2 in the Same Formation Across Time – Patterson Morrow Sand

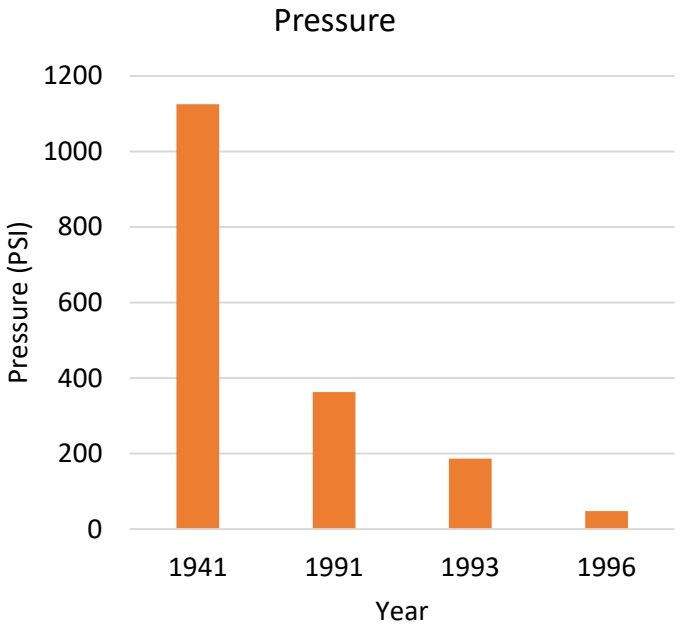
Morrow sand in Patterson filed has been under production since discovery in 1941

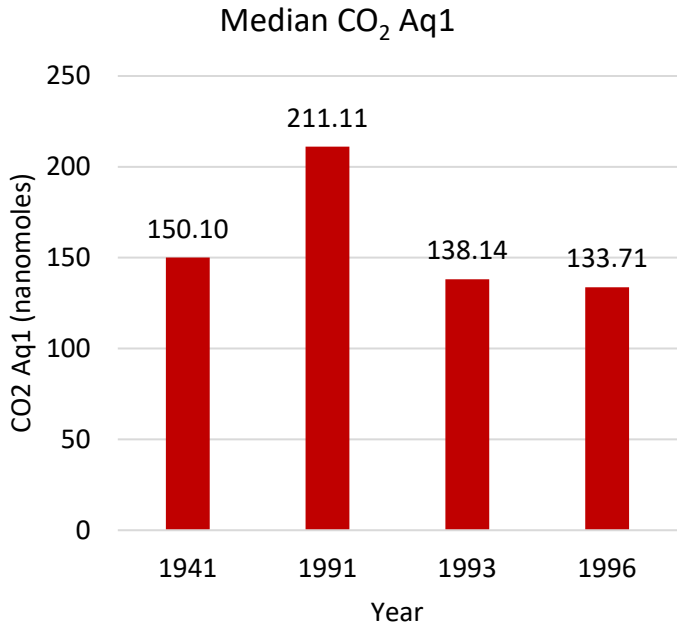
Four pressure measurements across time in the field are available – 1941, 1991, 1993, and 1996 all showing a consistent decrease with time and production

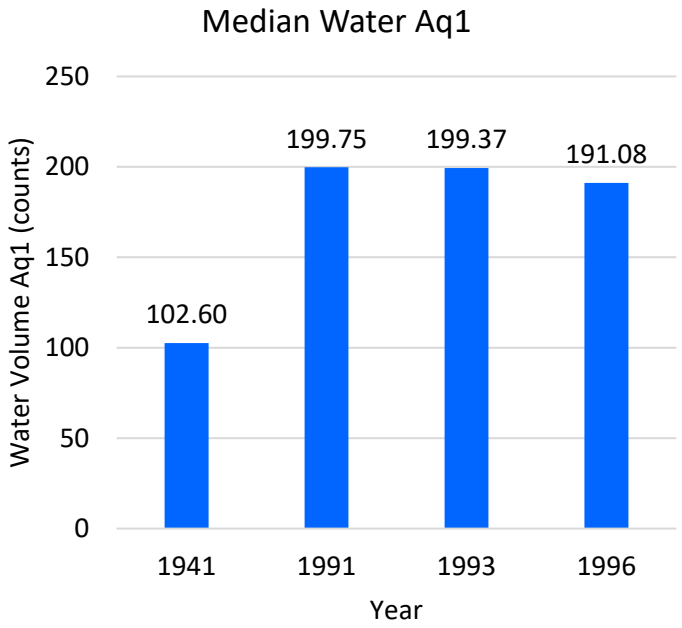
CO_2 from 1991-1996 display an expected trend -> 1941 well appears to be significantly off trend

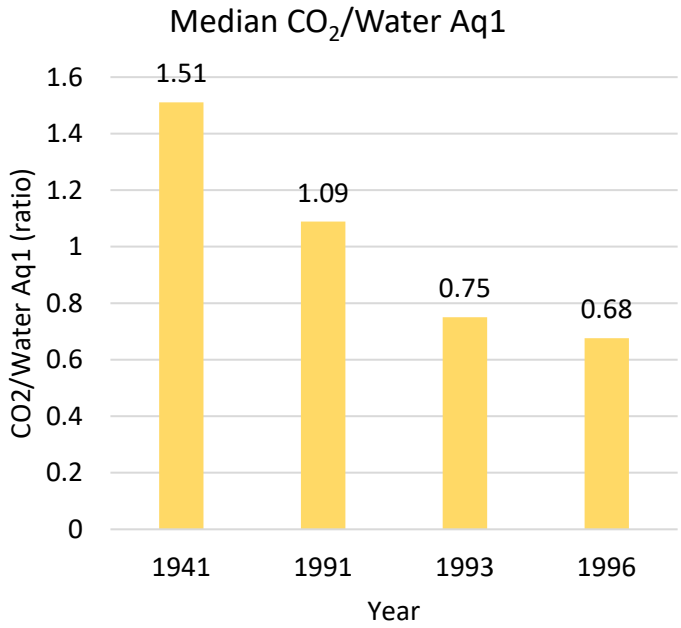
The 3 wells drilled and completed prior to 1958 initially had water free production, after 1958 water was present in production-> water data are consistent with this

Actual theoretical background says it is not CO_2 that is directly related to pressure, but CO_2 concentration in water -> **ratio of measured CO_2 and water in 20 mbar extraction demonstrates strong relationship to pressure across time**









Pressure vs CO_2 in the Same Formation Across Time – Patterson Morrow Sand

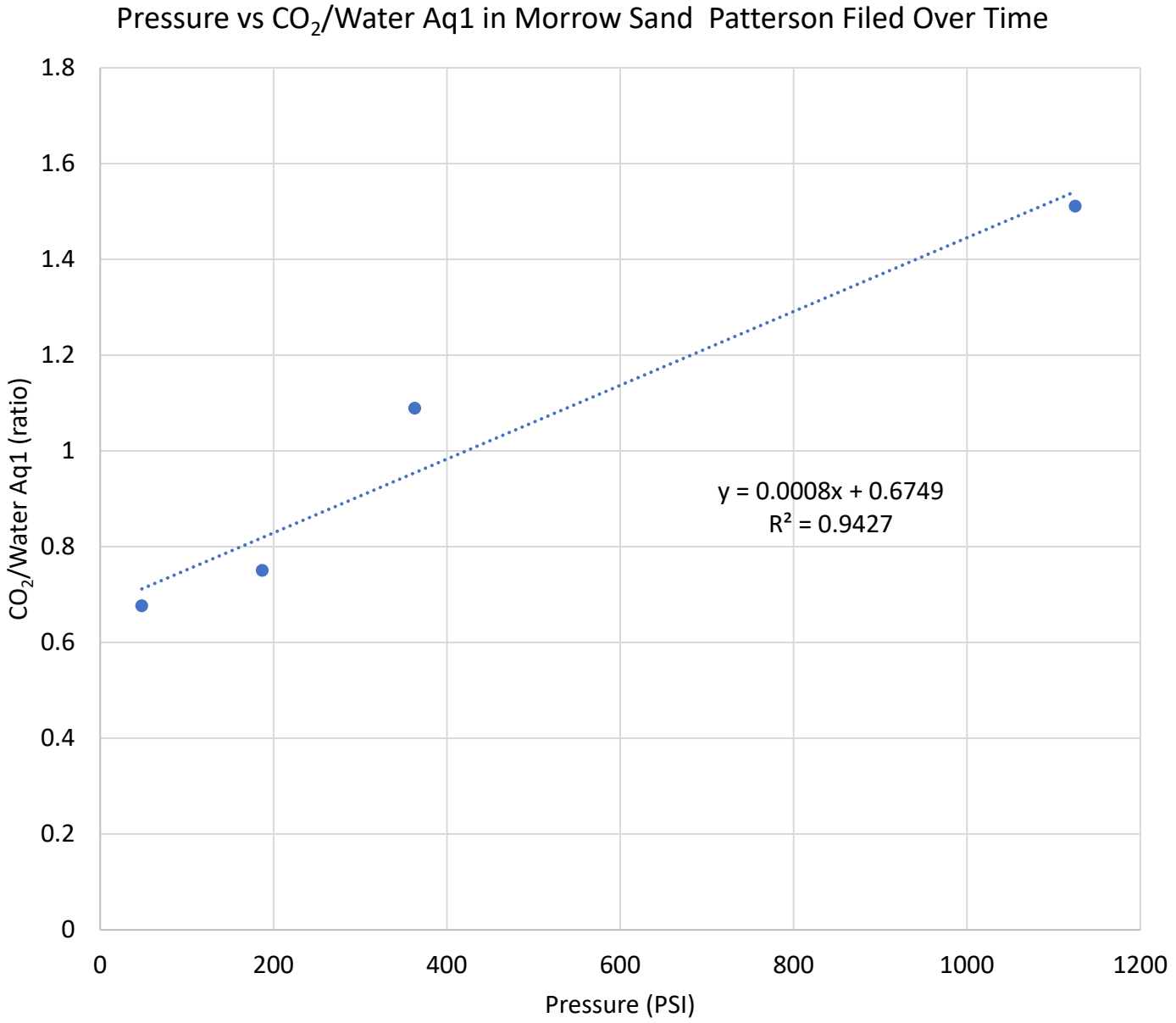
Morrow sand in Patterson filed has been under production since discovery in 1941

Four pressure measurements across time in the field are available – 1941, 1991, 1993, and 1996 all showing a consistent decrease with time and production

CO_2 from 1991-1996 display an expected trend -> 1941 well appears to be significantly off trend

The 3 wells drilled and completed prior to 1958 initially had water free production, after 1958 water was present in production-> water data are consistent with this

Actual theoretical background says it is not CO_2 that is directly related to pressure, but CO_2 concentration in water -> **ratio of measured CO_2 and water in 20 mbar extraction demonstrates strong relationship to pressure across time**



Pressure vs CO2 Concentration in Water in Patterson Across Time and Formations

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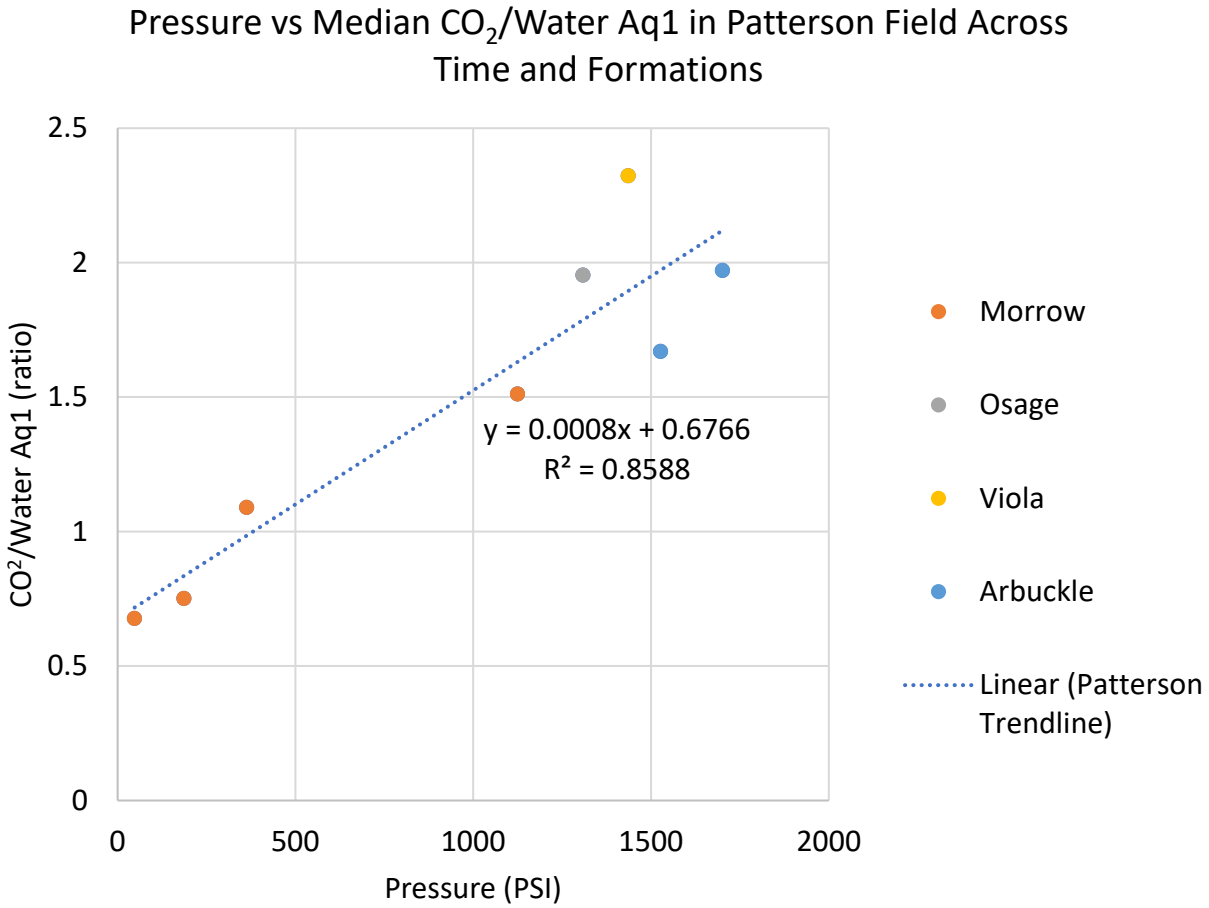
- In addition to the four wells with Morrow sand pressure data in 2020 KGS drilled the Patterson KGS 5-25 well as part of the CarbonSAFE Phase II program to assess the Patterson site
- Pressure data were acquired from from three deep carbonate formations with saline aquifers -> Osage (1), Viola (1), and Arbuckle (3)
- RVS was run on unsealed cuttings with coverage of 4 of zones involved in the pressure tests

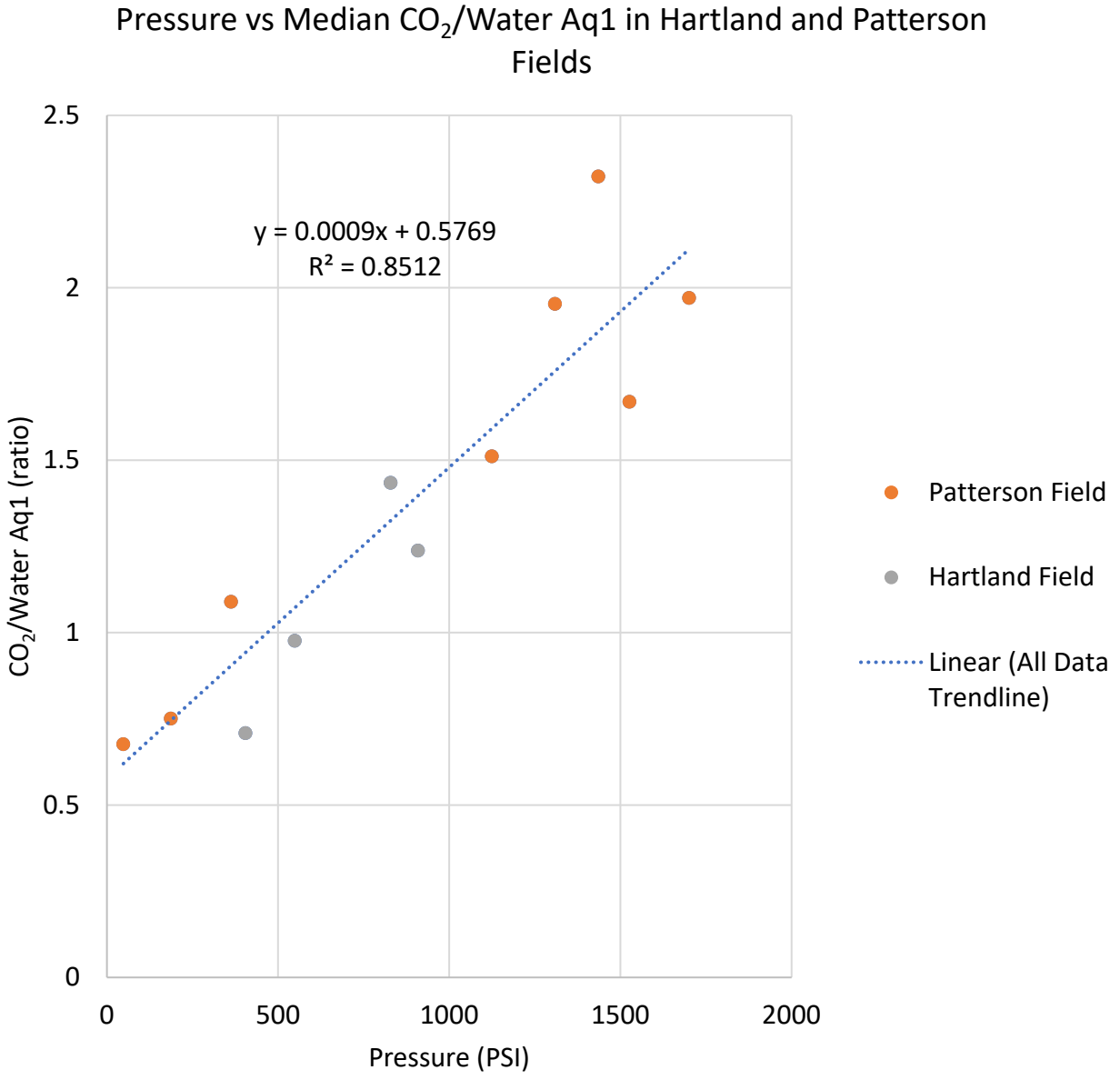
Data show strong correlation of all pressure measurements in field across time and formations to RVS CO_2/Water Data



Pressure vs CO_2 Concentration in Water Across Patterson and Hartland Fields

AHS

Across all measurements (n=12 in 6 wells across 2 fields and a range of 79 years in time and 2 orders of magnitude of pressure) there is a strong correlation between pressure and the concentration of CO_2 in water extracted at 20 mbar by RVS



Potential Improvements -> A More Descriptive Model

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- With a demonstrated correlation between CO_2 concentration in water from unsealed/unpreserved samples it is worth considering what additional information can be incorporated to develop a model that can achieve better predictions
- Known factors besides pressure the impact CO_2 concentration in water are:
  - Temperature
  - Salinity
  - pH
  - Sourcing

How may attempting to account for these improve a model?

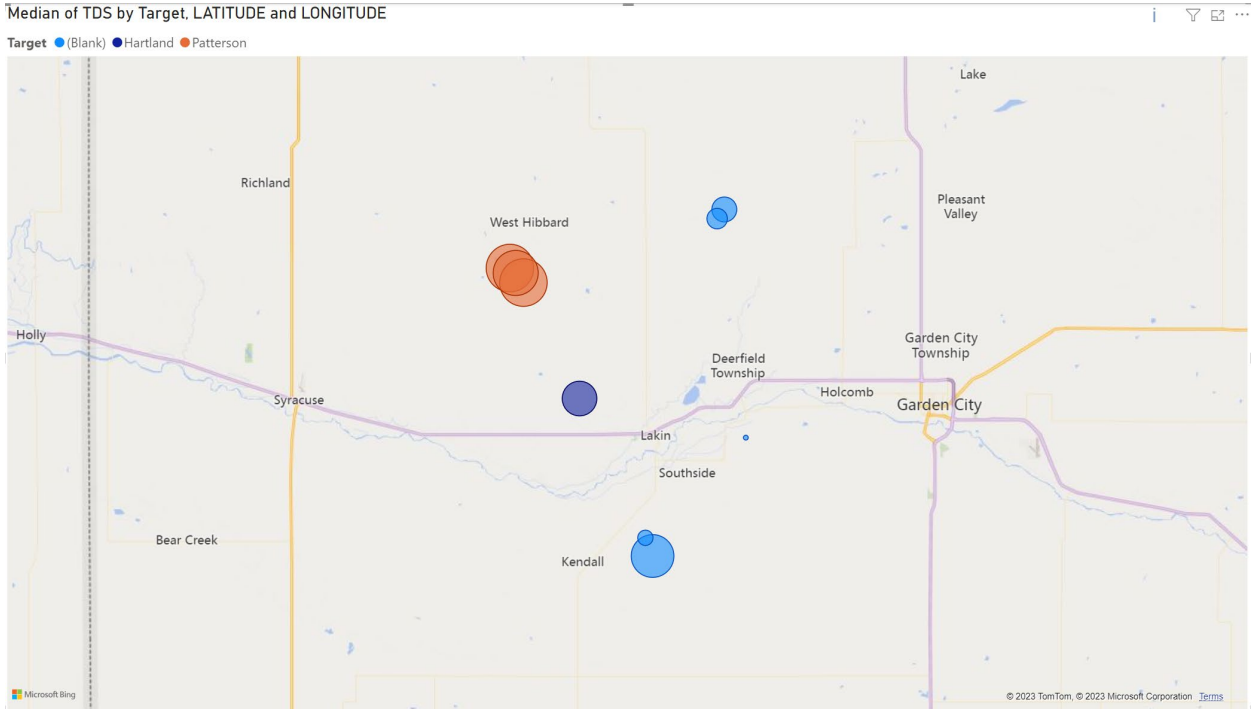
Brine Composition

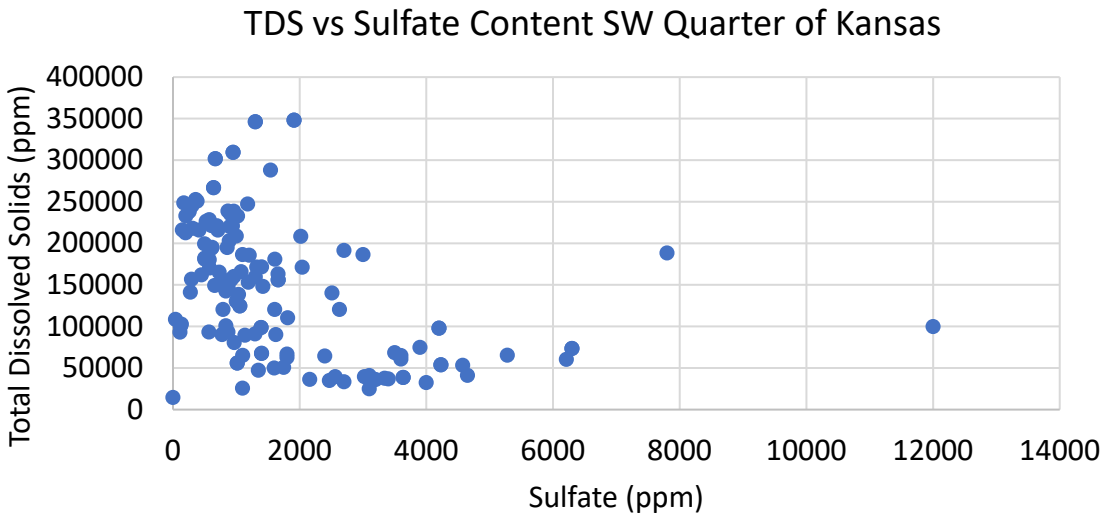
A H S

Greater salinity in Patterson than in the rest of Kearny county

61% of TDS content in single reported Hartland brine test (deep granite) compared to Patterson average 152,000 vs 93,000 ppm -> water in Patterson likely cannot dissolve as much CO2 as in Hartland

RVS does not measure salinity but it does have a sulfate proxy, on a broad regional scale (SW quarter of KS) there appears to be an oppositional relationship between the two -> possible proxy in model building



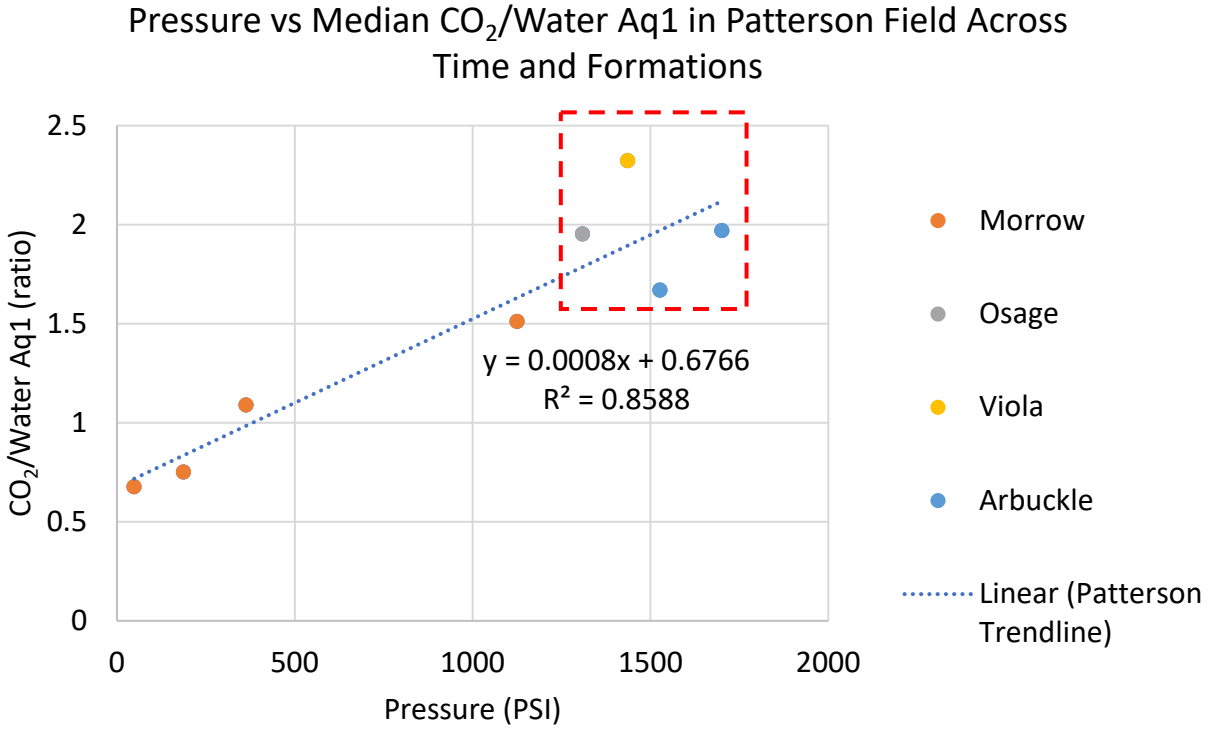


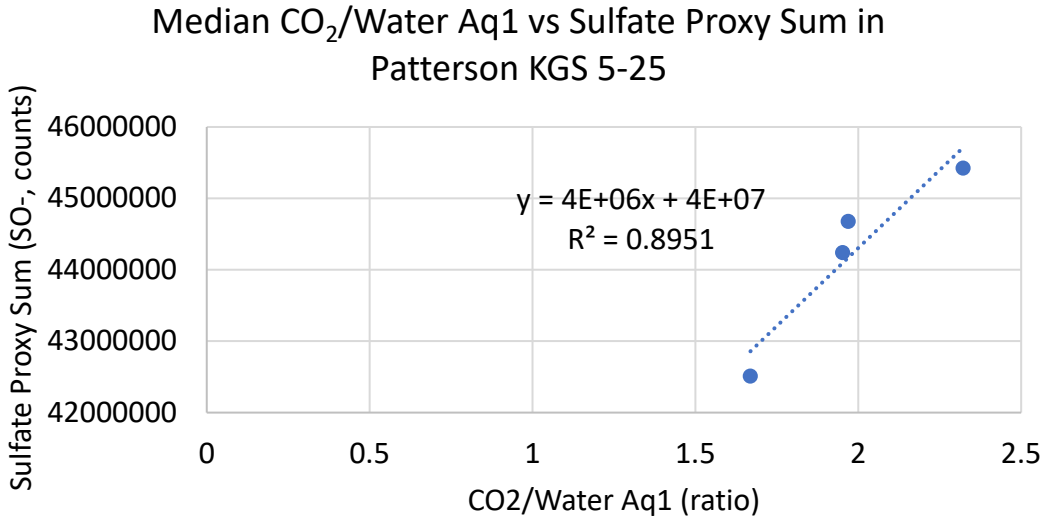
Sulfate as a Proxy for Salinity as a Model Input

AHS

While across all Patterson field data there is a strong correlation in the four deep saline aquifer zones the trend is not as clear -> no brine data from these depths

There is a clear correlation with these data vs the SO- proxy for sulfate analyzed in this well -> consistent with varying salinity acting as a control on the concentration across the borehole



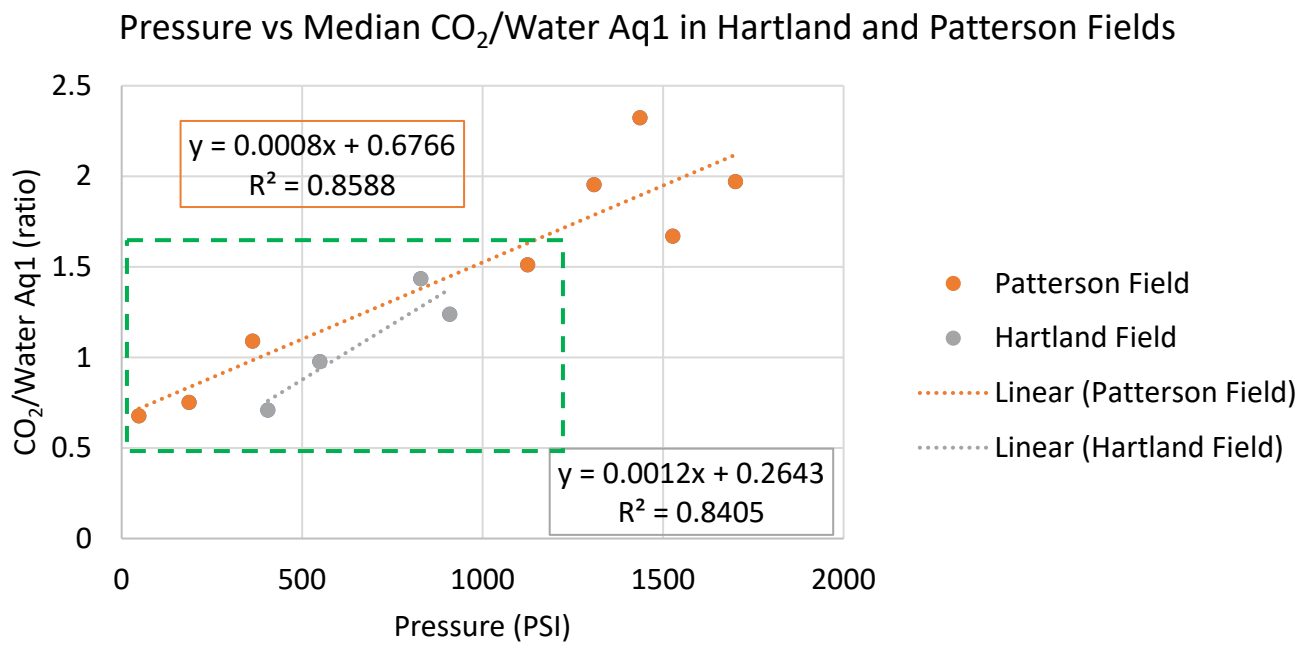


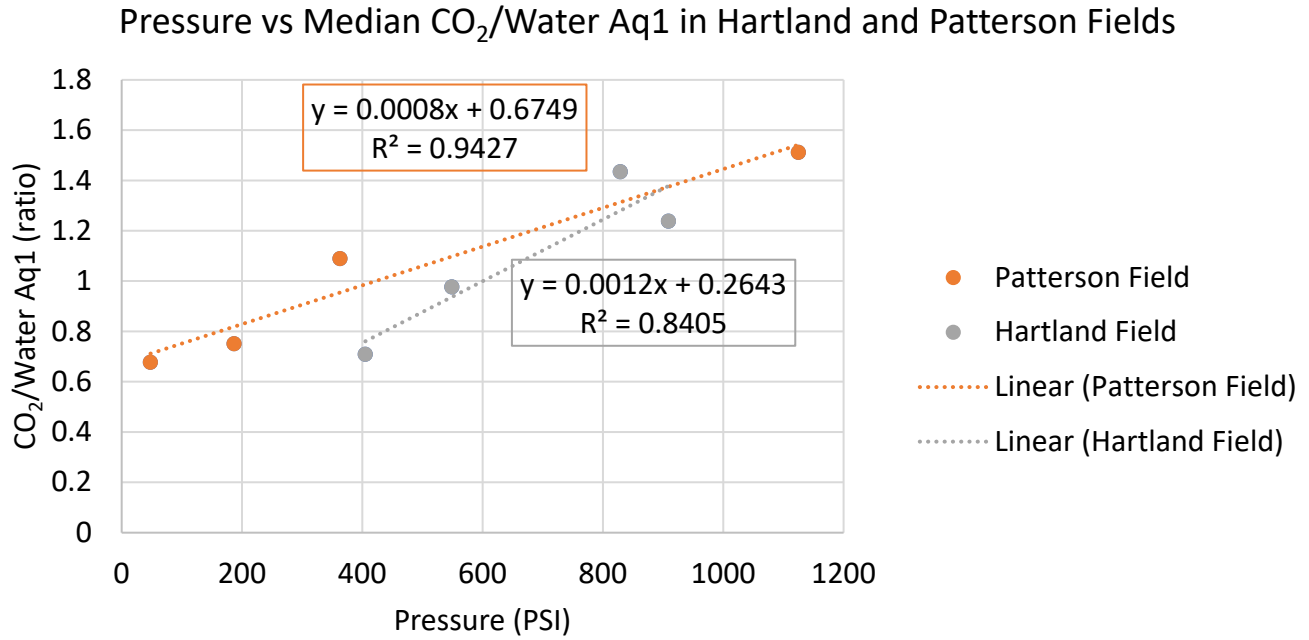
Sulfate as a Proxy for Salinity in Model Input

A H S

There is also a possible mismatch of the trendlines between Hartland and Patterson Fields

If the deeper saline aquifers are removed from consideration this become more apparent





Sulfate as a Proxy for Salinity in Model Input

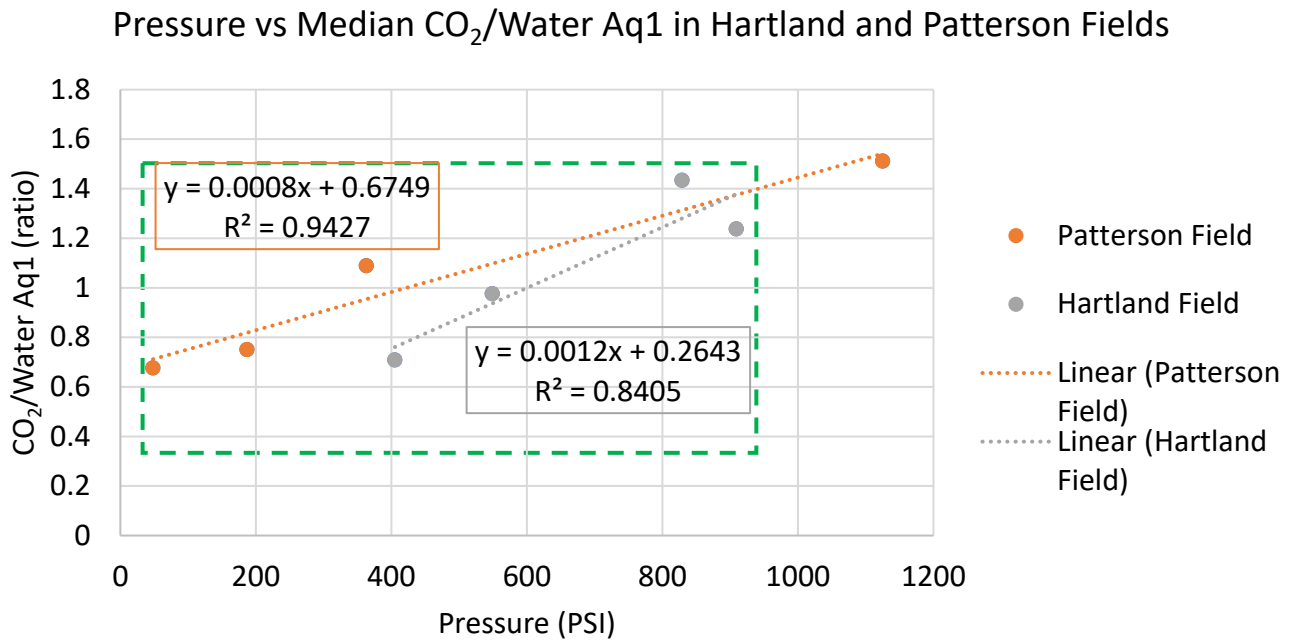
A H S

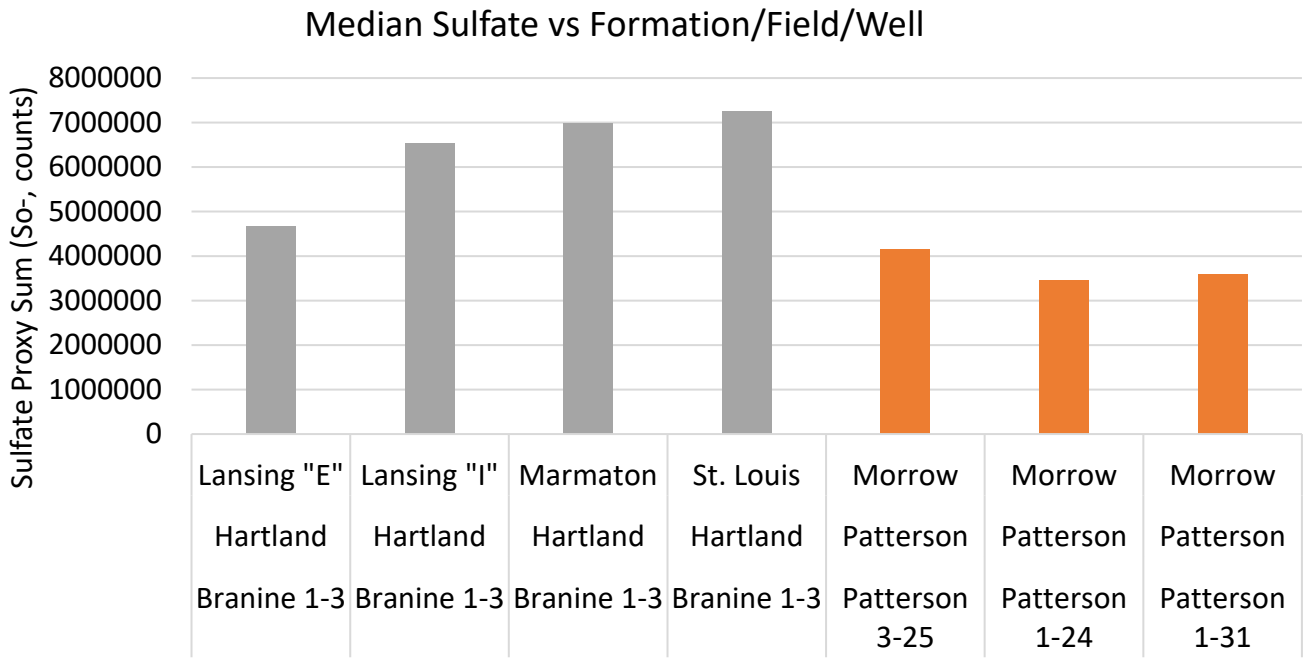
There is also a possible mismatch of the trendlines between Hartland and Patterson Fields

If the deeper saline aquifers are removed from consideration this become more apparent

There does appear to be a significant difference in sulfate content across the fields

The 7 indicated data the CO_2/water relationship has a R^2 of 0.745, initial models using the sulfate data achieve R^2 values of 0.96-0.98





Utility - Unconventionals

A
H
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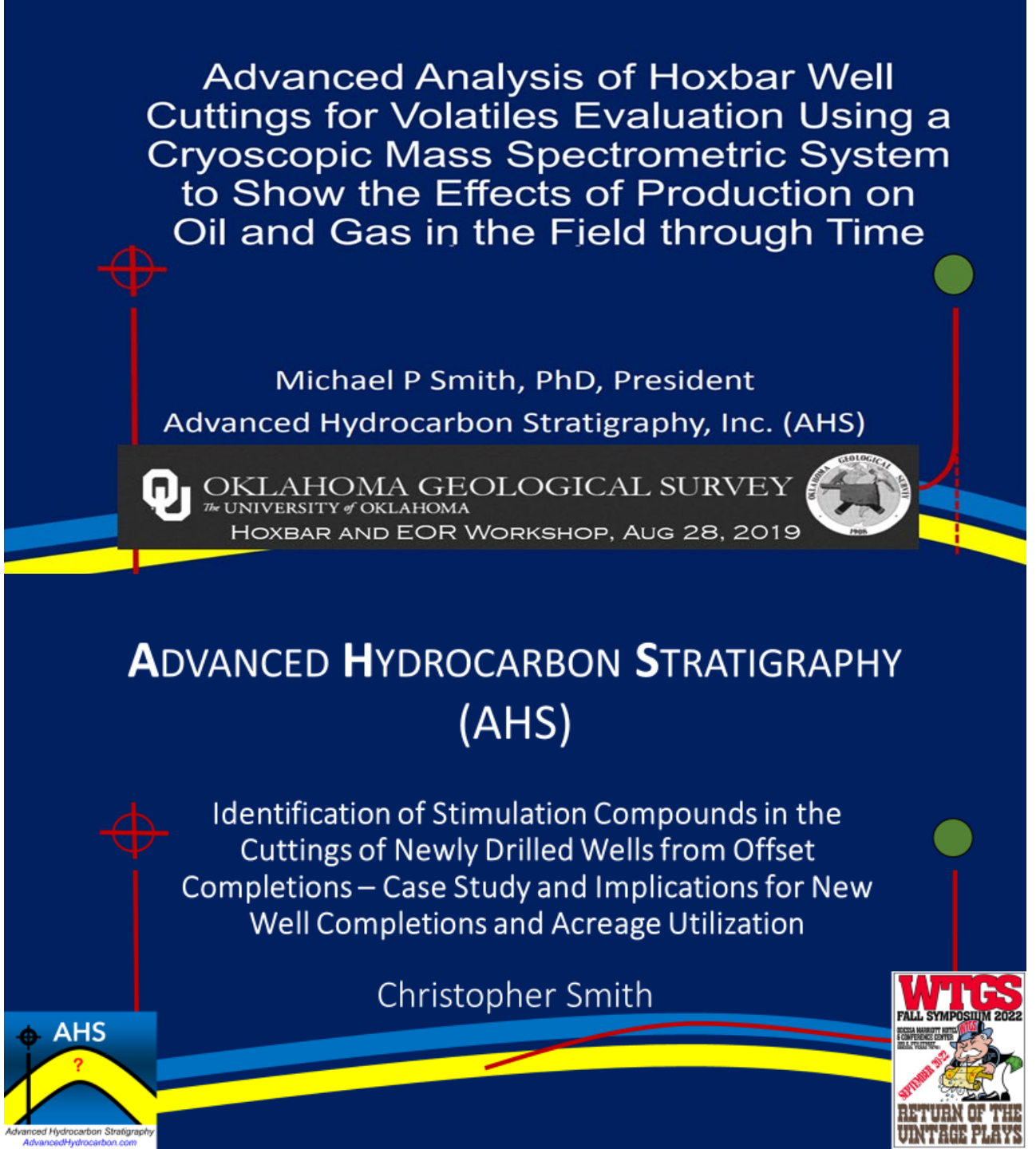
Experience in Oklahoma and West Texas has shown compared to production data and well histories that RVS CO_2 relate to pressure

This has been demonstrated and documented in the Hoxbar/Marchand sands and the Mayes carbonate in OK

CO_2 and water measured by RVS can likely be used to generate pressure models in tight unconventional formations



Next Steps

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- Expand study to include Hartland KGS 6-10 well and possibly one or two additional wells in Hartland field
- Begin integrating temperature data into the model and further evaluate use of sulfate as a proxy for salinity
- Evaluate if organic acids as a proxy for pH may serve as a meaningful input to a model
- In some wells biogenic activity or migrated CO_2 are clearly present (not in this study) -> can we account for this?

Conclusions

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- Previously there were significant production, well, and drilling histories to strongly demonstrate a link between CO_2 measured by RVS and pressure
- This analysis of unsealed/unpreserved cuttings from 6 wells drilled in 2 different fields over 79 years containing 12 pressure measurements covering 8 different sand and carbonate formations in Kearny country Kansas clearly demonstrates that the concentration of CO_2 in water extracted from these cuttings correlates to pressure measured at the time of drilling (R^2 of 0.85 across whole dataset)
- There are opportunities to generate a model for pressure that utilizes additional parameters, most from RVS, initial work has shown promise in this application

The ability to determine pressure from the remaining volatiles in unsealed and unpreserved cuttings offers unique opportunities for a variety of subsurface application including oil and gas and CCS/CCUS and appears to be applicable in both conventional and unconventional settings -> these data also respond to short time scale events such as oil and gas production and represent an amazing opportunity to acquire fine scale pressure data in the subsurface in ways and on a scale not previously considered or thought feasible

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Thanks

Questions?

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Visit our website for more information on this study and other studies utilizing CO_2 as a reservoir pressure proxy.