SULFATE GEOTHERMOMETRY OF THERMAL WATERS IN THE WESTERN UNITED STATES

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INTRODUCTION

Sulfate geothermometry recently gained acceptance as a geothermal exploration tool when it was adopted as one of the geothermometers in the Assessment of Geothermal Resources of the United States-1978 (Muffler 1979). Over 120 samples, 75 of which are from Known Geothermal Resource Areas, were used in the assessment. Data required for calculation of the sulfate geothermometer temperatures, along with Na-K-Ca, quartz, and chalcedony geothermometer temperatures for comparison, are listed in table 1. For greater accuracy data from new or better samples have occasionally supplemented or replaced data used in the 1978 assessment. Samples from Yellowstone National Park has been omitted because they were discussed by McKenzie and Truesdell (1974).

USE OF THE SULFATE GEOTHERMOMETER

The sulfate geothermometer is based on the assumption that the oxygen isotopes in a water and its dissolved sulfate have equilibrated in the geothermal reservoir. The rate of equilibration is both temperature and pH dependent requiring about 2 years at 300°C and 110 years at 25°C in near neutral waters. The equilibration is accelerated in acid solutions, but most geothermal reservoirs are near neutral at depth. Any introduction or loss of sulfate or addition of water after the sulfate-water isotopic equilibrium has been established in the reservoir may result in erroneous temperature estimates. Addition of near-surface sulfate from the oxidation of H_2S to H_2SO_4 by sulfur oxidizing bacteria and dilution of the geothermal water by ground water of different $\delta^{18}O$ content are two common interferences.

Near-surface sulfate can be minimized by selecting the spring with the lowest SO_4/Cl ratio in a group. Furthermore, if the SO_4/H_2S ratio is less than 25, the sample should be preserved either by adding Zn, Cd, or other heavy metal to precipitate the H_2S or formaldehyde or chloroform to kill the bacteria.

A suite of samples may be necessary to correct for dilution by ground water. The $\delta^{18}O$ of both the ground water and geothermal water must be determined and appropriate corrections applied to the mixed waters. Such corrections were not made in this paper.

The method of cooling that the water undergoes as it ascends to the surface can effect the $\delta^{18}O$ in the water. Three end member cases are given in table 1. T1 is calculated assuming conductive cooling with no steam loss and, therefore, no change in the $\delta^{18}O$ of the water. T1 is the best temperature estimate when the spring or well is substantially below boiling and in well samples collected with a downhole sampler. T2 is calculated assuming adiabatic cooling where the steam stays in contact and in isotopic equilibrium with the water until the mixture reaches the surface where steam loss then occurs. T2 is the best temperature estimate for isolated springs of near boiling temperature and well samples with two phase flow. T3 is an extreme case of continuous steam loss by the water from the time it leaves the reservoir until it reaches the surface. This case is most applicable to hot springs associated with fumaroles or steaming ground.

USE OF THE TABLE

Location of the area sampled is by latitude-longitude and township-range. Latitude and longitude are in degrees, minutes, and hundreths of a minute. Township-range designations are shown in Figure 1. The oxygen isotopes were analyzed according to methods described by Nehring and others (1977) and by Epstein and Mayeda (1953). Values are reported relative to SMOW as defined by Craig (1957) and have an accuracy of ±0.2. TR indicates what field treatment was applied to the sample:

N	none
F	formaldehyde
C	chloroform

The concentrations in mg/L of sulfate, hydrogen sulfide, and chloride are reported because of their importance in interpretation of the results. Sulfate was usually analyzed gravimetrically but in a few cases the concentration was determined by the thorin method. This is indicated by a "t" after the number in the table. T is the surface temperature or the downhole temperature in a well if the sample was collected without steam loss. Temperatures estimated from Na-K-Ca, quartz, and chalcedony geothermometers are included in the table for comparison. The reference number in the last column indicates the source of the chemical analysis used to calculate these temperatures or where the temperatures themselves are reported. An M after the Na-K-Ca temperature indicates the magnesium correction (Fournier and Potter 1978) was applied. The quartz temperature was usually calculated assuming conductive cooling but if an A follows the temperatures adiabatic cooling has been assumed. Three of the sulfate geothermometer variations are then reported; T1-conductive cooling, T2-single stage steam loss and T3-continuous steam loss.

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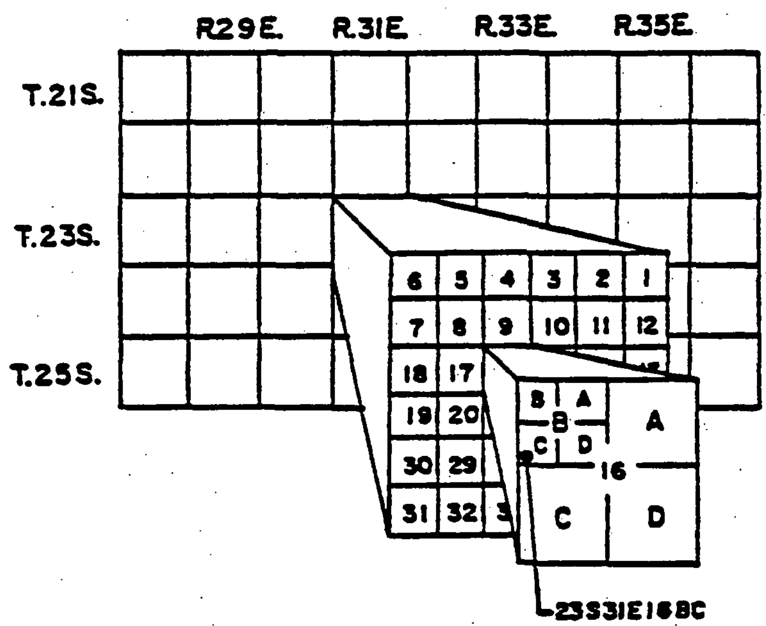

Figure 1.—Method used for reporting township-range.

Table 1. Description, location, raw data, and geothermometers of samples analysed for sulfate geothermometer temperatures. Temperature estimates should not be used without consulting section on use of the sulfate geothermometer.

DESCRIPTION	LAT	LONG	TOWN-RANGE	DATE	O-SO4	O-H2O	TR	SO4	H2S	CL	F	NAKCA	QTZ	CHAL	T1	T2	T3	REF
ALASKA																		
GEYSER BIGHT	53 13	168 28	n.d.	75JUN14	-4.05	-8.06	N	182	n.d.	640	102	177	182A	179	322	264	282	17
INDECISION CREEK	0 0	0 0	35S49W	73JUN16	5.87	-12.32	N	447	n.d.	470	59	20M	180	159	86	83	84	17
SERPENTINE HOT SPRING	65 51	164 42	5N25W12	72AUG04	4.72	-15.15	N	9	n.d.	1450	77	161	131	104	73	72	72	21
CIRCLE HOT SPRING	65 29	144 39	n.d.	72AUG13	0.98	-20.6	N	97	n.d.	249	54	143	134	107	60	60	60	20
ARIZONA																		
GILLARD HOT SPRING	32 58.5	109 21	5S29E27AA	75JAN16	-0.31	-10.87	N	182	<1	490	82	138	134	107	169	157	159	3
CALIFORNIA																		
SULFUR WORKS-LASSEN	40 27	121 32	30N4E21AA	75SEP24	-5.92	-6.91	N	469	n.d.	<5	95	n.d.	n.d.	n.d.	479	333	388	
BUMPASS HELL-LASSEN	40 27	121 30	30N4E14DB	75JUL16	-3.2	-7.37	N	299	n.d.	<0.5	94	n.d.	n.d.	n.d.	316	261	278	
DEVILS KITCHEN-LASSEN	40 26	121 25	30N5E21CD	75OCT10	-3.72	-12	N	49	n.d.	7	95	n.d.	n.d.	n.d.	208	190	194	
DEVILS KITCHEN-LASSEN	40 26	121 25	30N5E21CD	75SEP20	-11.77	-13.22	N	76	n.d.	<5	95	n.d.	n.d.	n.d.	446	322	366	
GROWLER-MORGAN SPRINGS	40 24.0	121 30.4	29N4E11BA	76OCT03	-3.58	-9.14	C	49	n.d.	2270	97	230	177A	177	272	235	245	7
NR BRIDGE-MORGAN SPRS	40 23.1	121 30.8	29N4E11CD	75SEP18	-2.13	-9.22	N	52	n.d.	2310	95	217	172	148	233	239	214	7
S MEADOW-MORGAN SPRS	40 23.4	121 30.3	29N4E11BD	75SEP24	-2.58	-8.67	N	51	n.d.	2080	95	n.d.	n.d.	n.d.	258	225	234	
MAGMA RICHIE 5-LONG VAL	37 38.9	118 54.8	3S28E32	72MAY19	-7.59	-14.16	N	136	n.d.	280	96	238	219	205	245	217	224	14
NR HOT CREEK-LONG VAL	37 39.4	118 48.3	3S29E31A	72MAY20	-7.2	-14.2	N	81t	0.8	170	58	176	161	138	235	198	208	14
HOT CREEK-LONG VAL	37 39.8	118 49.6	3S28E25	73AUG29	-7.36	-14.83	N	100t	n.d.	225	90	192	161	138	224	201	206	14
COSO HOT SPRINGS WELL	36 05	117 46	21S39E34B	78JUL12	1.02	-5.68	F	74	n.d.	2370	142	234	n.d.	n.d.	243	227	230	16
COSO CGEH 1	36 03	117 48	22S39E6A	78JUL12	0.72	-7.59	F	79	n.d.	2360	195	206	126	99	208	207	207	16
SHASTA SODA SPRINGS	41 15	122 16	39N4W13A	75AUG20	12.54	-9.89	N	67	<1	800	13	2M	132	105	56	52	53	11
JORDON HOT SPRINGS	36 14	118 18	n.d.	77NOV07	0.03	-12.41	F	259	n.d.	880	43	61M	177	155	143	129	132	11
SESPE HOT SPRINGS	34 35.7	118 59.9	6N20W21DD	77JAN31	5.72	-9.5	N	303	2.5	290	89	148	136	109	113	110	111	11
FALES HOT SPRING	38 20.0	119 24.0	6N23E24D	74OCT24	-4.29	-17.46	N	260t	n.d.	160	61	84M	145	119	134	125	126	13
HOT SPR MOTEL-SURPRISE V	41 31.9	120 04.7	42N17E6CA	73JUL27	-5.11	-13.81	N	322	n.d.	200	98	96	137	111	200	184	187	12
SEYFORTH-SURPRISE V	41 40.0	120 12.0	44N15E24AC	73JUL26	-5.62	-14.05	N	343	n.d.	220	85	129	143	116	205	185	189	12
TRAVERTINE HOT SPRINGS	38 14.8	119 12.1	5N25E34CD	74JUL28	-6.42	-16.64	N	920t	<.05	200	69	87	137	110	173	158	161	13
KELLEY HOT SPRINGS	41 27.5	120 50.0	42N10E29BA	74JUL23	-4.73	-13.54	N	300	n.d.	160	91.5	95	143	116	198	181	185	12
SPR NR WEST VALLEY RES	41 11.5	120 23.1	39N14E29AB	73JUL24	-7.66	-14.13	N	482	n.d.	150	77	138	152	127	247	212	222	12
MAGNESITE SPRING	39 04.4	122 34.0	n.d.	76SEP22	2.67	-5.2	N	259	n.d.	1920	22	22M	131	102	217	173	186	9
BENMORE CANYON WELL	39 01.5	122 34.2	n.d.	76SEP16	7.18	-3.75	N	537	n.d.	4050	21	21M	77	43	165	139	146	9
JONES FOUNTAIN OF LIFE	39 02.0	122 26.7	14N5W30DD	76JUN26	20.39	6.25	N	118	n.d.	11900	61	180M	128	99	126	119	120	9
TURKEY RUN MINE	39 01.1	122 26.4	14N5W32CA	76JUN26	3.08	-6.8	N	2392	n.d.	1150	22	22M	118	88	180	150	158	9
COMPLEXION SPRING	39 10.2	122 31.2	15N6W6CD	76JUN24	7.19	6.26	N	18	n.d.	24100	19	242	82	49	483	277	349	9
UPPER CRABTREE SPRING	39 17.4	122 49.3	17N9W25DC	76JUN23	4.29	-1.9	N	317	n.d.	9.8	36	37	104	72	256	202	219	9
WILBUR SPRINGS	39 02.8	122 25.3	14N5W28BA	76JUN24	18.28	4.95	N	455	n.d.	9810	50	145M	153	127	135	124	126	9

DESCRIPTION	LAT	LONG	TOWN-RANGE	DATE	D-SO4	D-H2O	TR	SO4	H2S	CL	T	NAKCA	QTZ	CHAL	T1	T2	T3	REF
COLORADO																		
MT PRINCETON HOT SPRS	38 43.9	106 10.2	15S78W19	76UNK00	-3.75	-16.4	N	98t	<1	10	83	93	130	103	140	133	134	18
IDAHO																		
BRUNEAU GRANDVIEW	43 02.60	116 19.43	4S1E34BA	73JUL09	-1.41	-17.53	N	39	n.d.	13	75.5	81	132	103	103	100	100	5
BRUNEAU GRANDVIEW	43 02.03	116 15.23	4S2E32BC	73OCT09	-11.72	-17.44	N	4.5	n.d.	31	43	131	142	115	266	205	224	5
BRUNEAU GRANDVIEW	43 01.37	116 10.48	5S2E1BB	73OCT09	-7.54	-16.97	N	7.1	n.d.	16	49.5	60	123	94	186	162	168	5
BRUNEAU GRANDVIEW	42 59.37	116 04.58	5S3E14CB	73JUL26	-3.59	-16.99	N	11	n.d.	18	58.5	62	126	96	131	122	123	5
BRUNEAU GRANDVIEW	42 57.83	116 04.53	5S3E26BC	73JUL09	-0.46	-17.49	N	78	n.d.	15	83	91	143	115	95	94	94	5
BRUNEAU GRANDVIEW	42 57.68	116 06.90	5S3E28BC	73JUL24	-3.31	-17.57	N	11	n.d.	15	65	106	136	108	121	115	116	5
BRUNEAU GRANDVIEW	42 54.40	115 56.63	6S4E14AB	73JUL09	-1.41	-17.56	N	64	n.d.	19	54	143	157	131	103	97	98	5
BRUNEAU GRANDVIEW	42 50.20	115 54.27	7S5E7AB	73JUL10	-1.77	-17.55	N	17	n.d.	9.8	39	187	132	103	106	98	99	5
BRUNEAU GRANDVIEW	42 45.68	115 45.68	8S6E3BD	73JUL17	-1.65	-17.06	N	15	n.d.	9.1	15	182	130	101	110	97	98	5
COVE CREEK-WEISER	44 12.67	116 42.62	10N3W9CC	73AUG21	-5.26	-12.26	N	265	n.d.	310	74	172	153	126	235	203	212	5
CRANE CREEK-WEISER	44 18.38	116 44.68	11N3W7BD	73AUG02	-7.99	-14.39	N	274	n.d.	200	92	163	173	151	249	218	226	5
NR WEISER HOT SPRINGS	44 17.92	117 02.97	11N6W10CC	73AUG06	-7.55	-13.4	N	147	n.d.	56	76	134	157	131	263	215	229	5
BRIDGE WELL-RAFT RIVER	42 06.5	113 23.6	15S26E23BB	74JUL13	-4.86	-17.86	N	61t	n.d.	840	89.5	147	120	90	135	131	131	7
BRIDGE WELL-RAFT RIVER	42 06.5	113 23.6	15S26E23BB	76OCT07	-4.66	-17.5	F	56	n.d.	n.d.	90	159	125	96	137	132	133	7
CRANK WELL-RAFT RIVER	42 05.8	113 22.7	15S26E23DC	74JUL13	-4.73	-17.23	N	60t	n.d.	1850	90	135	130	101	142	136	137	7
RRGE 2-RAFT RIVER	42 06.45	113 22.47	15S26E23AA	76OCT06	-4.34	-17.42	N	52	n.d.	578	95	187	161	136	135	130	131	7
ALMO 1-RAFT RIVER	42 04.9	113 31.6	15S25E29CD	76OCT06	1.44	-17.3	F	47	n.d.	n.d.	60	143	139	112	81	79	79	7
SPR AT NARROWS-RAFT RIV	42 04.1	113 27.9	16S26E5BA	74JUL13	-2.88	-17.54	N	44	n.d.	430	38	101	117	66	117	107	109	7
SIX MILE SPR-RAFT RIVER	42 07.58	113 09.47	15S28E15AA	74JUL13	-0.07	-16.36	N	64	n.d.	20	17	-6	31	-4	101	91	93	7
SPR E OF NAF-RAFT RIVER	42 00.7	113 15.9	16S27E23	74JUL13	1.04	-17.07	N	20	n.d.	n.d.	9	n.d.	n.d.	n.d.	86	77	78	
BIG CREEK HOT SPRINGS	45 18.8	114 19.2	23N18E22C	78MAY04	-4.19	-19.57	F	48	n.d.	29	93	179	157	133	110	108	108	22
VULCAN HOT SPRINGS	44 34.0	115 41.5	14N6E11BD	78MAY07	3.44	-18.44	F	40	1.2	15	87	138	140	114	59	61	61	22
NEINMEYER HOT SPRINGS	43 45.5	115 34.7	5N7E24	78MAY06	-1.12	-18.02	F	28	n.d.	2	75	90	137	110	96	94	94	22
SHARKEY HOT SPRINGS	45 00.8	113 36.3	20N24E24	78MAY05	-3.59	-19.42	F	163	n.d.	53	63	170	134	107	103	101	101	22
WHITE LICKS HOT SPRS	44 40.9	116 13.8	16N2E33BC	78MAY09	-4.24	-14.99	F	604	n.d.	150	67	144	140	114	166	151	154	22
BONNEVILLE HOT SPRINGS	44 09.5	115 18.4	10N10E31C	78MAY05	-1.01	-18.13	F	46	n.d.	7.6	85	136	136	110	94	93	93	22
BOILING SPRINGS	44 21.9	115 51.4	12N5E22BB	78MAY00	0.3	-17.44	N	110	n.d.	14	86	100	129	101	89	88	88	22
MONTANA																		
JARDINE(JACKSON) SPRS	45 21.8	113 24.7	5S15W26	75AUG16	-1.02	-20.44	N	48	0.6	7.7	58	57M	104	73	75	74	74	10
ALHAMBRA NORTH WELL	46 27.0	111 58.8	8N3W16A	76UNK00	-3.49	-19.95	N	88t	n.d.	8.7	56	75M	109	80	99	95	95	15
ALHAMBRA HOT SPRINGS	46 26.8	111 59.0	8N3W16A	76AUG23	-3.49	-19.23	N	89t	<0.5	10	56.5	86M	115	86	106	101	101	10
SILVER STAR HOT SPRINGS	45 41.5	112 17.2	2S6W1C	74AUG18	-5.46	-18.48	N	190t	1	31	71.5	139	143	116	135	128	129	10
BOULDER HOT SPRINGS	46 12.0	112 05.6	5N4W10CA	74AUG22	-5.45	-18.91	N	74t	<0.5	19	76	136	142	115	130	124	125	10
ENNIS(THEXTON) HOT SPRS	45 22.0	111 44.8	5S1W28DC	76APR01	-1.8	-18.74	N	206	n.d.	120	83	145M	135	108	95	94	94	15

NEVADA

DESCRIPTION	LAT		LONG		TOWN-RANGE	DATE														
SPRING 13-STEAMBOAT SPR	39	23.36	119	44.46	18N20E33BA	75JUL15	-5.42	-11.73	N	137	n.d.	n.d.	90	n.d.	n.d.	n.d.	251	220	228	
SPRING 26NW-STEAMBOAT	39	22.96	119	44.26	18N20E33DB	75JUL15	-3.28	-10.44	N	131	n.d.	751	95	203	197	179	232	207	213	7
KYLE HOT SPRING	40	24.4	117	52.9	29N36E1C	73JUN12	-3.93	-15.5	N	82	n.d.	770	77	81M	161	137	154	144	146	2
SULPHUR HOT SPRINGS	40	35.2	115	17.1	31N59E11B	73JUN17	-5.05	-16.09	N	93t	7.4	23	93	181	171	163	161	153	154	2
WABUSKA HOT SPRINGS	39	09.7	119	11.0	15N25E16D	74APR18	-3.22	-15.38	N	620t	0.7	55	97	146	143	116	146	140	141	2
SMITH CREEK VALLEY	39	18.7	117	32.5	17N39E11	73JUN18	-4.06	-16.48	N	102t	1.6	22	86	156	143	116	143	136	137	2
SODA LAKE WELL	39	34.0	118	51.1	20N28E28	74AUG01	0.28	-13.48	N	376	<1	1500	100	161	165	142	127	125	125	2
DESERT PEAK WELL	39	45.7	118	57.0	22N27E21AA	78NOV05	-5.26	-12.34	N	104	n.d.	3600	95	225	241	231	233	208	214	19
PINTO HOT SPRS W WELL	41	21	118	47	40N28E19AD	72JUL13	-7.09	-14.2	N	135	3.3	160	93	176	161	137	232	207	213	2
NR FERNLEY	39	35.9	119	06.4	20N26E18D	74APR18	-5.61	-13.3	N	415	<0.1	820	86	166	161	137	220	196	202	2
BEOWAWE HOT SPRINGS	40	34.2	116	34.8	31N48E17B	72JUL16	-10.01	-14.76	N	115	5.5	70	98	242	226	n.d.	295	251	264	2
STILLWATER WELL	39	31.3	118	33.1	19N31E7C	73AUG00	-3.14	-12.36	N	190t	n.d.	2200	96	140	159	146	191	177	179	2
BALTAZOR HOT SPRING	41	55.3	118	42.6	46N28E13B	72JUN15	-3.98	-15.26	N	220t	<.05	48	80	152	165	142	158	148	150	2
DIXIE VALLEY HOT SPRS	39	47.9	118	04.0	22N35E5D	73JUN19	-2.09	-15.89	N	121	7	126	72	143	145	119	127	120	121	2
BUFFALO VALLEY HOT SPRS	40	22.1	117	19.5	29N41E23D	72JUL15	-3.22	-15.85	N	100	0.6	29	49	135M	125	97	140	128	130	2
GREAT BOILING SPRINGS	40	39.7	119	21.7	32N23E15B	72JUN18	6.53	-10.83	N	350	0.7	2200	86	205	167	144	93	92	92	2
LEE HOT SPRINGS	39	12.6	118	43.4	16N29E34AB	72JUL20	-8.03	-13.21	N	470t	1.2	380	88	162	173	151	282	239	251	2
LEACH HOT SPRINGS	40	36.2	117	38.7	32N38E36D	72JUN17	-5.22	-15.7	N	53t	2.8	29	92	176	155	130	170	159	161	2
HUMBOLDT HOUSE	40	32.1	118	16.1	31N33E21DA	78JUN21	-4.57	-14.64	F	28	1	2230	200E	249	219	205	176	178	178	22
BRADY #8	39	47.3	119	00.1	22N26E12	77NOV05	-2.78	-13.59	F	n.d.	0.8	1400	98	156	153	n.d.	165	157	158	22

NEW MEXICO

DESCRIPTION	LAT		LONG		TOWN-RANGE	DATE														
SODA DAM	35	47.5	106	41.2	n.d.	72DEC01	4	-10.4	N	52t	<1	1500	48	173M	102	72	121	112	113	6
GILA HOT SPRINGS	33	11.9	108	12.3	13S13W5A	74DEC22	-0.96	-11.03	N	48	<1	105	68	78	122	89	177	160	164	3
TEST HOLE #1-JEMEZ	35	49.82	106	38.93	19N3E32CC	76FEB22	5.01	-10.81	N	247	n.d.	300	14	108	88	56	107	94	97	8
JEMEZ SPRING	35	46.30	106	41.43	n.d.	76FEB22	-1.68	-10.52	N	41	n.d.	920	74	190M	124	95	201	180	185	6
WINDMILL 5220-JEMEZ	34	48.50	107	04.07	n.d.	76FEB20	9.36	-8.1	N	1928	n.d.	480	19	60M	48	14	92	84	85	8
DIPPING VAT SPRING	34	55.82	107	06.40	n.d.	76FEB20	11.1	-8.5	N	1589	n.d.	380	16.5	67	80	46	76	69	70	8

OREGON

DESCRIPTION	LAT		LONG		TOWN-RANGE	DATE														
MICKEY SPRINGS	42	40.5	118	20.7	33S35E13	72AUG30	-7.91	-13.42	N	224	<0.5	240	73	207	180	159	273	227	240	1
ALVORD HOT SPRINGS	42	32.6	118	31.6	34S34E33	72AUG30	-6.05	-13.23	N	211	1.2	780	76	164M	148	122	231	201	209	1
HOT(BORAX) LAKE-ALVORD	42	20.1	118	36.0	37S33E15	72AUG30	-7.95	-11.57	N	383	<0.5	300	36	176	176	155	336	242	274	1
NR HOT LAKE-ALVORD	42	20.1	118	36.0	37S33E15	73JUN13	-8.58	-14.36	N	310	<1	250	96	176	156	142	265	231	240	1
ON TROUT CREEK-ALVORD	42	11.4	118	23.0	39S37E16	73JUN14	-9.22	-16.17	N	189	<0.5	24	52	143	140	114	235	196	207	1
LISKEY-KLAMATH FALLS	42	02.9	121	44.5	40S9E34AC	75JUL08	-2.13	-14.95	N	345	n.d.	59	93	82	131	104	138	133	134	4
OSBORNE-KLAMATH FALLS	42	03.3	121	44.9	40S9E27CD	75JUL08	-1.85	-14.95	N	331	n.d.	56	90	83	131	103	135	130	130	4
OLENE GAP SPR-KLAMATH	42	08.9	121	37.0	39S10E14CB	75JUL08	-4.82	-13.73	N	385	n.d.	59	87	79	136	108	196	179	182	4
MEDO BELL-KLAMATH	42	13.8	121	46.4	38S9E28CC	75JUL08	-5.45	-14.95	N	402	n.d.	54	81	75	126	96	185	170	173	4
MILLS SCHOOL-KLAMATH	42	13.5	121	45.9	38S9E33AC	75JUL08	-4.94	-14.83	N	437	n.d.	54	85	67	124	94	179	165	168	4

DESCRIPTION	LAT	LONG	TOWN-RANGE	DATE	O-SO4	O-H2O	TR	SO4	H2S	CL	T	NAKCA	QTZ	CHAL	T1	T2	T3	REF.
OREGON(CONT)																		
OIT #6-KLAMATH FALLS	42 15.1	121 46.8	38S9E20AD	75JUL08	-5.45	-14.99	N	393	n.d.	58	90	71	81	47	185	171	174	4
LISKEY-KLAMATH FALLS	42 02.2	121 43.7	41S9E28A	75AUG11	8.69	-8.67	N	5	n.d.	152	25	n.d.	n.d.	n.d.	93	85	54	
BOEHM-KLAMATH FALLS	42 03.7	121 45.8	40S9E28AC	75AUG11	15.42	-6.78	N	308	n.d.	205	25	n.d.	n.d.	n.d.	58	55	56	
SUBURBAN-KLAMATH FALLS	42 01.6	121 35.6	41S10E1CD	75AUG11	9.56	-10.79	N	83	n.d.	80	21	n.d.	n.d.	n.d.	70	65	66	
VALE HOT SPRINGS	43 59.4	117 14.0	18S45E20	74AUG14	-6.56	-15.18	N	95	<0.5	360	73	157	152	127	201	180	184	23
VALE HOT SPRINGS	43 59.0	117 14.0	18S45E20	74AUG07	-3.91	-15	N	112	n.d.	350	90	155	149	123	161	152	153	11
NEAL HOT SPRINGS	44 01.4	117 27.6	18S43E9B	72AUG26	-8.37	-16.52	N	112	1.6	120	87	181	173	151	210	189	194	1
CRUMPS SPRING	42 13.8	119 53.0	38S24E34C	72AUG03	-4.71	-13.28	N	209	0.5	240	78	144	173	151	202	182	186	1
HUNTER HOT SPRINGS	42 12.0	120 21.6	39S20E4	72AUG03	-3.69	-14.32	N	274	1.7	120	96	143	149	133	168	158	160	1
BELKNAP HOT SPRINGS	44 11.6	122 03.2	16S6E11DD	72AUG05	0.35	-11.74	N	169	n.d.	1300	71	82	135	108	148	138	139	1
HOT LAKE-UNION COUNTY	45 14.6	117 57.6	4S39 E5D	72AUG27	4.63	-16.56	N	65	7.5	140	80	90	102	70	63	65	65	1
BREITENBUSH HOT SPRS	44 46.9	121 58.5	9S7E20	72AUG05	-2.67	-11.66	N	140	<1	1300	92	149	127	99	195	179	182	1
BREITENBUSH HOT WELL	44 46.9	121 58.5	9S7E20	77UNK00	-3.28	-12.59	F	131	n.d.	1120	100	160	169	146	189	176	179	7
NR LITTLE VALLEY	43 53.5	117 30.0	19S43E30B	73JUL26	-8.63	-16.52	N	118	n.d.	74	70	118	145	119	215	189	195	1
CAREY(AUSTIN) HOT SPRS	45 01.2	122 00.6	6S7E 30B	72AUG05	-2.41	-12.22	N	154	0.8	430	86	87	126	98	181	167	170	1
SUMMER LAKE HOT SPRING	42 43.5	120 38.7	33S17E12A	72AUG04	-4	-13.32	N	126	n.d.	280	43	112	134	107	189	162	169	1
SWIM WARM SPRINGS-HOOD	45 17.7	121 44.3	3S8.5E24	77UNK00	1.52	-14.01	F	235	n.d.	159	26	n.d.	n.d.	n.d.	109	98	100	
UTAH																		
THERMO HOT SPRINGS	38 11.0	113 12.2	30S12W28CA	74DEC17	-2.52	-14.32	N	480t	<0.5	225	89.5	130M	144	118	151	144	145	3
THERMO HOT SPRINGS	38 11.0	113 12.2	30S12W28CA	76FEB11	-2.6	-15.07	N	374	n.d.	n.d.	82	n.d.	n.d.	n.d.	142	135	136	
THERMO HOT SPRINGS	38 11.0	113 12.2	30S12W28CA	76FEB11	-1.73	-14.71	N	465	n.d.	n.d.	65	n.d.	n.d.	n.d.	136	127	129	
RANCH CANYON SPRING	39 24.7	112 49.3	27S9W35DC	76FEB11	0.88	-14.91	N	8	n.d.	20	6	28	97	65	106	93	96	11
ROOSEVELT SEEP	38 30.3	112 51.9	26S9W34CC	76FEB14	-4.94	-12.79	N	110	<0.5	3150	25	233	167	143	216	174	187	11
MILFORD CITY WELL	38 22.4	113 00.9	28S10W7BB	76FEB13	4.89	-15.5	N	42	n.d.	16	15	55	81	48	69	64	64	11
SHALLOW WELL-ROOSEVELT	38 31.3	112 55.3	26S10W25AD	76FEB13	-1.14	-13.41	N	59	n.d.	2700	24	220	n.d.	n.d.	145	126	130	11
DEEP WELL-ROOSEVELT	38 29.6	112 51.6	27S9W3AC	76FEB13	-7.68	-13	N	61	3	3400	227	300	241A	270	278	272	272	11
DEEP WELL-ROOSEVELT	38 29.6	112 50.5	27S9W2CB	76NOV15	-8.03	-13.46	F	n.d.	n.d.	n.d.	152	n.d.	n.d.	n.d.	275	254	258	
DEEP WELL-ROOSEVELT	38 29.6	112 50.5	27S9W2CB	77APR04	-7.87	-13.11	F	n.d.	n.d.	n.d.	213	n.d.	n.d.	n.d.	280	271	272	
ABRAHAM HOT SPRINGS	39 36.8	112 43.9	14S8W10	74AUG15	12.77	-16.09	N	680t	<1	1500	84	86M	117	89	22	25	26	3
RED HILL HOT SPRINGS	38 38.2	112 06.2	25S3W10	74DEC16	8.21	-16.95	N	900	<1	660	76.5	114M	109	79	40	42	42	3
WASHINGTON																		
OHANAPECOSH HOT SPRS	46 44.2	121 33.6	14N10E4BA	77JUL24	0.32	-15	N	170	<1	880	48	135M	137	110	111	104	105	22
GARLAND MINERAL SPRS	47 53.6	121 20.5	28N11E25A	77JUL23	4.71	-7.37	N	181	<1	3600	29	80M	140	114	149	130	134	11

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