

CHEMICAL ANALYSES OF WATERS FROM THE BOUNDARY CREEK
THERMAL AREA, YELLOWSTONE NATIONAL PARK, WYOMING

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INTRODUCTION

Chemical analyses of water samples from hot springs, geysers, and pools emerging in Yellowstone National Park have been reported by various researchers for nearly one hundred years (Gooch and Whitfield, 1888; Allen and Day, 1935; White and others 1963; Noguchi and Nix, 1963; Scott, 1964; Rowe and others, 1973; Thompson and others, 1975; Thompson and Yadav, 1979; Stauffer and others, 1980). Until this work, springs issuing along and near Boundary Creek were not collected nor chemically analyzed because they are relatively remote. The possibility of geothermal exploration in the nearby Island Park Geothermal Area (IPGA) (Fig. 1) drew our attention to the hydrothermal activity in the southwestern corner of Yellowstone National Park. We have collected and chemically analyzed several samples of hot spring water and gas from this area in order to help assess changes in the thermal activity in the National Park that might result from exploitation of geothermal resources in the IPGA.

SAMPLE COLLECTION

Water samples from thermal and non-thermal springs were collected within or as close as possible to the primary orifices. Water samples collected from creeks are "grab" samples as no integrated sampling was attempted. Most water samples were collected during October 1979.

Water samples were collected as described by Thompson (1975). Anions (HCO_3^- , SO_4^{2-} , Cl^- , F^- , and Br^-) and boron were analyzed using 250 ml of water that was not filtered nor acidified in the field. Cations were analyzed using 125 ml of water that was filtered in the field with a $0.45\mu\text{m}$ membrane filter and then immediately acidified with 0.5 ml of 12N HCl per 125 ml of water (4 ml of 12N HCl per liter). All samples were collected in conventional polyethylene bottles. Those bottles used for cation analyses had been previously soaked in 10 percent HNO_3 for 5 days, thoroughly rinsed with deionized-distilled water, and soaked another 5 days in deionized-distilled water.

Gas samples were obtained by positioning a large, inverted, plastic funnel and attached plastic tubing, all filled with spring water, over a vent discharging sufficient gas so that the funnel rapidly filled with gas. After flushing the funnel and tubing with gas from the spring and without allowing any air to get into the apparatus, additional gas was carefully transferred into a 500 ml evacuated glass bottle containing 100 ml of 4M NaOH. The gas flow was interrupted whenever the water came within 5 cm of the top of the funnel. The above procedure was repeated until the rate of transfer of gas became quite slow (caused by increasing gas pressure in the once evacuated gas bottle) or the bottle became too hot to handle safely (caused by the exothermic reaction in the formation of CO_3^{2-}).

FIELD ANALYSIS

All temperature measurements of hot spring waters were obtained with a total immersion, maximum reading, mercury-in-glass thermometer; those of creeks and nonthermal springs were obtained with a total immersion, mercury-in-glass, conventional thermometer. Field determinations of pH were made with E.M. Colorphast¹ pH strips. Ammonia and hydrogen sulfide concentrations were determined in the field with a Bausch and Lomb (B and L) minispec 20¹ spectrophotometer and B and L spectrokits ¹ for ammonia and hydrogen sulfide which are based on APHA (1975) procedures 418B and 428C, respectively. Due to lack of time only half of the samples were analyzed for ammonia and a third for hydrogen sulfide. A visual discharge estimate was made for all springs where the complete discharge could be observed. Discharge estimates were not attempted for any creek samples.

LABORATORY ANALYSES

Water Analyses

Silica was analyzed at 640 nm by a modification of the molybdenum blue spectrophotometric procedure described by Shapiro and Brannock (1956) using 10 mL of spring water sample diluted in the field to approximately 60 mL and then brought to 100 mL total volume immediately prior to the determination.

Boron was determined spectrophotometrically by the carmin procedure at 600 nm (Brown and others, 1970).

Bicarbonate was determined as alkalinity using a constant drive buret, a combination pH glass electrode, an Orion 801 specific ion meter, a strip chart recorder, and standardized sulfuric acid (0.05N). The laboratory pH was taken as the start of the alkalinity titration.

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Sulfate was determined by a spectrophotometric titration using the thorin procedure (Brown and others, 1970) at 520 nm.

Chloride was determined by potentiometric titration using the same equipment as the alkalinity determination except that a silver billet electrode, a double junction reference electrode, and standardized silver nitrate (.015N) replaced the electrode and acid used for the alkalinity determination above.

Fluoride was determined by an Orion ion specific electrode; TISAB II was mixed 1:1 with samples and standards.

Bromide was determined spectrophotometrically at 590 nm by a modification of the phenol red method (APHA, 1975): the oxidizer concentration was increased 2x and the developing time was reduced to approximately two minutes.

Sodium and lithium were determined by flame emission spectroscopy (FES) in a fuel rich, air-acetylene flame with added potassium ion (0.1 percent v/v) at 589.0 nm and 670.8 nm respectively.

Potassium was determined also by FES in a fuel rich, air-acetylene flame with added cesium ion (0.1 percent v/v) at 766.5 nm.

Rubidium and cesium were determined by FES simultaneously in a fuel rich, air-acetylene flame with added potassium ion (0.1 percent v/v) at 780.0 and 852.1 nm, respectively.

Calcium and magnesium were determined simultaneously by atomic absorption spectroscopy (AAS) in a stoichiometric air-acetylene flame with added La(III) (1.0 percent v/v) at 422.7 and 285.2 nm, respectively.

Barium and strontium were determined simultaneously by AAS in a nitrous oxide-acetylene flame with added potassium ion (.1 percent v/v) at 553.5 and 460.7 nm, respectively.

Iron and manganese were determined simultaneously by AAS in an oxidizing, background corrected, air-acetylene flame at 248.3 and 279.5 nm, respectively.

Gas Analyses

Argon, methane, nitrogen, and oxygen were determined by gas chromatography with helium as the carrier gas at an inlet pressure of 414 kPa (60 psi) using a 2 meter Porapak Q and a 7 meter molecular sieve 5A column.

Helium and Hydrogen were determined by gas chromatography with argon as the carrier gas at an inlet pressure of 345 kPa (50 psi) using a 2 meter Porapak Q and a 7 meter molecular sieve column.

Ammonia was determined with an ammonia specific electrode on an aliquot from the sodium hydroxide solution.

Hydrogen sulfide was determined gravimetrically by oxidizing an aliquot of the sodium hydroxide solution with H_2O_2 to form SO_4^{2-} and precipitating the dissolved SO_4^{2-} with Ba^{2+} . The resulting precipitate was collected, dried, and weighed. All sulfur gases are, therefore, reported as hydrogen sulfide.

Carbon dioxide dissolved in the sodium hydroxide solution in the gas collecting bottle was determined gravimetrically by adjusting the pH of the solution to 9 with HCl and then precipitating the dissolved CO_3^{2-} with Sr^{2+} . The SrCO_3 precipitate was carefully filtered, dried, and weighed.

The results of the water analyses are presented in table 1, and the results of the gas analyses in table 2.

RESULTS and DISCUSSION

The thermal waters from the Southern, Central, and Silver Scarf Thermal Areas (Fig.1) are neutral sodium bicarbonate-chloride type water. Thermal waters collected from the Northern Thermal Area are from slightly acidic, relatively iron-rich springs (see sample nos. J7941 and J7942). Results of chemical geothermometry (Table 1) indicate that spring waters from the Southern, Central, and Silver Scarf Thermal Areas last equilibrated with rock at a temperature between 150 to 170°C. In the Northern Thermal Areas, only sample J7943 may be representative of a deep water component. The other thermal water samples (J7937, J7938, J7941, and J7942) all contain very low dissolved chloride concentrations when compared to typical Yellowstone thermal waters. The Boundary Creek Thermal Area waters are not at all similar to the deep Yellowstone thermal waters described by Fournier, White and Truesdell (1976) which equilibrated with rock at an estimated reservoir temperature of 200 to 340°C. Thompson and Hutchinson (1980) compared Boundary Creek thermal waters to Upper Geyser Basin hot spring waters (Hillside Springs, Ear Spring, and Bonita Pool), and proposed that the Boundary Creek and

Hillside Springs thermal waters may have a common origin. Hutchinson (1980) described the principle locations of the thermal activity in the southwestern corner of Yellowstone National Park and inferred that thermal water emerging along and near Boundary Creek is flowing along the Buffalo Lake Rhyolite and the Summit Lake Rhyolite contact. If so there might be a means of water flow from one side of the plateau to the other. The relatively high bicarbonate and low chloride concentrations from Boundary Creek thermal area waters indicate that these waters have not been extensively boiled (boiling would exsolve much of the bicarbonate) and that the deep component of the water has been diluted, probably by cold meteoric water.

The predominant gas in all the Yellowstone thermal spring, including those from the Boundary Creek thermal area, is CO_2 with varying amounts of dissolved air components. However, in the Boundary Creek thermal springs area there appears to be more helium and a lower nitrogen/argon ratio than in gases from springs in Upper and Lower Geyser Basins. This may be indicative of a radiogenic contribution and/or changes in relative solubilities with temperature and pressure and/or reduction of nitrogen.

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REFERENCES

- Allen, E.T., and Day, A.L., 1935, Hot Springs of the Yellowstone National Park: Carnegie Institution of Washington, Publication 466, p. 525.
- American Public Health Association, 1975, Standard method examination of water and waste water; 14th Ed.: Washington, D.C., p. 412-415 and 503-505.
- Brown, Eugene, Skougstad, M. W., and Fishman, M. D., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geol. Survey Techniques of Water Resources Inv., Chap A1, 160 p.
- Gooch, F.A., and Whitfield, J.E., 1888, Analyses of water of the Yellowstone National Park; U.S. Geological Survey Bulletin 47, p. 84
- Fournier, R. O., White, D. E., and Truesdell, A. H., 1976, Convective heat flow in Yellowstone National Park: In Proceedings, Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 1975, v. 1, U.S. Gov. Printing Office, Washington D.C., p. 731-739.
- Hutchinson, R. A., 1980, Boundary Creek thermal areas of Yellowstone National Park I: Thermal activity and geologic setting; Geothermal Resources Council Transaction vol. 4, p. 129-132.
- Noguchi, Kimio, and Nix, Joe, 1973, Geochemical studies of some geysers in Yellowstone National Park: Japan Academy Proceedings, v. 39, p. 370-375.

- Rowe, J. J., Fournier, R. O., and Morey, G. W., 1973, Chemical analysis of thermal waters in Yellowstone National Park, Wyoming, 1960-1965: U.S. Geol. Survey Bull. 1303, 31 p.
- Scott, R.C., 1964, Records in postearthquake quality of groundwater; in Hebgen Lake, Montana, earthquake of August 17, 1959: U.S. Geological Survey Professional Paper 435, p. 179-184
- Stauffer, R. E., Jenne, E. A., and Ball, J. W., 1980, Chemical studies of selected trace elements in hot-spring drainages of Yellowstone National Park: U.S. Geol. Survey Prof. Paper 1044F, 20 p.
- Shapiro, Leonard and Brannock, W. W., 1956, Rapid analysis of silicate rocks: U.S. Geol. Survey Bull. 1036C, p. 19-56.
- Thompson, J. M., 1975, Selecting and collecting thermal springs for chemical analysis: A method for field personnel: U.S. Geol. Survey Open-File Report 75-68, 11 p.
- Thompson, J.M. Presser, T.S., Barnes, R.B., and Bird, D.B., 1975, Chemical analyses of the waters of Yellowstone National Park, Wyoming, 1966-1973: U.S. Geological Survey Open-File Report 75-25, p. 59.
- _____ and Hutchinson, R. A., 1980, Boundary Creek thermal areas of Yellowstone National Park: II Thermal water analyses: Geothermal Resource Council, Transactions vol. 4, p.189-192.
- _____ and Yadav, Sandhya, 1979, Chemical analyses of waters from geysers, hot springs, and pools in Yellowstone National Park, Wyoming from 1974 to 1978: U.S. Geol. Survey Open-File Report 79-704, 48 p.

Truesdell, A.H., 1976, Summary of Section III - Geochemical and Geophysical Techniques in Exploration in Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, May 20-29, 1975, San Francisco, CA.: U.S. Government-Printing Office, p. liii - lxxxi.

White, D.E., Brannock, W.W., and Murata, K.J., 1956, Silica in hot spring waters: *Geochimica et Cosmochimica Acta*, v. 10, p. 27-59

White, D.E., Hem, J.D., Waring, G.A., 1963, Chemical composition of subsurface water, Chapter F, in *Data of Geochemistry*, 6th ed.: U.S. Geological Survey Professional Paper 440-F, 67 p.

Table 1.--Boundary Creek Thermal Areas

(Analyses in mg/L)

Sample	Date	Name and/or Description	Lat.	Long.	L/min	Temp	f pH ¹	l pH ²	SiO ₂	Fe	Mn	Ca	Mg	Sr	Est. flow	
															L/min	Temp
outhern Boundary Creek Thermal Area																
7710 ³	26 JUL 77	SPG, E SIDE CREEK, BLW DUNANDA FALLS	44°14.81'	111°01.44'	30	46	--	7.18	96	<.02	<.01	5.0	.58	--		
7945 ⁴	9 OCT 79	SPG, E SIDE CREEK, BLW DUNANDA FALLS	44°14.81'	111°01.44'	40	48	5.6	6.78	105	<.05	<.02	4.7	.55	<.01		
7711	26 JUL 77	SPG, W SIDE CREEK, BLW DUNANDA FALLS	44°14.80'	111°01.53'	72	53	--	7.94	110	<.05	<.01	5.0	.55	--		
7946	9 OCT 79	SPG, W SIDE CREEK, BLW DUNANDA FALLS	44°14.80'	111°01.53'	48	52	5.7	6.99	117	<.05	<.02	4.8	.76	<.01		
entral Boundary Creek Thermal Area																
7915	6 OCT 79	CRK AREA, HOT DISC N END OF AREA	44°16.86'	111°02.31'	4	58.5	6.5	8.01	192	<.05	.08	6.3	.30	<.01		
7916	6 OCT 79	CRK AREA, AT BASE OF TALUS, AT WTR L	44°16.81'	111°02.22'	6	70	6.8	7.72	187	<.05	.04	6.4	.34	<.01		
7917	6 OCT 79	CRK AREA, JUST ABV SMALL CASCADE	44°16.72'	111°02.15'	14	73	7.0	7.64	142	<.05	.08	6.1	.40	<.01		
7918	6 OCT 79	MD AREA, SMALL SPG ON W SIDE OF 3 SP	44°16.74'	111°01.96'	12	69	6.5	7.44	169	<.05	.11	5.7	.44	<.01		
7919	6 OCT 79	MD AREA, LARGE FLOWING SPG ATOP GRAY	44°16.72'	111°01.89'	80	83	6.5	7.66	176	<.05	.10	5.8	.27	<.01		
7920	6 OCT 79	MD AREA, 2ND RUNOFF CHANNEL, E OF 19	44°16.70'	111°01.82'	10	37	7.0	7.73	162	<.05	<.02	3.8	.32	<.01		
7921	6 OCT 79	MD AREA, 3RD RUNOFF CHANNEL, E OF 20	44°16.64'	111°01.79'	25	63	6.5	8.08	161	<.05	.02	3.8	.27	<.01		
7720	18 NOV 77	MD AREA, EASTERN MOST SPG, NO. 168	44°46.59'	111°01.77'	--	83	--	8.65	207	--	--	2.0	.40	--		
7922	6 OCT 79	MD AREA, EASTERN MOST SPG	44°46.59'	111°01.77'	40	82	6.5	7.47	183	<.05	.07	3.6	.15	<.01		
orthern Boundary Creek Thermal																
7937	8 OCT 79	2ND THERMAL AREA, ONLY DISC. SPG	44°18.54'	111°02.76'	100	48	5.3	5.59	93	.05	.67	7.8	.95	--		
7938	8 OCT 79	SML CRK DRAINING MEADOW N OF 2ND AR	44°18.63'	111°02.75'	200	24	5.6	7.10	70	<.05	.05	5.5	.87	--		
7939	8 OCT 79	BOUNDARY CREEK, ABV UPPER THERMAL AR	44°18.75'	111°02.64'	--	19	5.4	6.40	54	<.05	.13	5.2	.51	--		
7940	8 OCT 79	COLD SPG AT BASE OF MADISON PLATEAU	44°18.78'	111°01.96'	500	14	5.5	6.40	36	<.05	.09	5.7	.58	--		
7941	8 OCT 79	N-MOST THERMAL SPG, FE DEPOSITS	44°18.73'	111°02.70'	80	62	4.9	6.26	119	.81	1.57	8.9	.79	.1		
7942	8 OCT 79	1ST THERMAL AREA, FE DEPOSITS	44°18.09'	111°02.55'	14	77	5.7	6.92	145	.40	.56	12.5	.53	.1		
7943	8 OCT 79	LARGE POOL, E SIDE BOUNDARY CREEK	44°18.19'	111°02.12'	--	63	5.9	7.16	127	<.05	.07	4.7	.22	.1		
ilver Scarf Thermal Area																
7804	9 OCT 78	N AREA, "FRICTION SPRING"	44°16.59'	111°00.97'	120	69	--	7.52	176	--	--	4.9	.26	<.05		
7924	6 OCT 79	N AREA, "FRICTION SPRING"	44°16.59'	111°00.97'	100	72	6.3	7.56	181	<.05	.03	4.5	.20	<.1		
7923	6 OCT 79	N AREA, SPG IN RUNOFF NEAREST TALUS	44°16.58'	111°00.90'	10	41	6.2	7.47	98	<.05	.02	4.5	.56	<.1		
7925	7 OCT 79	MAIN, N END W SIDE, GASEOUS SPG	44°16.53'	111°01.11'	12	87	7.0	7.84	225	<.05	.11	3.2	.06	<.1		
7926	7 OCT 79	MAIN, SMALL SPOUTER, W OF PREV. SAMP	44°16.48'	111°01.05'	10	91	--	8.28	208	<.05	.26	3.6	.09	<.1		
7708	9 OCT 78	MAIN, SMALL SPG DRAINING NE	44°16.46'	111°01.18'	12	90	--	7.77	210	--	--	4.0	.20	<.05		
7927	7 OCT 79	MAIN, SMALL SPG DRAINING NE	44°16.46'	111°01.18'	8	85	6.8	7.86	202	<.05	.31	3.2	.13	<.1		
7928	7 OCT 79	MAIN, N SECT., UPPER SLOPES, 30 CM D	44°16.42'	111°01.20'	3	93	6.8	7.75	217	<.05	.12	3.9	.09	<.1		
7929	7 OCT 79	MAIN, N SECT., BLW BREAK IN SLOPE	44°16.38'	111°01.23'	10	89.5	6.9	7.78	209	<.05	.15	4.1	.10	<.1		
7930	7 OCT 79	MAIN, S SECT., UPPER SLOPE, 1M DEEP	44°16.35'	111°01.33'	10	92	6.9	7.94	210	<.05	.15	4.1	.10	<.1		
7931	7 OCT 79	MAIN, S SECT., LOWER SLOPE, SMALL SP	44°16.37'	111°01.32'	12	81	6.8	7.74	198	<.05	.13	3.7	.11	<.1		
7932	7 OCT 79	MAIN, S SECT., JUST N OF MANY SML RK	44°16.37'	111°01.36'	8	83.5	6.7	7.60	198	<.05	.09	3.4	.08	<.1		
78	19 OCT 78	S AREA, S PORTION	44°16.37'	111°01.36'	24	93	--	8.60	211	--	--	3.46	.13	--		
7934	7 OCT 79	S AREA, S PORTION, BLW MARSH TO S	44°16.15'	111°01.58'	12	91	6.8	7.93	208	<.05	.08	3.7	.13	<.1		
7935	7 OCT 79	S AREA, N PORTION, TRIANGULAR SHAPED	44°16.20'	111°01.48'	12	89	6.8	7.72	234	<.05	.11	4.0	.12	<.1		
7936	7 OCT 79	S AREA, TOP, SMALL, OVAL SHAPE, 25CM	44°16.21'	111°01.50'	4	83	6.8	7.48	212	<.05	.11	4.1	.11	<.1		
7944	9 OCT 79	BRINK OF SILVER SCARF FALLS	44°14.84'	111°01.20'	--	22.5	7.4	8.18	174	.04	.05	4.5	.30	--		
7933	7 OCT 79	COLD SPRING BETWEEN MAIN & S SECT.	44°16.08'	111°01.23'	8	14	5.4	6.40	42	<.05	.05	2.7	.35	--		

Field determined pH.

Laboratory determined pH.

³ H preceding sample number indicates RAH collected sample.⁴ J preceding sample number indicates JMT collected sample.

Table 1.--Boundary Creek Thermal Areas (cont.)

(Analyses in mg/L)

Chemical Geothermometry

Sample	Ba	Na	K	Li	Rb	Cs	NH ₄	HCO ₃	SO ₄	Cl	F	Br	B	H ₂ S	Zn	Qtz ⁷	Qtz ⁸	Chal ⁹	NA-K-Ca ¹⁰
Southern Boundary Creek Thermal Area																			
H7710	--	75	3.1	.31	.03	<.01	--	137	3	30	7.2	--	.6	--	--	132	135	107	135
J7945	<.1	62	4.4	.34	.02	.09	--	120	4	36	8.2	--	.6	--	--	136	140	112	158
H7711	--	95	3.6	.42	.4	<.01	--	165	3	38	9.4	--	.8	--	--	138	143	115	135
J7946	<.1	75	5.3	.42	.02	.10	--	140	4	38	10.6	.09	.8	--	--	141	146	119	161
Central Boundary Creek Thermal Area																			
Z7915	<.1	156	8.6	1.3	.05	.13	.6	267	14	83	14.6	--	1.5	--	.02	167	177	155	185
J7916	<.1	147	8.0	1.3	.04	.17	--	249	16	80	13.8	.18	1.4	--	.02	165	175	153	156
J7917	<.1	148	7.8	1.5	.04	.14	.4	252	15	79	15.2	.15	1.4	--	.01	150	158	132	155
J7918	<.1	147	6.9	1.7	.04	.14	--	261	16	74	15.4	.16	1.4	--	.03	160	169	145	150
J7919	<.1	159	6.8	1.3	.04	.14	<.1	254	16	79	16	.25	1.4	.02	.02	162	171	148	147
J7920	<.1	142	6.3	1.4	.03	.11	--	224	14	85	16	.37	1.4	--	<.01	158	166	142	150
J7921	<.1	154	5.9	1.6	.03	.12	.2	227	14	81	18	.32	1.4	--	.03	157	165	141	145
H7720	--	162	5.5	1.2	.05	.05	--	235	21	94	18	--	1.8	--	--	171	182	161	145
J7922	<.1	163	7.9	1.3	.04	.17	.34	246	13	89	19.2	.25	1.5	.05	<.01	164	174	151	157
Northern Boundary Creek Thermal Area																			
J7937	--	17	7.2	.13	.02	--	--	75	8	5	5.7	--	<.1	.19	<.01	130	133	105	231
J7938	--	10	4.7	.08	.01	--	--	50	6	7	5.4	--	.1	--	.01	118	118	88	230
J7939	--	8	2.5	.06	<.01	--	--	43	3	5	4.1	--	<.1	--	--	6/	6/	6/	6/
J7940	--	1.7	1.1	.01	<.01	--	--	22	2	5	3.1	--	<.1	--	--	6/	6/	6/	6/
J7941	.1	25	9.2	.35	.03	.03	.44	98	7	7	7.3	.14	<.1	.025	.02	142	147	120	228
J7942	.1	43	14.1	.3	.06	.28	.57	123	27	18	8.5	.16	.3	.035	.01	152	159	134	229
J7943	.1	99	6.4	.69	.03	.17	.57	144	5	79	14.3	.01	1.4	.04	.01	145	151	125	161
Silver Scarf Thermal Area																			
H7804	--	164	6.6	1.0	.06	.05	--	244	11	95	16.3	--	2.0	--	--	162	171	148	146
J7924	<.1	158	10.1	1.1	.05	.18	--	232	8	98	16.8	.33	1.6	--	.01	164	173	150	169
J7923	<.1	73	5.8	.65	.02	.07	.2	141	4	48	10.6	--	1.3	--	.01	133	136	108	167
J7925	<.1	182	11	1.26	.05	.15	--	266	10	116	19.5	.66	1.7	--	--	175	188	168	171
J7926	<.1	182	11.2	1.3	.05	.17	.5	254	10	119	19.5	.18	1.7	.02	--	171	182	161	171
H7708	--	179	7.0	1.4	.06	.05	--	300	9	99	22	--	2.5	--	--	172	183	162	148
J7927	<.1	168	10.9	1.5	.05	.15	--	228	7	95	22	.42	1.6	--	--	170	180	159	173
J7928	<.1	180	11.6	1.2	.05	.21	.44	271	11	109	19.8	.19	1.9	.02	--	174	185	165	173
J7929	<.1	175	11.4	1.2	.05	.07	--	287	9	111	19.2	.18	1.9	--	.01	172	183	162	172
J7930	<.1	181	11.2	1.2	.05	.21	.57	259	10	107	19.1	.24	1.9	.025	.01	169	180	158	170
J7931	<.1	174	11.2	1.3	.05	.15	--	266	9	106	19	.26	1.9	--	.01	169	179	157	172
J7932	<.1	147	10.8	1.4	.05	.14	.57	299	11	106	19.9	--	1.6	--	--	169	179	157	177
H78	--	176	6.8	.4	.05	.02	--	259	13	110	19.6	--	1.6	--	--	172	183	162	148
J7934	<.1	171	9.5	.35	.04	.15	.44	247	12	97	20.5	--	1.5	.04	--	171	182	161	179
J7935	<.1	173	9.8	1.3	.04	.26	--	224	10	98	20.3	.15	1.6	--	--	178	191	170	165
J7936	<.1	174	10.6	1.3	.04	.15	.4	208	13	97	19	--	1.6	--	--	172	184	163	169
J7944	--	141	8.3	1.2	.04	--	--	212	9	82	17.7	.15	1.5	--	.01	162	170	147	163
J7933	--	9	2.0	.08	<.01	.03	--	30	1	12	3.3	--	<.1	--	--	100	94	56	189

5/ Equations from Truesdell (1976).
 6/ Do not meet criteria for chemical geothermometry
 7/ Adiabatic SiO₂ Temperature
 8/ Conductive SiO₂ Temperature
 9/ Chalcedony SiO₂ Temperature
 10/ g/107 g/107

Table 2.--Boundary Creek Thermal Area Gases
(analyses in mole percent).

Samp No.	CO ₂	H ₂ S	NH ₃	He	H ₂	Ar	O ₂	N ₂	CH ₄
J7925	42.9	0	0	.0597	0.0	0.0	8.12	44.2	0.63
J7928	92.0	0	0	.0012	.0023	.21	.60	6.0	.37
J7934	48.4	0	0	.0056	0	*	5.2	40.7	.75
J7942	84.4	0	0	.0043	0	.41	.20	12.7	1.1

* Reported as O₂ + Ar

Gas analyses by N.L. Nehring, U.S.G.S.

GENERALIZED LOCATION MAP OF THE SOUTHWEST CORNER OF YELLOWSTONE NATIONAL PARK AND THE ISLAND PARK GEOTHERMAL AREA, MONTANA

