

**Table 1** Information of the wells sampled in this study. Wells sampled in 2006 have an ID starting with a capital letter; wells sampled in 2007 have a numerical ID. Besides USGS NO. 1 which was a spring, all wells were production gas wells. For wells Federal 34-31 and Timble Rock FED 23-15, two sets of fluid samples were taken.

Well ID	Well Name	Latitude ( $^{\circ}$ )	Longitude ( $^{\circ}$ )	Surface Elevation(ft)	Mean Perfo. Depth(ft)	Formation
K1	Federal 31-1	39.4395	-109.2119	7714.0	6226.0	Dakoda
K2	Anderson No. 1	39.4248	-109.1839	8240.0	6988.0	Dakoda
K3	Federal 34-31	39.4538	-109.2079	7995.0	7444.0	Dakoda
K4	Federal 34-31 Tank	39.4538	-109.2079	7995.0	7444.0	Dakoda
I1	Timble Rock FED 23-15 A	39.8435	-109.1940	5600.0	4580.0	Mesaverde
I2	Timble Rock FED 23-15 B	39.8435	-109.1940	5600.0	4580.0	Mesaverde
I3	DWR 12-21	39.7573	-109.3549	5780.0	5704.0	Mesaverde
I4	Archy Bench 12-23-42-16	39.7761	-109.3414	6023.1	6079.5	Wasa+Mesav
I5	USGS NO. 1	39.8775	-109.2698	5350.0	0.0	Mesaverde
I6	Rock house 4-36	39.9103	-109.3954	5601.6	6935.0	Mesaverde
I7	Rock house 10-22-21-36	39.9100	-109.3910	5601.5	6797.5	Mesaverde
I8	Rock house 10-22-14-36	39.8993	-109.3948	5511.0	6877.0	Mesaverde
I9	Rock house 11-36	39.9039	-109.3908	5390.6	6593.5	Mesaverde
I10	Rock house 5-32-10-23	39.9042	-109.3450	5249.2	6179.5	Mesaverde
G1	HCU 1-34F	39.9099	-109.6437	5241.0	6759.5	Wasa+Mesav
G2	HCU 12-34F	39.9023	-109.6572	5298.0	6829.5	Wasa+Mesav
G3	HCU 13-27F	39.9152	-109.6535	5171.0	7188.5	Wasa+Mesav
G4	HCU 11-27F	39.9156	-109.6537	5173.0	6910.0	Wasa+Mesav
G5	HCU 9-27F	39.9174	-109.6431	5163.0	6420.0	Wasa+Mesav
G6	HCU 3-27F	39.9250	-109.6530	5092.0	7060.0	Wasa+Mesav
G7	RBV 1-23F	39.9398	-109.6253	5090.0	5684.0	Wasatch
G8	RBV 12-11F	39.9634	-109.6370	5069.0	6295.0	Wasatch
1	Big Pack 11-21-11-28	39.8367	-109.5804	5893.0	7386.0	Mesaverde
2	Big Pack 12-21-22-2	39.8041	-109.5353	6036.0	7143.5	Mesaverde
3	Thurston FED 12-21-24-12	39.7828	-109.5183	6042.0	6460.0	Mesaverde
4	Buck Camp 12-22-21-2	39.8078	-109.4257	5664.0	3596.0	Wasatch
5	Buck Camp 12-22-31-2	39.8074	-109.4204	5599.0	5566.5	Wasa+Mesav
6	Buck Camp 11-22-14-36	39.8120	-109.4111	5413.0	6091.0	Mesaverde
7	Buck Camp 11-22-11-26	39.8369	-109.4293	5557.0	5921.5	Wasa+Mesav
8	Buck Camp 11-22-11-36	39.8231	-109.4111	5408.0	5549.0	Wasa+Mesav
9	Buck Camp 11-22-11-25	39.8368	-109.4103	5361.0	6462.0	Mesaverde
10	Buck Camp 11-23-44-32	39.8120	-109.3603	5904.0	5366.5	Wasa+Mesav
11	Buck Canyon 6-15	39.7971	-109.4956	5881.0	6134.5	Wasa+Mesav
12	Buck Camp 31-5	39.8086	-109.4775	6155.0	7324.5	Mesaverde
13	Uinta Oil Assn. 1321-8C	39.7069	-109.5943	5918.0	6468.0	Mesaverde
14	Mustang 1320-24E	39.6735	-109.6351	6288.0	7288.0	Mesav+Mancos
15	Mustang 1320-14P	39.6817	-109.6396	6212.0	6803.0	Mesaverde
16	Mustang 1320 11H	39.7037	-109.6391	5985.0	7199.0	Mesav+Mancos
17	Pine Springs 13-26-14-22	39.5764	-109.4291	7128.0	4922.0	Mesaverde
18	Main Canyon 2-8-15-23	39.5227	-109.3632	7579.0	5586.5	Mesaverde
19	Main Canyon 15-8-15-23	39.5243	-109.3849	7502.0	8570.0	Mancos
20	Divide NO.1	39.4496	-109.2773	8286.0	7772.0	Dakota
21	Lindisfarn 1-26	39.4801	-109.3155	8097.0	7505.5	Mancos+Dakota
22	Federal 13-17-14-23	39.6057	-109.3735	6902.0	9207.0	Mesav+Mancos
23	Pine Springs 15-36-14S-22E	39.5603	-109.4011	7150.0	5675.0	Mesaverde
24	SRU NO. 8	39.6663	-109.4161	6693.0	10241.5	Dakota
25	Bonanza 9-24-21-8	40.0562	-109.2423	5050.0	6285.5	Wasa+Mesav
26	Southman Canyon 9-24-11-30	40.0124	-109.2641	5371.0	7580.0	Mesaverde
27	Southman Canyon 9-24-42-30	40.0088	-109.2504	5399.0	6195.0	Wasa+Mesav
28	Southman Canyon 9-23-14-36	39.9866	-109.2815	5373.0	8165.0	Mesaverde
29	Southman Canyon 9-23-12-36	39.9943	-109.2827	5381.0	7531.0	Mesaverde
30	Southman Canyon 9-23-11-36	39.9963	-109.2808	5376.0	7298.0	Mesaverde
31	Southman Canyon 9-23-33-36	39.9898	-109.2721	5401.0	7441.5	Mesaverde
32	Southman Canyon 9-23-34-36	39.9868	-109.2726	5422.0	7338.0	Mesaverde
33	Southman Canyon 9-23-43-36	39.9908	-109.2684	5499.0	7417.0	Mesaverde
34	Southman Canyon 9-23-32-36	39.9939	-109.2734	5460.0	7447.5	Mesaverde
35	Redwash 9-24-34-30	40.0016	-109.2546	5411.0	7178.0	Mesaverde
36	Red Wash 9-24-23-30	40.0019	-109.2487	5457.0	6446.0	Wasa+Mesav

**Table 2** Elemental composition of the formation waters sampled. Well locations are shown in Fig 5. Saturation index for calcite is  $[SI] = \log[IAIP/KT]$ , where IAP is ion-activity product, and KT is the equilibrium constant. “WasaMesa” indicates wells perforated in the Wasatch and Mesaverde; “MesaManco” indicates wells perforated in the Mesaverde and Mancos; “MancoDak” indicates wells perforated in the Mancos and Dakota.

Well ID	Depth (ft)	pH	Density ( $g/cm^3$ )	Alkalinity (meq/L)	DIC (mM)	Cl (mM)	Br (mM)	SO <sub>4</sub> (mM)	Na (mM)	Ca (mM)	Mg (mM)	K (mM)	Sr (mM)	Ba (mM)	Fe (mM)	Si (mM)	SI
K1	6226	6.76	1.00	1.87	1.53	0.15	0.00	0.05	0.39	0.03	0.01	0.04	0.00	0.00	0.01	0.02	-3.41
K2	6988	6.53	1.00	2.70	1.07	3.18	0.01	0.04	3.11	0.23	0.07	0.13	0.01	0.00	0.97	0.02	-1.76
K3 <sup>1</sup>	7444	6.73	1.00	2.60	3.06	55.89	0.00	0.33	47.27	4.01	0.95	0.50	0.17	0.01	0.18	0.10	-0.60
K4	7444	6.65	1.01	4.45	3.06	201.30	0.37	2.04	167.83	15.97	3.99	3.35	0.66	0.00	0.95	0.17	-0.11
II <sup>2</sup>	4580	7.40	1.01	9.32	8.70	181.20	0.25	0.04	182.60	4.22	1.83	1.36	0.05	0.07	0.27	0.54	0.43
I2	4580	7.43	1.01	9.25	8.45	181.52	0.26	0.04	183.14	4.30	1.73	1.67	0.05	0.07	0.01	0.48	0.46
I3	5704	7.09	1.03	19.71	12.06	601.40	0.85	0.06	599.49	9.68	3.95	7.15	0.34	0.90	1.57	0.65	0.53
I4	6080	7.98	1.01	20.69	17.10	41.52	0.00	58.10	172.13	5.55	1.57	0.56	0.06	0.00	0.39	0.42	1.24
I5	0	9.17	1.00	9.14	7.23	0.58	0.00	3.45	16.74	0.03	0.02	0.03	0.00	0.00	0.00	0.22	0.19
I6	6935	8.02	1.03	22.69	14.03	491.41	0.90	11.18	515.58	11.11	2.68	6.89	0.25	0.01	0.02	0.62	1.56
I7	6798	7.18	1.03	16.47	12.50	595.31	0.95	17.17	627.20	17.14	4.74	3.53	0.34	0.01	1.71	0.62	0.77
I8	6877	7.41	1.02	15.79	8.09	486.42	0.83	9.05	500.45	12.94	3.15	3.29	0.28	0.03	0.91	0.60	0.91
I9	6594	7.20	1.04	15.53	8.57	932.83	1.40	14.08	927.47	25.72	5.77	9.40	0.51	0.01	1.69	0.68	0.85
II0	6180	7.63	1.03	26.03	20.20	589.64	1.01	0.52	603.20	11.14	3.12	3.36	0.34	0.36	0.73	0.82	1.24
G1	6760	7.41	1.02	6.88	5.09	400.87	1.10	10.03	399.30	9.78	2.39	3.73	0.10	0.00	0.05	0.62	0.33
G2	6830	7.07	1.02	11.56	4.28	318.14	0.67	39.58	381.91	5.58	2.30	5.46	0.09	0.00	1.67	0.22	-0.49
G3	7189	6.57	1.02	8.69	4.58	360.49	0.86	12.09	371.70	4.83	1.88	3.70	0.06	0.00	0.07	0.60	0.28
G4	6910	7.27	1.02	11.98	6.95	330.68	0.78	18.20	398.38	6.69	2.31	3.39	0.18	0.01	0.05	0.57	0.27
G5	6420	7.25	1.02	8.68	5.45	381.50	0.94	8.73	357.33	3.18	1.59	4.00	0.09	0.01	0.12	0.59	0.04
G6	7060	7.31	1.02	8.43	4.78	346.72	0.67	2.79	392.84	6.79	3.00	2.41	0.24	0.20	0.75	0.45	-0.75
G7	5684	6.60	1.02	3.48	3.74	404.74	0.94	0.04	51.90	0.97	0.21	0.56	0.03	0.03	0.70	0.15	-1.78
G8	6295	6.32	1.00	1.70	2.74	52.54	0.14	0.10	583.30	17.12	4.53	2.45	0.39	0.00	0.02	0.51	1.98
1	7386	8.87	1.03	13.75	13.35	519.51	1.32	28.82	934.98	30.21	6.75	5.05	0.62	0.04	0.64	1.31	1.31
2	7144	7.80	1.04	17.07	10.56	929.92	1.30	12.67	363.82	9.22	3.31	8.24	0.11	0.00	0.07	0.30	1.55
3	6460	8.40	1.02	11.02	9.26	290.10	0.43	32.75	209.76	0.20	0.27	1.01	0.00	0.00	0.00	0.00	-1.37
4	3596	7.38	0.94	4.71	0.35	156.06	0.21	19.55	532.11	14.35	3.45	5.89	0.12	0.00	0.00	0.00	1.54
5	5567	7.66	1.02	57.22	38.55	376.25	0.42	39.16	1078.77	31.48	7.53	5.24	0.34	0.00	1.04	0.41	0.56
6	6091	7.05	1.05	18.18	4.78	1068.54	1.81	30.36	1255.19	32.84	8.39	6.09	0.54	0.01	3.25	0.49	0.95
7	5922	7.22	1.05	24.78	3.85	1096.66	2.31	19.35									

<sup>1</sup> K3 and K4 are two samples collected from the same well; K3: separator; K4: storage tank (older water);  
<sup>2</sup> II and II2 are two samples collected from the same well; II: processed on site; II2: processed 6 hours later;  
<sup>3</sup> Water vial missing; cations not analyzed.

**Table 3** Elemental composition of the formation waters sampled (Table 2 continued).

Well ID	Depth (ft)	pH	Density (g/cm <sup>3</sup> )	Alkalinity (meq/L)	DIC (mM)	Cl (mM)	Br (mM)	SO <sub>4</sub> (mM)	Na (mM)	Ca (mM)	Mg (mM)	K (mM)	Sr (mM)	Ba (mM)	Fe (mM)	Si (mM)	SI
8	5549	7.67	1.04	21.41	12.70	720.50	0.85	25.07	778.31	19.21	5.02	3.23	0.30	0.00	0.06	0.47	1.19
9	6462	6.96	1.04	21.73	15.01	960.06	2.29	8.91	1015.45	23.25	6.28	5.24	0.42	0.01	1.57	0.47	0.48
10	5367	7.53	1.02	32.65	2.96	258.15	0.38	7.13	327.54	4.57	1.50	1.74	0.09	0.00	0.10	0.43	0.88
11	6135	8.09	1.03	2.40	1.50	650.80	1.44	5.16	770.43	10.22	5.90	4.96	0.38	0.00	0.00	0.01	0.04
12	7325	6.40	1.06	20.10	7.51	1221.79	1.26	16.98	1154.48	31.84	8.11	8.43	0.57	0.00	2.67	0.52	-0.01
13	6468	7.48	1.03	13.75	13.17	603.35	1.21	14.43	529.81	17.81	5.17	68.22	0.34	0.00	0.66	0.36	0.80
14	7288	7.34	1.04	20.91	15.30	699.02	1.57	23.74	691.00	27.96	8.11	23.86	0.35	0.00	0.64	0.75	1.00
15	6803	7.55	1.03	17.98	12.08	462.41	0.76	35.38	494.90	14.78	6.08	47.11	0.18	0.00	1.06	0.50	0.97
16	7199	7.40	1.05	12.14	2.89	1087.08	1.29	17.80	1030.58	49.12	11.11	6.25	0.98	0.01	0.96	0.52	0.74
17	4922	7.00	1.04	58.90	2.93	751.38	0.95	20.49	546.07	96.30	32.30	46.92	0.37	0.00	3.60	0.47	0.68
18	5587	6.80	1.01	7.02	1.47	218.18	1.90	0.47	214.80	6.02	1.86	6.38	0.27	0.26	0.11	0.22	-0.56
19	8570	7.50	1.01	3.67	0.27	111.54	0.19	0.97	98.64	4.92	0.74	10.63	0.31	0.00	1.99	0.40	-0.06
20	7772	8.20	1.00	1.13	0.24	0.23	0.00	0.17	0.26	0.91	0.00	0.02	0.00	0.00	0.00	0.00	0.07
21	7506	8.73	1.03	8.50	3.13	578.00	0.95	1.39	481.53	34.76	4.13	28.82	2.12	0.07	1.47	0.94	1.76
22	9207	7.30	1.01	32.50	10.09	231.60	1.05	1.66	250.87	3.73	0.59	13.17	0.21	0.01	0.75	1.90	0.11
23	5675	7.56	1.02	4.64	0.00	528.64	2.05	2.75	507.45	11.83	4.91	6.98	0.54	0.01	0.66	0.29	0.43
24	10242	6.97	1.00	8.78	0.11	19.21	0.04	0.24	20.54	1.49	1.14	1.74	0.02	0.00	3.99	0.42	-0.58
25	6286	7.35	1.01	23.43	22.81	313.13	2.48	0.05	334.87	3.30	1.07	2.13	0.15	0.23	1.00	0.73	0.44
26	7580	7.40	1.03	17.09	14.65	722.54	3.28	0.07	687.14	18.62	4.99	4.09	0.85	1.30	1.77	0.70	0.83
27	6195	7.56	1.03	16.75	11.68	652.46	0.78	0.00	605.50	14.50	3.88	3.20	0.66	0.85	0.74	0.72	-0.52
28	8165	7.50	1.03	16.93	14.02	734.94	1.35	4.75	690.85	21.26	4.80	4.32	0.48	0.01	0.25	0.78	0.97
29	7531	7.40	1.05	12.73	12.18	1017.14	2.29	0.40	906.65	29.83	7.82	6.23	1.16	2.27	1.25	0.70	0.71
30	7298	7.40	1.05	9.97	9.02	1172.98	2.12	2.37	1158.56	27.83	7.37	11.97	1.27	0.02	0.21	0.73	0.66
31	7442	7.50	1.02	22.48	6.69	504.20	0.78	4.04	482.79	12.41	2.88	4.27	0.34	0.01	0.04	0.89	0.93
32	7338	7.68	1.03	15.45	14.75	602.72	1.40	12.02	584.83	20.96	4.67	2.96	0.42	0.01	0.63	0.62	1.02
33	7417	7.60	1.04	15.37	14.34	863.46	2.92	0.03	763.68	25.31	6.06	4.77	1.25	2.04	0.36	0.67	0.91
34	7448	7.67	1.04	14.02	4.35	735.59	1.96	2.28	690.55	23.27	4.87	4.01	0.80	0.02	0.47	0.75	0.96
35	7178	7.40	1.03	16.28	8.19	725.73	2.37	0.77	660.39	18.89	4.54	5.42	0.78	0.17	0.20	0.86	0.65
36	6446	7.50	1.03	19.89	13.48	717.36	1.53	0.42	699.39	15.64	4.21	3.75	0.78	0.82	0.49	0.65	0.95

**Table 4** Stable isotope composition of formation waters. Note that only a select subset of the original 56 samples are analyzed for stable isotopes.

Well ID	$\delta^{18}O_{H_2O}$ (‰ VSMOW)	$\delta D_{H_2O}$ (‰ VSMOW)	$\delta^{13}C_{DIC}$ (‰ VPDB)
K3	-5.20	-61.20	3.28
I1	-13.71	-111.10	15.91
I3	-1.69	-43.10	3.71
I6	-2.55	-42.00	-2.12
I9	-2.98	-46.10	6.48
G3	-4.33	-44.10	5.49
G4	-3.69	-41.60	-3.78
G5	-3.81	-40.10	-6.83
G7	-3.43	-40.20	-0.22
1	-3.80	-39.3	-4.51
2	-3.17	-42.0	1.05
3	-3.71	-41.8	-13.05
4	-	-	-
8	-3.74	-43.9	0.29
12	-3.97	-45.1	2.35
13	-4.77	-56.1	-4.26
17	-2.99	-23.4	10.29
22	1.23	-48.2	-3.89
24	-2.52	-59.7	9.28
25	-1.44	-50.0	-3.22
26	-2.61	-52.6	0.72
28	-2.60	-46.8	0.35
34	-3.27	-49.2	2.48

<sup>1</sup> Water sample is dominated by organic solvent, thus no isotope data were available.

**Table 5** Composition and stable isotope values of the subset of gases sampled by us in the Uinta Basin. Note that the well IDs correspond to those of the formation waters analyzed for stable isotopes (Table 4).

Name	He	H <sub>2</sub>	Ar	O <sub>2</sub>	CO <sub>2</sub>	N <sub>2</sub>	CO	CH <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>8</sub>	iC <sub>4</sub>	nC <sub>4</sub>	iC <sub>5</sub>	nC <sub>5</sub>	C6+	$\delta^{13}C_{CO_2}$ (‰)	$\delta^{13}C_{CH_4}$ (‰)	$\delta D_{CH_4}$ (‰)	Specific Gravity	BTU
K3	0.07	0.01	0.01	0.03	1.40	1.22	0.00 <sup>1</sup>	87.67	6.16	1.85	0.39	0.48	0.22	0.14	0.36	-9.98	-41.46	-187.60	0.65	1106
I1	0.00	0.00	0.00	0.03	0.18	0.18	0.00	93.71	3.39	1.36	0.30	0.38	0.14	0.11	0.22	- <sup>2</sup>	-38.47	-195.40	0.61	1088
I3	0.01	0.00	0.00	0.02	1.21	0.24	0.00	85.07	6.26	4.22	0.72	1.27	0.36	0.30	0.33	-7.04	-39.10	-198.20	0.69	1189
I6	0.00	0.00	0.00	0.02	0.39	0.19	0.00	92.21	4.32	1.60	0.34	0.43	0.15	0.11	0.25	-7.99	-36.88	-172.20	0.62	1100
I9	0.00	0.00	0.00	0.02	1.10	0.11	0.00	89.22	4.96	2.69	0.49	0.75	0.21	0.16	0.28	-5.66	-37.24	-180.50	0.65	1131
G3	0.00	0.00	0.00	0.01	0.24	0.25	0.00	91.07	5.28	1.65	0.37	0.41	0.18	0.13	0.40	-	-37.38	-172.90	0.63	1117
G4	0.00	0.00	0.00	0.04	0.32	0.17	0.00	91.76	4.97	1.50	0.34	0.36	0.15	0.11	0.27	-12.46	-37.75	-175.90	0.62	1104
G5	0.00	0.00	0.00	0.02	0.21	0.30	0.00	93.18	3.80	1.23	0.29	0.34	0.14	0.11	0.36	-	-36.50	-168.00	0.61	1092
G7	0.00	0.00	0.00	0.03	0.21	0.15	0.00	95.01	3.05	0.83	0.17	0.19	0.08	0.06	0.21	-	-35.95	-166.00	0.59	1066
1	0.01	0.00	0.02	0.36	0.22	0.58	0.00	89.62	5.63	2.08	0.45	0.50	0.18	0.13	0.24	-	-37.51	-175.50	0.63	1116
2	0.01	0.00	0.01	0.12	1.41	0.39	0.00	80.63	7.61	5.87	1.20	1.67	0.51	0.37	0.21	-6.71	-39.27	-202.90	0.73	1242
3	0.01	0.00	0.02	0.31	0.11	0.79	0.00	93.75	3.29	1.00	0.20	0.23	0.09	0.06	0.15	-	-36.23	-164.50	0.60	1062
4	0.01	0.02	0.03	0.08	0.00	2.63	0.00	91.86	3.59	1.03	0.22	0.23	0.09	0.07	0.14	-	-36.74	-169.00	0.61	1049
8	0.00	0.01	0.01	0.09	0.76	0.26	0.00	88.91	4.54	3.06	0.70	0.84	0.31	0.21	0.31	-7.65	-37.24	-180.40	0.65	1146
12	0.01	0.01	0.01	0.09	2.11	0.35	0.00	81.20	7.37	5.60	1.07	1.33	0.37	0.28	0.22	-5.67	-39.70	-209.90	0.72	1213
13	0.01	0.00	0.01	0.09	0.68	0.42	0.00	80.24	8.97	5.63	0.99	1.55	0.49	0.40	0.52	-8.60	-43.17	-217.40	0.73	1261
17	0.01	0.00	0.00	0.07	0.43	0.34	0.00	87.64	6.88	2.83	0.47	0.69	0.21	0.16	0.27	-1.12	-43.12	-199.70	0.65	1149
22	0.02	0.01	0.01	0.09	0.92	0.63	0.00	86.23	6.70	3.10	0.54	0.82	0.30	0.24	0.41	-7.44	-42.91	-197.80	0.67	1158
24	0.02	0.00	0.00	0.08	1.53	0.25	0.00	93.17	3.90	0.63	0.15	0.09	0.05	0.02	0.10	-2.33	-39.70	-172.60	0.60	1046
25	0.01	0.00	0.01	0.09	0.50	0.33	0.00	84.96	7.83	3.90	0.75	0.95	0.29	0.20	0.19	-9.40	-39.68	-196.90	0.68	1185
26	0.00	0.01	0.00	0.08	1.59	0.18	0.00	78.31	8.88	6.66	1.12	1.80	0.64	0.53	0.20	-6.71	-38.85	-194.10	0.75	1275
28	0.00	0.00	0.00	0.06	0.92	0.22	0.00	86.99	5.65	3.53	0.69	1.01	0.33	0.27	0.32	-6.87	-37.75	-184.90	0.67	1168
34	0.00	2.14	0.00	0.01	0.97	0.17	0.00	83.19	5.93	4.31	0.88	1.21	0.40	0.32	0.47	-8.82	-37.63	-185.60	0.68	1186

<sup>1</sup> Values given as "0.00" means not detected;

<sup>2</sup> blank under  $\delta^{13}C_{CO_2}$  means the CO<sub>2</sub> concentrations were too low for isotope analysis.

<sup>3</sup> VPDB;

<sup>4</sup> VSMOW.