Chemical Analysis of Thermal Waters in Yellowstone National Park, Wyoming, 1960-65

By J. J. ROWE, R. O. FOURNIER, *and* G. W. MOREY

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Results for samples collected from 89 geysers, pools, and hot springs are compiled together with previous analyses

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CHEMICAL ANALYSIS OF THERMAL WATERS IN YELLOWSTONE NATIONAL PARK, WYOMING, 1960-65

By J. J. Rowe, R. O. Fournier, and G. W. Morey [1]

ABSTRACT

Analytical results for 166 samples collected during 1960–65 from 89 geysers, pools, and hot springs are compiled together with previous analyses to provide a comprehensive collection of available analytical data on the thermal waters of Yellowstone National Park, Wyo. These data permit further study of the variation of composition with time or geologic occurrences. Data are presented for pH, temperature, silica, aluminum, iron, calcium, magnesium, sodium, potassium, lithium, ammonia, bicarbonate, carbonate, sulfate, chloride, fluoride, boron, arsenic, and the semiquantitative spectrographic analysis of residues from evaporation of some of the waters.

The chemical characteristics of waters from various localities in Yellowstone are graphically compared and discussed.

INTRODUCTION

Extensive chemical analyses of waters from hot springs and geysers in Yellowstone National Park have been reported by Gooch and Whitfield (1888) and by Allen and Day (1935). Scott (1964) analyzed ten thermal waters from Yellowstone to determine possible effects of the nearby Hebgen Lake, Montana, earthquake of August 17, 1959, upon the hydrothermal system. White, Hem, and Waring (1963) reported six new chemical analyses and Noguchi and Nix (1963) published partial chemical analyses of waters from five geysers. Field measurements of silica dissolved in the hot-springs waters were reported by White, Brannock, and Murata (1956) and by Morey, Fournier, Hemley, and Rowe (1961). The new results reported here and the compilation of previous analyses are part of an effort by the U.S. Geological Survey to reevaluate the geology and geochemistry of Yellowstone.

We are indebted to many colleagues in the Survey who have contributed to this study, especially to D. E. White for his advice

[1] Deceased.

and assistance and to A. H. Truesdell, J. J. Hemley, and J. L. Ramisch for their participation in various aspects of the collection and analytical determinations carried out in the field. We are particularly grateful to J. C. Hamilton who performed the spectrographic analysis of residues and to the U.S. National Park Service for their cooperation and assistance.

SAMPLE COLLECTION

The samples were collected in narrow-mouthed bottles, held in a flexible metal loop at the end of a 20-foot-long jointed rod made of aluminum tubing. By inserting the bottle in the pool upside down and righting it at the desired sample location, collections could be made anywhere in reach of the rod. Most of the samples were collected in polyethylene bottles, but samples for the determination of HCO_3^- and CO_3^{-2} were collected in glass bottles. Collections were made from the hottest regions of the pools and as near the vents as possible. Temperature measurements were made either by a portable potentiometer and a copper-constantan thermocouple passing through the aluminum tube and lowered into the hot spring with the aid of a lead weight, or by a maximum thermometer suspended from the end of the rod.

ANALYTICAL METHODS

Silica was determined by a modification of the molybdenum blue method described by Shapiro and Brannock (1956). Ionic silica was determined on the samples in the field without treatment except for filtration of samples containing suspended matter. For the determination of total silica, samples were evaporated with NaOH and fused to convert the polymerized forms to ionic species before the analysis was performed. Field determinations for silica were carried out as reported by Morey, Fournier, Hemley, and Rowe (1961).

Aluminum was determined spectrophotometrically by measuring the absorbance of the calcium–aluminum–alizarin red-S complex, according to a modification of the method reported by Shapiro and Brannock (1956, 1962). For samples high in fluorine a preliminary evaporation of an acidified solution in Vycor dishes was made to volatilize the fluorine.

Iron was determined by orthophenanthroline using a modification of the method described by Shapiro and Brannock (1956).

Sodium and potassium were determined flame photometrically. Dilution methods were used for the sodium to overcome any possible potassium interference. Standards were prepared containing sodium and potassium concentrations similar to those found in the waters. The emission was measured at 489 nm for sodium and at 766 nm for potassium.

Lithium was determined flame photometrically, measuring the emission at 671 nm. The method of addition was used to check the accuracy of the method and to overcome matrix effects.

Calcium was determined flame photometrically by the releasing-addition method described by Rowe (1963). For samples high in calcium, analyses were done by the EDTA (ethylenediaminetetra-acetic acid) titration of Shapiro and Brannock (1956).

Magnesium was determined spectrophotometrically by the Erio-chrome Black T method using a modification of the methods of Harvey, Komarmy, and Wyatt (1953) and Rainwater and Thatcher (1960).

Carbonate and bicarbonate were determined by titration with standardized sulfuric acid as described by Rainwater and Thatcher (1960).

Sulfate was determined by the barium chromate method of Iwasaki, Utsumi, Hagino, Taratani, and Ozawa (1958) after separation of the sulfate on an activiated alumina column as described by Fritz, Yamamura, and Richard (1957).

Chloride was determined by a potentiometric titration, modified from Kolthoff and Kuroda (1951) using a charting method and constant rate of delivery of $AgNO_3$ standard solution.

Fluoride was determined after distillation by the spectrophoto-metric thoron–thorium nitrate method of Grimaldi, Ingram, and Cuttitta (1955). It was also determined directly by this method without distillation for samples containing very small amounts of aluminum. Fluoride results for some samples were confirmed by the cerium[3]–alizarin complexan method of Belcher and West (1961); aluminum was extracted when present, by 8-hydroxy-quinoline and chloroform.

Boron was determined spectrophotometrically with dianthri-mide using the method described by Rowe (1962).

Field pH measurements were made with a portable pH meter using a high-temperature glass electrode, range 0 to 14, and a silver–silver chloride reference electrode. The electrodes were standardized in buffer solutions brought to the temperature of the pool.

Spectrographic analysis was made on the residues from evaporation of about 500 milliliters of each water sample. The evaporation factor was derived from the weight of residue and volume of the sample so that the analysis value, in percent, multiplied by the factor gives parts per million in the original water sample.

RESULTS

Our analyses are given in table 1 along with previous analyses of waters from the same springs or geysers. The locations of unnamed springs are described in table 2. Analyzed springs at Norris Geyser Basin also are located in figure 1. Semiquantitative spectrographic analyses of the evaporated residues of some of the waters listed in table 1 are given in table 3. A comparison of the chemical characteristics of hot-spring waters found in various parts of the park is given in figure 2.

The springs at Mammoth issue from Mesozoic shales and sandstones. Limestone is present deep in the stratigraphic section. The springs at Norris Geyser Basin and those listed in table 1 between Norris Geyser Basin and Lower Geyser Basin issue from Cenozoic rhyolitic ash-flow tuff. All the other springs listed in table 1 are within a large caldera and issue from Pleistocene rhyolite or glacial sediments derived mainly from rhyolite.

The hot springs of Mammoth are noted for the abundant deposition of travertine. These waters are particularly rich in bicarbonate, sulfate, calcium, and magnesium. The chloride content is relatively low and sodium is present in excess of chloride. The silica content is very low and the potassium content, relative to sodium, is very high. The composition of the hot-spring water probably reflects reaction with carbonate sediments at depth.

At Norris Geyser Basin, two end-member types of chloride-rich hot-spring waters can be distinguished by their potassium-lithium and potassium-sodium ratios. Both ratios generally are lower in waters from the western part of the basin than in waters of the eastern part (fig. 2). In other respects, the chloride-rich waters at Norris Geyser Basin are very similar: They have the highest silica and chloride contents and the lowest bicarbonate contents of any waters in Yellowstone. The very low bicarbonate content leaves the pH of the water essentially unbuffered so that mixing with a very small amount of acid sulfate water may lower the pH to 3 or 4, giving rise to an acid chloride water such as from Little Whirligig Geyser (loc. YF37). Silica deposits readily from the neutral waters. However, dissolved silica polymerizes very slowly in the acid chloride water and little silica deposition occurs.

Acid sulfate waters are found throughout Yellowstone, particularly at higher elevations and at the Mud Volcano area. According to White, Sandberg, and Brannock (1953), acid sulfate waters may form where steam, rich in acid-forming gases, intersects near-surface groundwater. Oxidation of H_2S to H_2SO_4 commonly lowers the pH to about 2 and subsequent reaction of this water

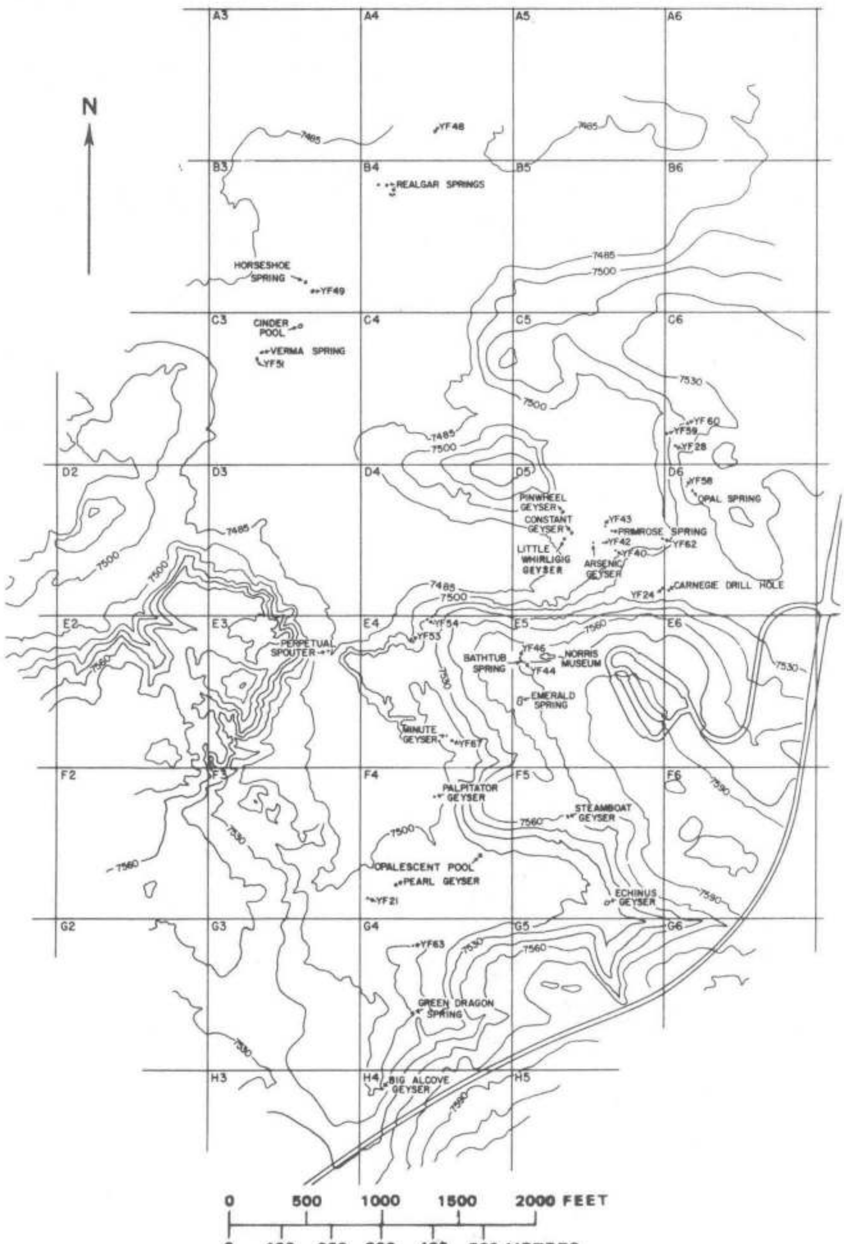

FIGURE 1.—Norris Geyser Basin showing locations of hot springs and geysers. Base from U.S. Geological Survey, 1973 (in compilation). Grid areas keyed to table 2. Unnamed springs identified by the locality numbers applied during the study.

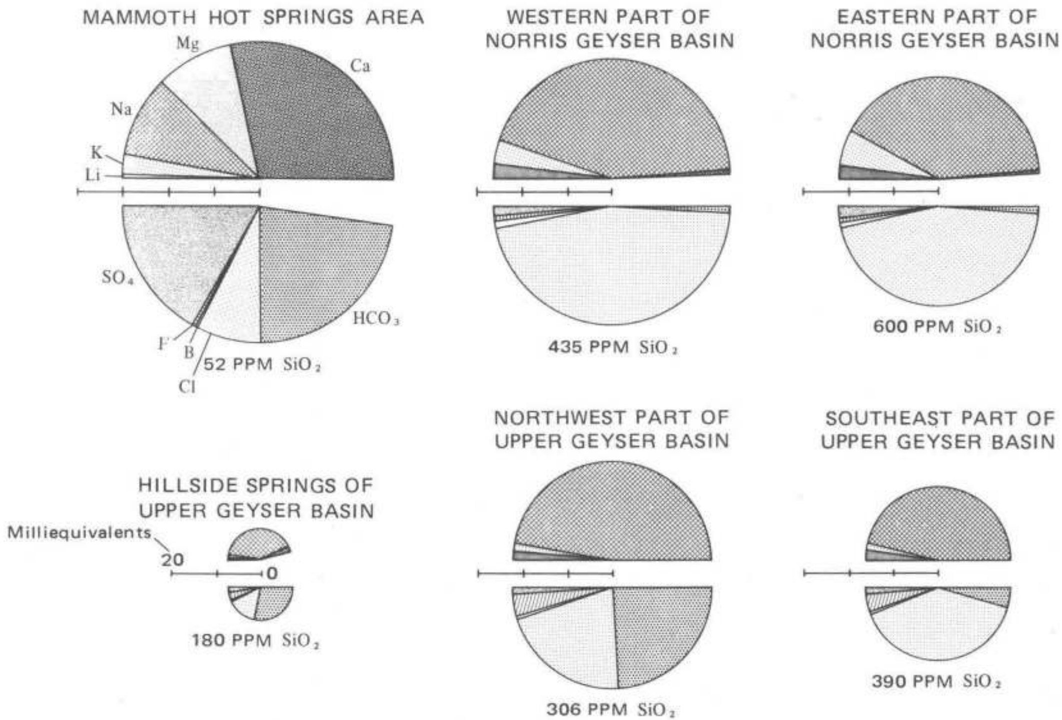
MAMMOTH HOT SPRINGS AREA
Mg
Ca
Na
K
Li
SO4
HCO3
F
B
52 PPM SiO2
Cl
WESTERN PART OF NORRIS GEYSER BASIN
435 PPM SiO2
EASTERN PART OF NORRIS GEYSER BASIN
600 PPM SiO2
HILLSIDE SPRINGS OF UPPER GEYSER BASIN
Milliequivalents
20
0
180 PPM SiO2
NORTHWEST PART OF UPPER GEYSER BASIN
306 PPM SiO2
SOUTHEAST PART OF UPPER GEYSER BASIN
390 PPM SiO2

FIGURE 2.—Comparison of water compositions typical of various localities in Yellowstone National Park. Each circle is divided according to the relative milliequivalent concentrations of the major dissolved constituents in the water; cations in the upper hemisphere; anions in the lower hemisphere. The radius of each circle is proportional to the square root of the sum of either cation milliequivalents or anion milliequivalents, whichever is greater, so that the area of the circle is proportional to the total number of equivalents present. The circumference is marked off in arc lengths proportional to the number of equivalents of each species as indicated and the area of each sector is proportional to the number of equivalents of the particular species. A missing sector indicates the charge unbalance in the summation of analyzed cations as compared to anions.

with the enclosing rock yields water of a composition such as at Norris (loc. YF58) and at the Mud Volcano area (loc. YF13). The concentrations of sodium and potassium are low in this type of water, but the potassium-sodium ratio is very high. These waters are relatively rich in aluminum and iron and poor in chloride.

Compared with the chloride-rich alkaline waters of the Norris Geyser Basin, neutral to alkaline hot-spring waters within the confines of the caldera contain comparatively low concentrations of chloride, potassium, silica, and boron and high concentrations of fluoride, bicarbonate, and carbonate. In terms of atomic proportion, dissolved lithium commonly exceeds potassium. Also, spectrographic data for evaporated residues show that the waters from within the caldera are relatively rich in tungsten, containing 0.2 to 0.3 ppm (parts per million). No tungsten was detected in the waters from Norris Geyser Basin. High values of pH and carbonate have little significance; they are due to the escape of carbon dioxide from convecting surficial pools of hot-spring water. The deep-seated waters are near neutral in pH. For instance, Daisy Geyser and Bonita Pool in Upper Geyser Basin have been shown by exchange function (Marler, 1951) and tracer studies (Rowe and others, 1965) to be connected at depth. Daisy Geyser (loc. YF5) does not have a big surficial pool and water was collected during the preliminary overflow just before eruption. There was little opportunity for escape of CO_2 from the water before analysis; the pH was 7.6. On the other hand, Bonita Pool (loc. YF70) has a large surficial pool, and in-pool pH measurement gave a value of 8.55. Also, the sum of equivalents of bicarbonate plus carbonate in water from Bonita Pool equals the equivalents of bicarbonate in water from Daisy Geyser.

In Upper Geyser Basin, two end-member types of neutral to alkaline hot-spring waters may be distinguished by their $Cl:(HCO_3+CO_3)$. In terms of equivalents, this ratio is greater than 3 for waters from the southeast part of Upper Geyser Basin and is about 1 for waters from the northwest part of Upper Geyser Basin. In addition, waters from the southeast part have slightly higher Li:K, Li:Na, and K:Na as compared to waters in the northwest part. Both types of water deposit silica.

Black Warrior Lake (loc. YF30) is typical of moderately dilute hot-spring waters that tend to occur at the margins of the Upper and Lower Geyser Basins. These waters are relatively rich in calcium and magnesium and have low $Cl:HCO_3$. They deposit small to moderate amounts of travertine and manganese oxides and very little silica.

Additional work is underway to define the distribution of types of hot-spring water within Yellowstone National Park, and to determine their genesis.

REFERENCES CITED

Allen, E. T., and Day, A. L., 1935, Hot springs of the Yellowstone National Park: Carnegie Inst. Washington Pub. 466, 525 p.

Belcher, R., and West, T. S., 1961, A study of the cerium[3]–alizarin complexan–fluoride reaction: Talanta, v. 8, p. 851–862.

Fritz, J. S., Yamamura, S. S., and Richard, M. J., 1957, Titration of sulfate following separation with alumina: Anal. Chemistry, v. 29, p. 158–161.

Gooch, F. A., and Whitfield, J. E., 1888, Analyses of waters of the Yellowstone National Park, with an account of the methods of analysis employed: U.S. Geol. Survey Bull. 47, 84 p.

Grimaldi, F. S., Ingram, Blanche, and Cuttitta, Frank, 1955, Determination of small and large amounts of fluorine in rocks: Anal. Chemistry, v. 27, p. 918–921.

Harvey, A. E., Komarmy, J. M., and Wyatt, G. M., 1953, Colorimetric determination of magnesium with Eriochrome Black T: Anal. Chemistry, v. 25, p. 498–500.

Iwasaki, Iwajii, Utsumi, Satori, Hagino, Ken, Taratani, Toshikazu, and Ozawa, Takeijiro, 1958, Spectrophotometric determination of a small amount of sulfate ion: Japan Chem. Soc. Jour., pure chemistry sec., v. 79, p. 38–44.

Kolthoff, I. M., and Kuroda, P. K., 1951, Determination of traces of chloride: Anal. Chemistry, v. 23, p. 1304–1306.

Marler, G. D., 1951, Exchange of function as a cause of geyser irregularity: Am. Jour. Sci., v. 249, p. 329–342.

Morey, G. W., Fournier, R. O., Hemley, J. J., and Rowe, J. J., 1961, Field measurements of silica in water from hot springs and geysers in Yellowstone National Park, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–C, p. C333–336.

Noguchi, Kimio, and Nix, Joe, 1963, Geochemical studies of some geysers in Yellowstone National Park: Japan Acad. Proc., v. 39, p. 370–375.

Rainwater, F. H., and Thatcher, L. L., 1960, Methods for collection and analysis of water samples: U.S. Geol. Survey Water-Supply Paper 1454, 301 p.

Rowe, J. J., 1962, Determination of boron in waters containing fluoride, *in* Short papers in geology, hydrology, and topography: U.S. Geol. Survey Prof. Paper 450–B, p. B114–B116.

——— 1963, Releasing-addition method for the flame-photometric determination of calcium in thermal waters: Geochim. et Cosmochim. Acta, v. 27, p. 915–923.

Rowe, J. J., Fournier, R. O., and Morey, G. W., 1965, Use of sodium iodide to trace underground water circulation in the hot springs and geysers of the Daisy geyser group, Yellowstone National Park, *in* Geological Survey research 1965: U.S. Geol. Survey Prof. Paper 525–B, p. B184–B186.

Scott, R. C., 1964, Records of postearthquake chemical quality of ground water, *in* The Hebgen Lake, Montana, earthquake of August 17, 1959: U.S. Geol. Survey Prof. Paper 435, p. 179–184.

Shapiro, Leonard, and Brannock, W. W., 1956, Rapid analysis of silicate rocks: U.S. Geol. Survey Bull. 1036–C, p. 19–56.

——— 1962, Rapid analysis of silicate, carbonate, and phosphate rocks: U.S. Geol. Survey Bull. 1144–A, 56 p.

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

White, D. E., Hem, J. D., and Waring, G. A., 1963, Chemical composition of subsurface waters, Chap. F *in* Data of geochemistry, 6th edition: U.S. Geol. Survey Prof. Paper 440–F, 67 p.

White, D. E., Sandberg, C. H., and Brannock, W. W., 1953, Geochemical and geophysical approaches to the problems of utilization of hot-spring water and heat: Pacific Sci. Cong., 7th, New Zealand, 1949, Proc., v. 2, p. 490–499.

TABLES 1 - 3

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*

[See table 2 for location of unnamed hot springs and geysers. Locality numbers were applied during this study. Tr., trace; Alk., alkaline]

Locality	References	Date of Collection	Temperature (°C)	pH		SiO_2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Mammoth Hot Springs area										
Blue Spring, main terrace	White and others, 1956	Aug. 1954	70.5	----	6.88	---	56	----	----	209
Cupid Spring (YF132)	This study	Oct. 1962	73	----	----	51	52	0.2	<0.1	310
East Jupiter Terrace (YF17)	D. E. White, unpub. data	Sept. 1960	75	----	----	---	---	----	----	-----
Do	This study [1]	----do	72	6.25	6.70	52	52	<.1	<.1	339
Jupiter Spring, main terrace	Allen and Day, 1935	ca. 1930	----	----	----	---	46	Tr.	0	338
Mammoth Spring, main terrace, near west edge.	White and others, 1963	Sept. 1957	72	----	6.6	---	60	.2	.06	272
Opal Spring (YF18)	D. E. White, unpub. data	Oct. 1947	72	----	6.48	---	---	----	----	-----
Do	----do	Sept. 1960	69	----	6.45	---	50	----	----	-----
Do	This study [1]	----do	69	----	6.45	51	51	<.1	<.1	315
Spring near Opal Spring (YF26)	This study	----do	----	----	----	53	55	<.1	<.1	-----
Norris Geyser Basin										
Bathtub Spring (YF45)	Allen and Day, 1935	1928	----	----	----	---	503	----	Tr.	6
Do	----do	ca. 1930	----	----	----	---	327	48	[2]37	11
Do	This study	Sept. 1961	91	----	4.40	400	426	1.5	.2	1.8
Do	----do	May 1965	92	4.45	4.18	452	456	----	----	-----
Big Alcove Geyser (YF57)	----do	Sept. 1961	87.5	----	6.3	222	227	0.41	.1	2.4
Cinder Pool (YF 25)	D. E. White, unpub. data	Sept. 1947	90.5	----	4.17	---	---	----	----	-----
Do	----do	Sept. 1957	92	----	4.2	---	270	----	----	8.4
Do	----do	Sept. 1960	86	----	3.83	---	---	----	----	-----
Do	This study [1]	----do	86	3.9	3.8	316	348	1.6	.1	6.4
Do	This study	Sept. 1961	84	----	4.05	317	321	1.8	.1	7.0
Constant Geyser (YF38)	Gooch and Whitfield, 1888.	Sept. 1885	92	----	Acid	---	468	4.8	Tr.	14.6
Do	This study	Sept. 1961	77	----	3.0	458	460	1.9	1.1	3.15
Echinus Geyser (YF23)	Gooch and Whitfield, 1888.	Aug. 1884	91	----	Acid	---	253	2.7	0	11.5
Do	D. E. White, unpub. data	Sept. 1947	----	----	3.35	---	---	----	----	-----
Do	Scott, 1964	Sept. 1959	82	----	3.5	---	250	1.6	2.3	5.6
Do	D. E. White, unpub. data	Sept. 1960	82	----	3.49	---	---	----	----	-----
Do	This study [1]	----do	87	3.55	3.40	280	287	2.2	1.8	1.6
Do	This study	Sept. 1961	87	----	3.60	273	279	2.5	2.6	4.2
Do	----do	Sept. 1962	83	----	3.4	294	294	2.3	1.2	4.3
Do	----do	May 1965	86	3.50	3.42	---	273	----	----	-----
Emerald Spring (YF47)	----do	Sept. 1961	87.5	----	4.3	552	558	0.8	.2	3.1
Do	----do	Sept. 1962	86	----	3.93	---	570	0.6	----	3.1
Do	----do	May 1965	86	4.60	4.40	---	596	----	----	-----

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Mammoth Hot Springs area—Continued												
Blue Spring, main terrace	78	129	56	1.4	----	526	0	529	169	---	4.4	---
Cupid Spring (YF132)	68	122	42	1.5	----	-----	----	578	161	1.6	4.0	---
East Jupiter Terrace (YF17).	----	124	52	1.6	----	-----	----	-----	163	---	3.8	---
Do	67	130	56	1.8	----	816	0	479	165	3.0	4.2	0.60
Jupiter Spring, main terrace.	71	143	56	----	----	871	0	528	169	---	---	---
Mammoth Spring, main terrace, near west edge.	68	129	69	2.3	1.0	667	0	501	170	2.4	4.3	.5
Opal Spring (YF18)	----	-----	-----	----	----	-----	----	-----	168	---	---	---
Do	----	-----	-----	----	----	-----	----	477	165	---	---	---
Do	61	134	56	1.9	----	747	0	477	165	4.0	4.2	.63
Spring near Opal Spring (YF26).	62	141	55	1.8	----	-----	----	-----	-----	---	4.0	---
Norris Geyser Basin—Continued												
Bathtub Spring (YF45)	1	517	52	----	19	19	----	97	810	---	5.3	---
Do	1	274	16	----	46	0	----	813	416	---	10.6	---
Do	.2	326	33	4.0	----	0	0	70	553	3.5	5.7	---
Do	----	-----	39	----	----	-----	----	-----	-----	---	---	---
Big Alcove Geyser (YF57)	.3	193	22	1.5	----	8	0	84	265	5.2	5.2	---
Cinder Pool (YF25)	----	-----	-----	----	----	-----	----	-----	668	---	---	---
Do	.2	518	72	5.9	----	0	0	-----	790	---	12	---
Do	----	406	60	5.1	----	0	0	125	727	---	10	---
Do	.9	423	66	5.2	----	0	0	87	720	5.2	11.8	---
Do	.9	419	61	4.8	----	0	0	-----	-----	5.3	11.4	---
Constant Geyser (YF38)	1.8	319	74	3	1.0	0	0	[3]111	574	---	9.9	1.3
Do	.5	349	86	5.1	----	0	0	134	584	2.7	10	---
Echinus Geyser (YF23)	0	126	40	Tr.	----	0	0	[3]232	121	---	5.4	1.2
Do	----	-----	-----	----	----	-----	----	-----	108	---	---	---
Do	4.9	164	54	1.2	----	0	0	310	105	6.0	1.0	.08
Do	----	151	49	1.5	----	0	0	286	108	---	1.7	---
Do	1.1	160	51	.9	----	0	0	284	108	6.0	2.2	---
Do	1.0	163	50	.7	----	0	0	280	115	6.0	2.0	---
Do	----	157	50	.7	----	0	0	270	107	---	---	---
Do	----	-----	50	----	1.5	-----	----	-----	-----	---	---	---
Emerald Spring (YF47)	.5	352	65	5.0	----	0	0	-----	-----	4.4	12.4	---
Do	----	360	68	5.2	----	0	0	85	618	---	9.7	---
Do	----	-----	57	----	----	-----	----	-----	-----	---	---	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Norris Geyser Basin—Continued										
Green Dragon Spring (YF19)	White and others, 1963	Aug. 1954	87	----	2.47	---	369	1.5	.8	6.5
Do	D. E. White, unpub. data	Sept. 1957	----	----	3.0	---	---	----	----	5.2
Do	---do	Sept. 1960	----	----	2.86	---	---	----	----	-----
Do	This study [1]	---do	71	2.9	2.9	428	441	3.1	.4	4.8
Do	This study	Sept. 1961	85	----	2.9	390	392	3.0	.6	4.8
Do	---do	Sept. 1962	90	----	2.87	---	426	2.9	----	-----
Little Whirligig Geyser (YF37)	This study	Sept. 1961	91	----	3.2	406	420	2.1	1.0	2.5
Minute Geyser (YF68)	---do	---do	92	----	6.1	432	444	.16	<.1	6.5
Do	---do	May 1965	92	5.40	5.38	---	404	----	----	-----
Opal Spring [4] (YF27)	Allen and Day, 1935	ca. 1930	----	----	----	---	717	0	Tr.	6
Do	White and others, 1956	Sept. 1947	Boiling	----	*8.08*	*500±30*	---	----	----	-----
Do	---do	Aug. 1954	94	----	7.68	---	---	----	----	1.1
Do	D. E. White, unpub. data	Sept. 1957	93	----	8.5	---	---	----	----	3.2
Do	---do	Sept. 1960	----	----	2.42	---	---	----	----	-----
Do	This study [1]	---do	91	2.5	2.3	179	189	1.7	.5	0
Do	This study	Sept. 1961	87	----	1.9	168	168	6.1	.7	.7
Palpitator Geyser (YF66)	---do	---do	77	----	7.0	351	359	.1	<.1	7.2
Do	---do	May 1965	80	6.70	6.85	---	---	----	----	-----
Pearl Geyser (YF64)	Gooch and Whitfield, 1888	Aug. 1884	84	----	----	---	464	3.1	Tr.	6.4
Do	This study	Sept. 1961	82	----	5.5	426	440	<.1	<.1	6.8
Do	---do	May 1965	82	7.35	6.60	468	---	----	----	-----
Perpetual Spouter (YF52)	---do	Sept. 1961	93	----	8.25	288	291	.1	<.1	7.7
Do	---do	Sept. 1962	92.5	----	8.54	---	---	.18	----	-----
Do	---do	May 1965	92	7.63	8.18	---	291	----	----	-----
Pinwheel Geyser (YF29)	White and others, 1956	Sept. 1947	----	----	3.01	420±30	---	----	----	-----
Do	This study [1]	Sept. 1960	95	2.75	2.90	456	460	1.8	1.1	-----
Do	This study	Sept. 1961	84	----	3.1	444	444	1.9	1.1	2.1
Primrose Spring (YF41)	---do	---do	92	----	3.15	400	410	1.6	1.7	2.7
Do	---do	Sept. 1962	92	----	3.45	414	416	1.0	1.0	2.7
Do	---do	May 1965	93	3.25	3.45	---	416	----	----	-----
Steamboat Geyser (YF22)	D. E. White, unpub. data	Sept. 1947	Boiling	----	6.4	---	---	----	----	-----
Do	---do	Sept. 1957	---do	----	7.3	---	---	----	----	2.0
Do	---do	Sept. 1960	---do	----	7.2	---	---	----	----	-----
Do	This study	---do	---do	7.0	7.7	550	570	<.1	<.1	-----
Do	---do	Sept. 1962	---do	----	7.87	---	556	----	<.1	2.4
Opalescent Pool (YF20)	This study	Sept. 1960	40	7.8	7.7	358	492	.1	.2	-----
Unnamed Spring (YF21)	D. E. White, unpub. data	Sept. 1947	90.5	----	6.47	450±30	---	----	----	-----
Do	White and others, 1963	Aug. 1951	84.5	----	8.0	---	529	----	----	5.8
Do	D. E. White, unpub. data	Sept. 1957	88	----	7.8	---	---	----	----	7.2

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Norris Geyser Basin—Continued												
Green Dragon Spring (YF19).	0	243	61	3.2	3.4	0	0	454	408	---	6.9	---
Do	1.0	-----	-----	----	----	0	0	-----	550	---	---	---
Do	----	328	52	4.3	----	0	0	189	522	---	7.8	---
Do	.7	315	55	4.4	----	0	0	149	500	4.8	8.0	---
Do	.5	289	54	3.5	----	0	0	164	457	4.3	8.0	---
Do	----	285	55	3.5	----	0	0	185	456	---	---	---
Little Whirligig Geyser (YF37).	0.5	349	83	5.3	----	0	0	113	607	3.3	9.2	---
Minute Geyser (YF68)	.4	352	44	4.9	----	0	0	58	623	5.4	9.4	---
Do	----	-----	42	----	----	-----	----	-----	----	---	---	---
Opal Spring[4] (YF27)	Tr.	437	107	----	3	56	0	41	742	---	9.0	---
Do	----	-----	-----	----	----	-----	----	-----	748	---	---	---
Do	0	400	92	5.8	----	47	0	25	708	---	11	---
Do	1.0	-----	-----	----	----	30	7.9	-----	740	---	---	---
Do	----	10	5.2	.1	----	-----	----	-----	6.0	---	.4	---
Do	1.1	9	4.2	.2	----	0	0	325	8.0	2.4	.4	0.43
Do	<.1	4.5	2.2	.05	----	0	0	760	5	4	.6	---
Palpitator Geyser (YF66)	.4	334	40	4.2	----	31	0	59	568	6.2	8.6	---
Do	----	-----	34	----	----	-----	----	-----	----	---	---	---
Pearl Geyser (YF 64)	.9	404	54	2.2	----	[5]10.5	----	272	652	---	8.5	2.9
Do	.4	400	54	5.8	.21	-----	----	113	702	6.8	10.6	---
Do	----	-----	54	----	----	-----	----	-----	----	---	---	---
Perpetual Spouter (YF52)	.7	349	46	5.3	----	-----	----	69	599	6.7	13.8	---
Do	----	360	-----	----	----	28	0	-----	536	---	---	---
Do	----	-----	46	----	----	-----	----	-----	----	---	---	---
Pinwheel Geyser (YF29)	----	-----	-----	----	----	-----	----	-----	560	---	---	---
Do	<.1	356	91	5.0	----	0	0	55	600	---	10.0	2.8
Do	.5	352	86	5.1	----	0	0	-----	603	2.6	8.4	---
Primrose Spring (YF41)	.8	286	74	3.9	----	0	0	122	469	2.6	8.8	---
Do	----	283	55	3.9	----	0	0	93	436	3.7	7.8	---
Do	----	-----	58	----	----	-----	----	-----	----	---	---	---
Steamboat Geyser (YF22)	----	-----	-----	----	----	-----	----	-----	396	---	---	---
Do	.7	431	80	5.5	----	24	0	100	700	---	12	---
Do	----	373	54	4.6	----	-----	----	-----	566	---	9.5	---
Do	<.1	352	65	4.9	----	-----	----	-----	584	---	9.4	---
Do	----	377	60	5.2	----	-----	----	75	601	18	---	---
Opalescent Pool (YF20)	.2	467	77	6.6	----	-----	----	-----	----	---	13.4	---
Unnamed Spring (YF21)	----	-----	-----	----	----	-----	----	-----	752	---	---	---
Do	.2	439	74	8.4	.1	27	0	38	744	4.9	12	3.1
Do	1.2?	-----	-----	----	----	23	----	-----	780	---	---	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO_2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Norris Geyser Basin—Continued										
Unnamed Spring (YF21)	D. E. White, unpub. data	Sept. 1960	72	----	7.5	---	---	----	----	-----
Do	This study [1]	do	71	7.10	7.45	428	435	<.1	<.1	6.4
Do	This study	Sept. 1961	72	----	7.45	420	430	<.1	<.1	10.4
Do	do	Sept. 1962	68	----	7.68	432	450	.2	----	8.6
Unnamed Spring (YF24)	D. E. White, unpub. data	Aug. 1954	70	----	2.20	---	259	----	----	2.6
Do	do	Sept. 1957	64.5	----	2.40	---	184	----	----	2.4
Do	do	Sept. 1960	54	----	2.29	---	---	----	----	-----
Do	This study [1]	do	54	2.20	2.29	204	205	20	1.3	2.4
Unnamed Spring (YF28)	do	do	91	7.20	7.65	573	608	<.1	<.1	<.1
Do	This study	Sept. 1961	92	----	6.4	400	434	<.1	<.1	2.8
Unnamed Spring (YF40)	do	do	89	----	3.25	343	371	7.0	.7	2.8
Unnamed Spring (YF42)	do	do	89	----	3.65	474	494	1.2	.9	1.8
Unnamed Spring (YF43)	do	do	89	----	3.2	409	430	1.4	1.4	2.5
Unnamed Spring (YF44)	This study	Sept. 1961	90	----	5.45	426	444	0.1	<.1	2.4
Do	do	May 1965	89	5.95	6.25	489	490	----	----	-----
Unnamed Spring (YF46)	do	Sept. 1961	78	----	5.75	494	496	.08	<.1	3.5
Do	do	Sept. 1962	82.5	----	5.35	570	570	.2	----	1.8
Do	do	May 1965	86	5.65	6.4	491	---	----	----	-----
Unnamed Spring (YF48)	do	Sept. 1961	53	----	2.8	229	234	7.7	2.1	7.4
Unnamed Spring (YF49)	do	do	88	----	3.0	276	311	2.7	1.4	3.4
Unnamed Spring (YF51)	do	do	75	----	3.05	267	267	3.0	1.3	3.6
Unnamed Spring (YF53)	do	do	92	----	3.6	350	347	3.2	1.0	3.7
Unnamed Spring (YF54)	do	do	87	----	4.0	381	389	.6	1.1	3.6
Do	do	Sept. 1962	92	----	7.27	---	448	.2	<.1	3.2
Do	do	May 1965	92	6.80	7.15	----	456	----	----	-----
Unnamed Spring (YF58)	do	Sept. 1961	92	----	2.0	290	290	28.9	1.6	.2
Do	do	Sept. 1962	92	----	2.17	----	207	12.0	1.1	.3
Unnamed Spring (YF59)	do	Sept. 1961	79	----	5.4	484	504	.21	<.1	3.0
Do	do	Sept. 1962	94	----	8.04	636	692	.17	<.1	3.1
Do	do	May 1965	91	7.20	7.82	----	588	----	----	-----
Unnamed Spring (YF60)	do	Sept. 1961	82	----	2.6	332	338	6.0	1.6	3.1
Do	do	Sept. 1962	85	----	3.21	374	383	3.8	.5	2.4
Unnamed Spring (YF62)	do	Sept. 1961	91	----	7.4	550	560	<.1	<.1	2.9
Do	do	Sept. 1962	85.5	----	3.45	496	496	2.2	.5	2.5
Do	do	Oct. 1962	85.5	----	----	---	432	1.7	.4	2.5
Do	do	May 1963	93	3.50	3.35	---	450	----	----	-----
Unnamed Spring (YF63)	do	Sept. 1961	82	----	2.7	315	323	2.3	.3	2.5
Unnamed Spring (YF67)	do	do	69	----	2.3	262	258	4.9	1.1	2.8

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As

Norris Geyser Basin—Continued

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Unnamed Spring (YF21)	----	516	56	7.0	----	-----	----	883	----	---	11	---
Do	.5	526	66	7.4	----	18	0	33	860	---	15.0	---
Do	.7	512	56	6.5	----	25	0	76	826	7.5	12.4	---
Do	----	502	56	6.5	----	-----	0	26	780	7.0	---	---
Unnamed Spring (YF24)	1.0	27	24	<.1	----	0	0	482	6.0	---	1.5	---
Do	0	10	12	<.1	----	0	0	471	7.0	---	.6	---
Do	----	15	15	.06	----	0	0	548	7.0	---	.66	---
Do	<.1	15	13	<.1	----	0	0	504	7.0	---	.8	0.2
Unnamed Spring (YF28)	<.1	400	91	6.2	----	34	0	24	700	6.0	11.2	3.0
Do	<.1	308	66	5.3	----	11	0	95	543	4.6	8.2	---
Unnamed Spring (YF40)	.5	304	79	4.6	----	0	0	183	504	3.0	4.5	---
Unnamed Spring (YF42)	.7	329	87	5.1	----	0	0	86	586	3.6	4.9	---
Unnamed Spring (YF43)	.9	282	77	4.1	----	0	0	121	485	2.8	4.8	---
Unnamed Spring (YF44)	0.2	356	40	5.1	---	8	0	51	627	5.2	12.8	---
Do	---	----	41	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF46)	.3	404	50	5.6	---	20	0	196	687	5.7	13.8	---
Do	---	375	43	5.2	---	-----	----	35	620	5.6	10.4	---
Do	---	----	40	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF48)	1.0	297	63	3.6	---	0	0	230	471	2	9.8	---
Unnamed Spring (YF49)	.7	282	60	3.4	----	0	0	165	438	2.4	9.2	---
Unnamed Spring (YF51)	.7	260	42	2.7	----	0	0	140	411	1.6	9.0	---
Unnamed Spring (YF53)	.5	289	23	2.9	---	0	0	86	438	3.6	7.2	---
Unnamed Spring (YF54)	.4	390	31	3.9	---	0	0	60	642	4.3	11.6	---
Do	---	397	31	4.2	----	18	0	29	626	5.6	10.6	---
Do	---	----	32	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF58)	.6	15	18	0.4	---	0	0	925	224	6	.6	---
Do	---	4.8	8.2	0.1	---	0	0	560	6	1.1	.3	---
Unnamed Spring (YF59)	.2	378	85	6.2	---	6	0	172	687	5	10.0	---
Do	---	420	73	6.3	----	29.5	0	41	668	5	10.8	---
Do	---	----	90	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF60)	.2	356	87	6.3	---	0	0	288	721	2.5	10.0	---
Do	---	455	81	6.5	---	0	0	150	732	5	12.0	---
Unnamed Spring (YF62)	<.1	390	87	6.0	---	28	0	58	593	5.4	11.0	---
Do	---	385	85	5.8	---	0	0	106	640	4.6	10.2	---
Do	---	372	76	6.2	---	-----	----	84	650	4.0	---	---
Do	---	----	83	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF63)	.3	267	39	3.8	---	0	0	137	458	2.4	7.0	---
Unnamed Spring (YF67)	1.3	141	21	1.3	---	0	0	353	170	1.0	3.0	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO_2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Between Norris and Lower Geyser Basins										
Chocolate Pots (YF136)	Allen and Day, 1935	ca. 1930	54	----	----	---	98	0	6	25
Do	This study	Oct. 1962	53	----	----	---	105	.2	<.1	10.7
Unnamed Spring (YF137)	----do	----do	83	----	----	---	152	4.0	2.2	3.3
Beryl Spring (YF31)	Allen and Day, 1935	July 1928	91	----	----	---	---	----	----	-----
Do	D. E. White, unpub. data	Sept. 1960	93	----	6.8	---	---	----	----	-----
Do	This study [1]	----do	91	6.4	6.8	269	268	<.1	<.1	1.6
Do	This study	Sept. 1961	92	----	6.8	262	266	<.1	<.1	4.6
Do	----do	Sept. 1962	92	----	7.01	269	---	.6	----	5.1
Do	----do	May 1965	93	6.65	7.25	---	270	----	----	-----
Lower Geyser Basin										
Black Warrior Lake	Scott, 1964	Sept. 1959	65	----	----	---	175	0	0	18
Black Warrior Lake (vent)	D. E. White, unpub. data	Sept. 1960	93	----	7.3	---	199	----	----	14
Black Warrior Lake (Steady Geyser) (YF30).	This study [1]	----do	92	6.9	8.1	209	211	<.1	<.1	11
Do	This study	Sept. 1961	94	----	7.0	196	198	<.1	<.1	12.1
Do	----do	Sept. 1962	93	----	7.62	---	204	.17	.1	12.3
Clepsydra Geyser (YF75)	----do	Sept. 1961	87	----	8.85	329	338	<.1	<.1	.3
Do	----do	Sept. 1962	87	----	9.23	---	347	.16	----	-----
Do	----do	May 1965	87	8.45	9.10	---	---	----	----	-----
Firehole Pool (YF154)	This study	May 1965	90	7.80	8.40	---	323	----	----	-----
Great Fountain Geyser (YF35)	Gooch and Whitfield, 1888	Aug. 1884	93	----	Alk.	---	318	2.1	Tr.	1.7
Do	Allen and Day, 1935	ca. 1930	----	----	----	---	316	1	1	Tr.
Do	This study [1]	Sept. 1960	95	6.25	8.7	324	325	<.1	<.1	<.1
Do	This study	Sept. 1961	95	----	8.6	317	315	<.1	<.1	.5
Narcissus Geyser (YF34)	D. E. White, unpub. data	Oct. 1947	----	----	8.95	300±20	---	----	----	-----
Do	----do	Sept. 1960	----	----	7.4	---	---	----	----	-----
Do	This study [1]	----do	90	6.45	6.8	331	354	<.1	<.1	<.1
Do	This study	Sept. 1961	92	----	7.9	338	332	<.1	<.1	.7
Do	----do	Sept. 1962	92	----	7.71	---	328	.07	----	1.0
Do	----do	May 1965	89	7.25	8.00	---	---	----	----	-----
Ojo Caliente Spring (YF156)	Allen and Day, 1935	1929	----	----	----	---	218	0	1	4
Do	White and others, 1956	Sept. 1947	95.7	----	----	---	240±30	----	----	-----
Do	This study	May 1965	95	7.40	7.75	---	253	----	----	-----
Shelf Spring (YF81)	----do	Sept. 1961	95	----	8.65	350	352	<.1	<.1	.7
Do	----do	Sept. 1962	95	----	8.76	400	412	.02	----	-----
Do	----do	May 1965	95	8.00	8.70	---	350	----	----	-----

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Between Norris and Lower Geyser Basins—Continued												
Chocolate Pots (YF136)	1	114	31	---	---	353	0	28	29	---	---	---
Do	---	118	21	0.7	---	---	---	30	27	4	0.4	---
Unnamed Spring (YF137)	---	35	11	.4	---	---	---	296	18	<.1	.3	---
Beryl Spring (YF31)	---	---	---	---	---	146	0	66	549	---	---	---
Do	---	409	23	5.3	---	---	---	---	543	---	6.2	---
Do	.4	400	22	6.1	---	129	0	43	540	16	7.8	3.3
Do	.3	408	22	6.0	---	---	---	---	---	17	7.2	---
Do	---	410	22	5.9	---	140	0	63	534	---	---	---
Do	---	---	22	---	---	---	---	---	---	---	---	---
Lower Geyser Basin—Continued												
Black Warrior Lake	0	96	12	0.9	0.5	155	0	35	53	11	0.42	0
Black Warrior Lake (vent)	.7	89	13	.46	---	150	---	26	52	---	.65	---
Black Warrior Lake (Steady Geyser) (YF30).	.9	89	13	.5	---	145	0	22	52	10	.6	.01
Do	.7	93	14	.5	---	---	---	---	---	10	.6	---
Do	---	85	14	.5	---	136	0	37	53	10	.5	---
Clepsydra Geyser (YF75)	<.1	341	14	2.5	---	178	85	49	346	21	1.05	---
Do	---	335	14	2.3	---	136	106	23	324	---	---	---
Do	---	---	14	---	---	---	---	---	---	---	---	---
Firehole Pool (YF154)	---	---	11.5	---	---	---	---	---	---	---	---	---
Great Fountain Geyser (YF35).	2.3	335	15	2.5	---	[5]292	---	[3]22	351	---	3.1	1.3
Do	0	366	14	---	---	182	83	18	343	16	4.0	---
Do	<.1	334	14	3.4	---	223	42	19	340	20	4.0	3.6
Do	<.1	338	13	3.4	---	---	---	---	---	21	3.6	---
Narcissus Geyser (YF34)	---	---	---	---	---	---	---	---	356	---	---	---
Do	---	312	16	2.0	---	---	---	---	348	---	2.7	---
Do	<.1	312	20	2.3	---	221	0	14	340	18	4.0	2.3
Do	<.1	297	21	2.1	---	---	---	---	---	20	4.0	---
Do	---	310	17	2.3	---	236	0	18	336	---	---	---
Do	---	---	18	---	---	---	---	---	---	---	---	---
Ojo Caliente Spring (YF156).	0	335	12	---	---	208	29	29	324	24	5.1	---
Do	---	---	---	---	---	---	---	---	---	---	---	---
Do	---	---	9.5	---	---	---	---	---	---	---	---	---
Shelf Spring (YF81)	<.1	326	16	2.4	---	200	35	68	370	18	4.0	---
Do	---	335	18	2.4	---	170	51	21	347	---	---	---
Do	---	---	17	---	---	---	---	---	---	---	---	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Lower Geyser Basin—Continued										
Surprise Pool (YF83)	This study	Sept. 1961	95	----	8.55	286	292	<.1	.01	.7
Do	do	Sept. 1962	95	----	8.67	---	327	.17	----	-----
Do	do	May 1965	95	7.80	8.40	---	294	----	----	-----
Midway Geyser Basin										
Excelsior Geyser (YF10)	Gooch and Whitfield, 1888	Aug. 1884	92	----	----	---	221	1.2	1.8	2.2
Do	Allen and Day, 1935	ca. 1930	91	----	----	---	237	1	1	3
Do	White and others, 1956	Oct. 1947	----	----	8.45	280±30	---	----	----	-----
Do	Scott, 1964	Sept. 1959	63	----	8.4	---	255	.2	0	1.6
Do	D. E. White, unpub. data	Sept. 1960	76	----	8.0	---	---	----	----	-----
Do	This study [1]	do	76	8.0	8.35	283	303	<.1	<.1	<.1
Do	This study	Sept. 1961	88	----	7.5	280	282	<.1	<.1	2.5
Upper Geyser Basin										
Artemsia Geyser (YF2)	Gooch and Whitfield, 1888	Sept. 1884	89	----	Alk.	---	274	7.9	Tr.	1.4
Do	Allen and Day, 1935	ca. 1930	91.5	----	----	---	268	0	0	Tr.
Do	This study [1]	Sept. 1960	89	8.20	8.95	267	275	.2	.2	0
Do	This study	Sept. 1961	90	----	8.8	271	272	<.1	.1	.9
Bonita Pool (YF70)	do	do	92	----	8.7	294	293	<.1	<.1	.3
Do	do	Sept. 1962	92	8.55	9.11	---	296	1.2	<.1	-----
Do	do	May 1965	92	8.25	8.95	---	292	----	----	-----
Chinaman Spring (YF129)	Allen and Day, 1935	ca. 1930	93.5	----	----	---	---	----	----	-----
Do	D. E. White, unpub. data	Sept. 1960	Boiling	----	7.7	---	128?	----	----	1.2
Do	This study	Sept. 1962	92.5	----	----	---	323	.3	<.1	.9
Do	do	May 1965	94	7.85	7.75	---	327	----	----	-----
Daisy Geyser (YF5)	Allen and Day, 1935	ca. 1930	88.6	----	----	---	---	----	----	-----
Do	White and others, 1956	Oct. 1947	----	----	7.64	280±20	---	----	----	-----
Do	This study [1]	Sept. 1960	90.5	7.60	7.80	306	304	<.1	<.1	.8
Ear Spring (YF86)	This study	Sept. 1961	95	----	9.25	390	388	<.1	<.1	.7
Do	do	Sept. 1962	95	----	9.4	---	374	.09	<.1	-----
Do	do	May 1965	95	8.35	9.25	---	392	----	----	-----
Giantess Geyser (YF7)	Gooch and Whitfield, 1888	Aug. 1884	----	----	Alk.	---	394	4.9	Tr.	0.7
Do	Allen and Day, 1935	ca. 1930	94	----	----	---	372	0	0	0
Do	This study	Sept. 1960	95	7.95	8.85	384	417	<.1	.1	-----
Do	do	Sept. 1962	95	----	9.1	---	397	<.7	<.1	.4
Do	do	Oct. 1962	92	----	----	---	392	----	----	-----
Do	do	May 1965	93	8.07	9.00	---	400	----	----	-----

Locality	Mg	Na	K	Li	NH4	HCO3	CO3	SO4	Cl	F	B	As
Lower Geyser Basin—Continued												
Surprise Pool (YF83) ---	.2	334	14	3.8	---	310	26	55	301	25	3.4	---
Do	---	335	14	3.5	---	282	39	17	296	---	---	---
Do	---	----	13	---	---	-----	----	-----	----	---	---	---
Midway Geyser Basin—Continued												
Excelsior Geyser (YF10) --	2.2	419	33	2.0	0.01	[5]530	----	[8]18	279	---	5.0	2.0
Do	0	410	14	---	---	562	0	21	271	20	2.5	---
Do	---	----	---	---	---	-----	----	-----	278	---	---	---
Do	.5	408	12	2.6	---	527	20	21	278	18	2.5	2.0
Do	---	400	12	2.2	---	-----	----	-----	280	---	2.8	---
Do	.1	385	15	2.8	---	546	0	34	270	24	3.4	2.3
Do	.2	382	14	2.7	---	-----	----	-----	----	24	3.0	---
Upper Geyser Basin—Continued												
Artemsia Geyser (YF2) ---	0	398	16	7.0	0.21	[5]361	----	[8]15	300	---	5.5	1.1
Do	---	422	16	---	---	411	75	18	289	---	3.1	---
Do	<.1	385	17	4.0	---	425	58	27	290	22	3.0	1.4
Do	<.1	390	16	3.8	---	-----	----	-----	----	26	3.2	---
Bonita Pool (YF70) -------	.2	441	19	4.3	---	452	83	19	340	30	3.2	---
Do	---	440	15	3.9	---	452	76	17	305	---	---	---
Do	---	----	19	---	---	-----	----	-----	----	---	---	---
Chinaman Spring YF129) --	---	----	---	---	---	174	0	49	385	---	---	---
Do	<.1	338	17	4.6	---	155	0	42	375	---	3.3	---
Do	---	325	18	4.9	---	-----	----	25	371	23	4.4	---
Do	---	----	17	---	---	-----	----	-----	----	---	---	---
Daisy Geyser (YF5) ------	---	----	---	---	---	619	15	8	311	---	---	---
Do	---	----	---	---	---	-----	----	-----	302	---	---	---
Do	<.1	460	21	4.4	---	621	0	20	310	29	3.2	---
Ear Spring (YF86) -----	<.1	341	20	5.1	---	59	18	21	446	25	4.8	---
Do	---	347	20	5.6	---	0	47	17	420	---	---	---
Do	---	---	19.5	---	---	-----	----	-----	----	---	---	---
Giantess Geyser (YF7) ----	1.2	345	40	5.7	---	[5]105	----	[8]16.7	441	---	7.2	0.45
Do	0	362	20	---	---	113	51	23	429	20	4.6	---
Do	.1	349	21	5.8	---	-----	----	-----	----	---	5.0	---
Do	---	360	20.7	5.8	---	40	68	22	427	29	---	---
Do	---	364	20.7	5.4	---	-----	----	22	418	---	---	---
Do	---	----	18.5	---	---	-----	----	-----	----	---	---	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO_2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Upper Geyser Basin—Continued										
Hillside Springs (YF6)	Allen and Day, 1935	ca. 1930	----	----	----	---	170	0	0	9
Do	D. E. White, unpub. data	Aug. 1951	----	----	7.43	---	---	----	----	-----
Do	----do	Sept. 1960	86	----	6.6	---	175	----	----	8.4
Do	This study	----do	86	6.55	7.0	---	190	.1	<.1	-----
Do	----do	Sept. 1961	86	----	6.65	180	180	<.1	<.1	8.4
Ink Well Spring (YF130)	----do	Sept. 1962	91	----	----	---	286	.12	<.1	.7
Iron Spring (YF3)	Allen and Day, 1935	ca. 1930	90.8	----	----	---	365	0	Tr.	2
Do	This study[1]	Sept. 1960	95	3.65	3.45	455	456	.6	1.2	3.2
Old Faithful Geyser (YF33)	Gooch and Whitfield, 1888.	Sept. 1884	84–88	----	Alk.	---	383	.9	Tr.	1.5
Do	Allen and Day, 1935	ca. 1930	----	----	8.97	---	357	0	Tr.	4
Do	This study[1]	Sept. 1960	90	----	9.3	356	381	<.1	<.1	-----
Do	This study	Sept. 1961	85	----	9.15	374	390	<.1	.1	.7
Do	Noguchi and Nix, 1963	1962	----	----	----	---	384–396	----	----	-----
Punch Bowl Spring (YF144)	Allen and Day, 1935	ca. 1930	92.8	----	----	---	328	0	0	0
Do	This study	Sept. 1962	95	----	7.94	---	340	.03	<.1	.4
Do	----do	May 1965	95	7.45	8.05	---	348	----	----	-----
Riverside Geyser (YF8)	Allen and Day, 1935	ca. 1930	93.5	----	----	---	242	0	0	0
Do	White and others, 1956	Oct. 1947	----	----	9.02	---	240±20	----	----	-----
Do	This study[1]	Sept. 1960	95	8.6	8.9	226	268	<.1	<.1	.1
Do	This study	Sept. 1961	93	----	8.7	256	248	<.1	<.1	.5
Do	----do	May 1965	95	8.15	8.8	---	---	----	----	-----
Sapphire Geyser (YF9)	Allen and Day, 1935	ca. 1930	94.5	----	8.69	---	321	0	Tr.	4
Do	White and others, 1956	Oct. 1947	95	----	9.15	---	320±20	----	----	-----
Do	Scott, 1964	Sept. 1959	----	----	9.2	---	244?	.3	.3	1.6
Do	D. E. White, unpub. data	Sept. 1960	----	----	9.1	---	---	----	----	-----
Do	This study[1]	----do	92	8.3	9.2	348	352	<.1	<.1	-----
Do	This study	Sept. 1961	90	----	9.0	326	355	<.1	<.1	.5
Do	----do	Sept. 1962	94	----	9.0	---	322	.8	<.1	.3
Do	----do	May 1965	94	8.1	8.7	---	331	----	----	-----
Sentinel Geyser (YF103)	Allen and Day, 1935	ca. 1930	93.5	----	----	---	---	----	----	-----
Do	This study	Sept. 1962	94	----	9.02	---	262	.8	<.1	.3
Solitary Geyser (YF99)	Allen and Day, 1935	ca. 1930	92.5	----	----	---	365	0	0	4
Do	Noguchi and Nix, 1963	1962	----	----	----	---	374–393	----	----	-----
Do	This study	Sept. 1962	91	----	9.21	---	364	.9	<.1	.3
Spouter Geyser (YF90)	Allen and Day, 1935	ca. 1930	92.5	----	----	---	---	----	----	-----
Do	This study	Sept. 1961	92	----	8.8	313	309	<.1	<.1	.7
Do	----do	Sept. 1962	92	----	9.0	---	309	.51	<.1	-----
Tortoise Shell Spring (YF102)	Allen and Day, 1935	ca. 1930	94.5	----	----	---	329	----	----	0
Do	Scott, 1964	Sept. 1959	95	----	9.2	---	259?	0.1	0	1.6
Do	D. E. White, unpub. data.	Sept. 1960	----	----	9.3	---	---	----	----	-----
Do	This study	Sept. 1962	93.5	----	9.45	---	340	.9	<.1	.5

Upper Geyser Basin—Continued

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Hillside Springs (YF6)	0	124	10	---	---	249	0	12	55	---	1.6	---
Do	---	----	---	---	---	-----	----	-----	66	---	---	---
Do	0	133	6.9	.7	---	246	0	14	71	---	1.0	---
Do	.7	145	8.3	.8	---	-----	----	12	----	---	1.2	---
Do	.6	133	8	.7	---	252	0	17	72	10	1.2	---
Ink Well Spring YF130)	---	375	30	3.7	---	-----	----	15	262	25	3.1	---
Iron Spring (YF3)	Tr.	77	28	---	---	0	0	231	1	1.2	2.2	---
Do	1.4	122	45	.3	---	0	0	220	6	2.0	---	---
Old Faithful Geyser (YF33)	.6	367	27	5.6	0.01	[5]124	----	[3]18	439	0	4.6	1.6
Do	----	372	31	---	---	0	100	21	435	22	5.6	---
Do	<.1	349	21	5.7	---	-----	----	-----	----	----	5.0	---
Do	<.1	326	22	5.3	---	-----	----	45	434	23	5.0	---
Do	---	----	---	---	---	-----	----	18.5–21	451–466	----	---	---
Punch Bowl Spring (YF144)	0	450	20	---	---	597	10	19	297	20	5.9	---
Do	---	425	19.5	3.6	---	568	0	18	294	34	3.3	---
Do	---	----	20	---	---	-----	----	-----	----	---	---	---
Riverside Geyser (YF8)	---	372	19	---	---	329	54	16	296	---	3.1	---
Do	---	----	---	---	---	-----	----	-----	288	---	---	---
Do	<.1	338	17	3.8	---	334	41	12	300	24	3.2	---
Do	<.1	341	16	3.5	---	-----	----	-----	----	25	3.2	---
Do	---	----	16	---	---	-----	----	-----	----	---	---	---
Sapphire Geyser (YF9)	Tr.	453	17	---	---	466	66	15	307	21.5	3.7	---
Do	---	----	---	---	---	-----	----	-----	308	---	---	---
Do	0	420	18	2.2	---	332	99	22	309	18	2.6	2.5
Do	---	429	16	1.8	---	-----	----	-----	305	---	2.9	---
Do	<.1	423	19	2.1	---	-----	----	14	270?	---	3.4	---
Do	<.1	412	20	2.1	---	366	103	55	308	28	3.4	---
Do	---	445	20	2.3	---	406	82	18	296	32	---	---
Do	---	----	18	---	---	-----	----	-----	----	---	---	---
Sentinel Geyser (YF103)	---	----	---	---	---	303	90	12	240	---	---	---
Do	---	355	17	3.3	---	328	69	18	242	26	2.6	---
Solitary Geyser (YF99)	0	317	23	---	---	68	47	21	377	21.5	---	---
Do	---	----	---	---	---	-----	----	27–28.9	401–416	---	---	---
Do	---	320	24	4.4	---	0	76	23	373	32	4.5	---
Spouter Geyser (YF90)	---	----	---	---	---	463	87	29	313	---	---	---
Do	.5	415	18	3.5	---	452	81	43	326	27	3.6	---
Do	---	425	20	3.3	---	454	74	18	312	35	---	---
Tortoise Shell Spring (YF102).	0	420	23	---	---	282	76	18	381	---	4.7	---
Do	0	408	19	4.8	---	174	102	27	382	18	2.2	2.5
Do	----	396	17	4.4	---	-----	----	-----	385	---	6.1	---
Do	----	405	22	5.0	---	157	60	20	378	32	4.4	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH		SiO_2		Al	Fe	Ca
				Field	Laboratory	Field	Laboratory			
Upper Geyser Basin—Continued										
Turban Geyser (YF36)	Gooch and Whitfield, 1888	Sept. 1884	91	----	Alk.	---	304	3.2	Tr.	2.8
Do	This study[1]	Sept. 1960	89	8.15	8.50	315	318	<.1	<.1	<.1
Do	do	Sept. 1961	91	----	9.0	322	---	<.1	<.1	.3
Do	do	Sept. 1962	92	----	9.45	---	318	.8	<.1	-----
Do	do	May 1965	92	8.72	9.25	---	---	----	----	-----
Unnamed Spring (YF1)	D. E. White, unpub. data.	Oct. 1947	85	----	4.39	---	200±20	----	----	-----
Do	do	Sept. 1960	71	----	4.40	---	---	----	----	-----
Do	This study[1]	do	71	4.6	4.3	270	278	.2	.2	<.1
Do	This study	Sept. 1961	71	----	3.7	268	266	.1	.2	.5
Do	do	Sept. 1962	70	----	4.5	---	262	.2	.2	-----
Unnamed Spring (YF4)	White and others, 1963	Oct. 1957	94	----	9.6	---	363	.2	.06	.8
Do	D. E. White, unpub. data.	Sept. 1960	92.5	----	9.6	---	---	----	----	-----
Do	This study[1]	do	92.5	8.75	9.7	361	374	<.1	<.1	.1
Do	This study	Sept. 1961	91	----	9.4	367	370	<.1	<.1	.5
Do	do	Sept. 1962	92	----	9.78	---	358	1.2	.4	-----
Do	This study[1]	May 1965	92	8.65	9.60	---	368	----	----	-----
Unnamed Spring (YF32)	do	Sept. 1960	78	----	8.9	313	318	<.1	<.1	<.1
Unnamed Spring (YF96)	This study	Oct. 1962	94	----	----	---	320	1.0	<.1	.8
Unnamed Spring (YF109)	do	Sept. 1962	82	----	----	---	256	.07	<.1	2.1
Smoke Jumper Hot Springs										
Unnamed Spring (YF14)	This study[1]	Sept. 1960	91	----	6.9	246	256	<.1	<0.1	<0.1
Unnamed Spring (YF15)	do	do	82	----	6.3	254	264	<.1	<.1	-----
Unnamed Pool (YF16)	do	do	92	----	2.3	262	300	38	5.2	-----
West Thumb Pools										
Abyss Pool (YF11)	Scott, 1964	Sept. 1959	81	----	8.2	---	197?	0.2	0	1.6
Do	D. E. White, unpub. data.	Sept. 1960	92	----	8.4	---	---	----	----	-----
Do	This study	do	91	7.58	8.5	282	297	<.1	<.1	-----
Do	do	Sept. 1961	91	----	8.45	286	289	<.1	<.1	.7
Do	do	Sept. 1962	92	----	8.49	---	290	.9	----	.53
Occasional Geyser (YF12)	This study[1]	Sept. 1960	94	7.80	8.6	262	283	<.1	<.1	<.1
Do	do	Sept. 1961	95	----	8.4	266	266	<.1	<.1	1.2
Do	do	Sept. 1962	92	----	8.85	---	262	.6	----	1.1
Potts Hot Spring Basin										
Unnamed Spring (YF79)	This study	Sept. 1961	89	----	9.1	310	303	<0.1	<0.1	0.5
Do	do	Sept. 1962	92	----	7.32	---	305	.7	<.1	-----
Unnamed Spring (YF106)	do	do	92	----	8.13	---	143	.6	<.1	.6

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Upper Geyser Basin—Continued												
Turban Geyser (YF36)	0	382	16.7	3.6	---	[4]270	----	[3]25	377	---	7.6	.8
Do	<.1	371	18	4.7	---	185	83	25	370	28	4.0	1.7
Do	<.1	371	19	4.7	---	-----	----	-----	----	27	4.0	---
Do	----	364	18	4.4	---	145	54	20	366	---	---	---
Do	----	----	18	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF1)	----	----	---	---	---	-----	----	-----	4	---	---	---
Do	----	37	19	.18	---	0	0	122	1.2	---	.05	---
Do	<.1	42	20	.3	---	0	0	121	2	2	.06	---
Do	<.1	40	20	.2	---	-----	----	-----	----	1.4	.02	---
Do	----	37	18	.16	---	-----	----	116	----	---	---	---
Unnamed Spring (YF4)	0	352	24	5.2	---	0	70	23	405	25	4.4	1.5
Do	----	355	20	4.5	---	-----	----	-----	406	---	4.4	---
Do	<.1	356	26	5.0	---	-----	----	21	400	28	4.6	1.6
Do	<.1	341	23	5.1	---	-----	----	-----	----	24	4.2	---
Do	----	334	23	4.8	---	0	50	21	400	---	---	---
Do	----	----	22.5	---	---	-----	----	-----	----	---	---	---
Unnamed Spring (YF32)	<.1	297	16	4.9	---	50	49	17	370	22	4.2	1.4
Unnamed Spring (YF96)	----	415	20	3.0	---	-----	----	15	301	33	3.6	---
Unnamed Spring (YF109)	----	370	20	2.7	---	168	0	35	430	16	5.5	---
Smoke Jumper Hot Springs—Continued												
Unnamed Spring (YF14)	0.2	33	14	<0.1	---	34	0	48	0	8	0.32	---
Unnamed Spring (YF15)	<.1	40	15	<.1	---	-----	----	-----	----	---	.38	---
Unnamed Pool (YF16)	1.2	10	7.5	<.1	---	-----	----	-----	----	---	4.4	---
West Thumb Pools—Continued												
Abyss Pool (YF11)	0	444	20	3.4	---	598	0	55	298	19	3.0	2.0
Do	----	428	17	3.1	---	-----	----	-----	298	---	3.3	---
Do	<.1	423	21	3.5	---	-----	----	-----	----	---	4.0	---
Do	<.1	427	17	3.3	---	-----	----	-----	----	26	3.8	---
Do	----	420	21	3.5	---	518	35	52	298	28	---	---
Occasional Geyser (YF12)	<.1	337	17	2.4	---	415	18	27	230	22	3.4	<.01
Do	<.1	352	15	2.4	---	406	28	85	254	23	3.0	---
Do	----	335	16	2.4	---	338	59	42	235	---	---	---
Potts Hot Spring Basin—Continued												
Unnamed Spring (YF79)	0.2	334	15	3.5	---	220	106	68	258	24	3.2	---
Do	---	385	17	4.0	---	490	0	53	254	---	---	---
Unnamed Spring (YF106)	---	357	18	3.4	---	466	0	38	243	26	3.1	---

See footnotes at end of table.

TABLE 1.—*Chemical composition, in parts per million, of thermal waters, Yellowstone National Park*—Continued

Locality	References	Date of Collection	Temperature (°C)	pH Field	pH Laboratory	SiO_2 Field	SiO_2 Laboratory	Al	Fe	Ca
Shoshone Geyser Basin										
Taurus Spring (YF133)	Gooch and Whitfield, 1888	June 1887	----	----	Alk.	---	293	4	Tr.	Tr.
Do	This study	Oct. 1962	93	----	----	---	305	.3	<0.1	<0.1
Unnamed Spring (YF134)	----do	----do	92	----	----	---	280	.3	<.1	1.0
Mud Volcano Area										
Churning Cauldron (YF13)	D. E. White, unpub. data	July 1956	48	----	4.6	---	230	----	----	79
Do	Scott, 1964	Sept. 1959	33	----	3.0	---	225	38	55	171
Do	D. E. White, unpub. data	Sept. 1960	55	----	2.0	---	---	----	----	-----
Do	This study [1]	----do	55	1.7	2.0	297	325	51	38	152

Locality	Mg	Na	K	Li	NH_4	HCO_3	CO_3	SO_4	Cl	F	B	As
Shoshone Geyser Basin—Continued												
Taurus Spring (YF133)	0.9	320	23.5	0.9	---	[5]445	----	[3]46	193.5	---	4.6	0.53
Do	---	322	13	1.2	---	-----	----	48	200	23	3.0	---
Unnamed Spring (YF134)	---	250	23	1.2	---	-----	----	35	125	16	1.8	---
Mud Volcano Area—Continued												
Churning Cauldron (YF13)	28	65	46	---	---	5	0	494	2.2	---	---	---
Do	69	150	46	0 6	---	0	0	1440	20	0.6	0.34	0
Do	---	70	24	.06	---	0	0	3440	2.5	---	.25	---
Do	73	77	46	.1	---	0	0	1066	----	2	.4	---

[1] See table 3 for spectrographic analyses of residues.
[2] 6 ppm Fe^{+2}, 31 ppm Fe^{+3}.
[3] SO_3 calculated as SO_4^{-2}.
[4] Spring on Porcelain Terrace near old road.
[5] Total CO_2 calculated as HCO_3^-.

TABLE 2.—*Locations of unnamed hot springs*

Locality No.	Location	Locality No.	Location	Locality No.	Location
Norris Geyser Basin [Locations for Norris Geyser Basin are keyed to figure 1]					
YF21	F4	YF46	E5	YF58	D6
24	D5	48	A4	59	C6
28	C6	49	B3	60	C6
40	D5	51	C3	62	D5
42	D5	53	E4	63	G4
43	D5	54	E4	67	E4
44	E5				

Locality No.	Location
Between Norris and Lower Geyser Basin	
YF137	Spring on east bank of Gibbon River at first bridge upstream from Beryl Spring.
Upper Geyser Basin	
YF1	Murky spring 70 ft S. 35° W. of Splendid Geyser.
4	40 ft south of 1929 drill hole.
32	Small spring 30 ft N. 70° W. of Old Faithful.
96	Small spring on east side of Firehole River 70 ft S. 40° E. of Cliff Geyser, Black Sand Basin.
109	Small spring between Lone Star Geyser and parking lot.
Smoke Jumper Hot Springs	
YF14	Clear discharging spring 6 ft in diameter on Continental Divide, west of Little Summit Lake.
15	Cloudy discharging spring 150 ft south of YF14.
16	Large boiling pool south of Summit Lake trail at Continental Divide.
Potts Hot Spring Basin	
YF79	Very small spring on Yellowstone Lake side of main road near parking lot.
106	Small intermittent spring flowing from beneath rocks at west end of hot spring area.
Shoshone Geyser Basin	
YF134	Small pool 200 ft S. 45° E. from patrol cabin.

TABLE 3.—*Semiquantitative spectrographic*

[Visual detection limit for each element is given in parentheses. Percentage figures are reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, 0.15, ... M, major constituent; 0, looked for but not found. Italic figures beneath each analysis value, parts per million in the original solution, were calculated by multiplying the analysis value by the evaporation factor indicated below the YF locality number.
The following elements were looked for but not found: P(0.1), As(0.01), Bi(0.003),

Upper Geyser Basin

	YF1 5.85	YF2 14.7	YF3 11.4	YF4 17.1	YF5 18.3	YF8 15.3	YF9 18.4
Al(0.001)	0.07	0.07	0.07	0.07	0.07	0.03	0.3
	.4	*1*	*.8*	*1*	*1*	*.5*	*6*
Fe(0.003)	.015	<.005	.3	<.005	<.005	<.005	.015
	.09	-----	*3*	-----	-----	-----	*.3*
Mg(0.00003)	.03	<.001	.15	<.001	<.001	.007	.007
	.2	-----	*2*	-----	-----	-----	-----
Ca(0.0001)	.15	.07	.7	.07	.07	.07	.07
	.9	*1*	*8*	*1*	*1*	*1*	*1*
Na(0.01)	7	M	M	M	M	M	M
	40	*>140*	*>110*	*>170*	*>180*	*>150*	*>180*
K(0.2)	7	1.5	7	3	3	1.5	1.5
	40	*22*	*77*	*50*	*55*	*23*	*28*
Ti(0.0002)	0	0	0	0	0	0	.0007
	-----	-----	-----	-----	-----	-----	*.01*
Mn(0.0001)	.007	<.0005	.03	<.0005	<.0005	<.0005	.0015
	.04		*.3*	-----	-----	-----	*.03*
B(0.003)	.007	.03	.007	.07	.03	.015	.03
	.04	*.4*	*.08*	*1*	*.6*	*.2*	*.6*
Ba(0.0003)	.007	.0007	.007	<.0005	<.0005	.0007	.0015
	.04	*.01*	*.08*	-----	-----	*.01*	*.03*
Be(0.0001)	0	0	.0007	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Cr(0.0003)	.003	0	.0003	.0003	.0003	.0003	.0003
	.02	-----	*.03*	*.005*	*.005*	*.005*	*.006*
Cu(0.00003)	.003	.0015	.0015	.003	.0015	.003	.0015
	.02	*.02*	*.02*	*.05*	*.03*	*.05*	*.03*
Ga(0.0001)	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Ge(0.0003)	0	.003	0	0	.003	0	0
	-----	*.04*	-----	-----	*.05*	-----	-----
Hg(0.3)	0	0	0	-----	-----	-----	-----
	-----	-----	-----	-----	-----	-----	-----
Li(0.003)	.07	1.5	.15	1.5	1.5	.7	.7
	.4	*22*	*2*	*26*	*27*	*11*	*13*
Mo(0.0003)	0	.0015	0	.0015	.0015	.0015	.0015
	-----	*.02*	-----	*.03*	*.03*	*.02*	*.03*
Ni(0.003)	.0007	0	0	.0007	.0015	0	0
	.004	-----	-----	*.01*	*.03*	-----	-----
Pb(0.0001)	.007	0	.003	0	0	0	.007
	.04	-----	*.03*	-----	-----	-----	-----
Sn(0.0003)	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Sr(0.0003)	<.0005	<.0005	.003	0	0	0	0
	-----	-----	*.03*	-----	-----	-----	-----
V(0.0001)	0	0	0	0	.003	0	0
	-----	-----	-----	-----	*.05*	-----	-----
W(0.003)	0	.015	0	.015	.015	.015	.015
	-----	*.2*	-----	*.3*	*.3*	*.2*	*.3*
Y(0.003)	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Yb(0.0001)	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----

analyses, in percent, of evaporated residues

Cd(0.001), Ce(0.01), Co(0.0001), Dy(0.003), Er(0.001), Eu(0.001), Gd(0.003), Hf(0.002), Ho(0.001), In(0.0001), Ir(0.003), La(0.003), Lu(0.001), Nb(0.0003), Nd(0.01), Os(0.003), Pr(0.01), Re(0.003), Ru(0.003), Sb(0.01), Sc(0.0001), Sm(0.01), Ta(0.01), Tb(0.01), Te(0.03), Th(0.01), Tl(0.001), Tm(0.001), U(0.03), Zn(0.01), Zr(0.0003). The following elements were not determined. Ag, Au, Cs, F, Pd, Pt, Rb, Rh, Si. Analyst, J. C. Hamilton]

	Upper Geyser Basin—Continued			Midway Geyser Basin	West Thumb Pools	Mud Volcano area	Smoke Jumper Hot Springs
	YF32 17.4	YF33 28.6	YF36 17.6	YF10 19.7	YF12 17.0	YF13 25.6	YF14 5.08
Al(0.001)	0.07 *1*	0.07 *2*	0.07 *1*	.15 *3*	.07 *1*	0.7 *18*	0.07 *.4*
Fe(0.003)	.015 *.3*	<.005 -----	<.005 -----	.007 *.1*	<.0015 -----	1.5 *38*	.015 *.08*
Mg(0.00003)	.015 *.3*	.007 *.2*	.007 *.1*	.003 *.06*	<.001 -----	1.5 *38*	.03 *.2*
Ca(0.0001)	.15 *3*	.15 *4*	.15 *3*	.3 *6*	.15 *3*	7 *180*	.15 *.8*
Na(0.01)	M *>170*	M *>280*	.M *>176*	M *>200*	M *>170*	7 *180*	7 *35*
K(0.2)	1.5 *26*	3 *90*	1.5 *26*	1.5 *30*	1.5 *26*	1.5 *38*	7 *35*
Ti(0.0002)	.003 *.05*	0 -----	0 -----	.0007 *.01*	0 -----	0 -----	0 -----
Mn(0.0001)	.0007 *.01*	<.0005 -----	<.0005 -----	.003 *.06*	<.0005 -----	.15 *4*	.007 *.04*
B(0.003)	.03 *.5*	.07 *2*	.015 *.03*	.03 *.6*	.03 *.5*	<.005 -----	.03 *.2*
Ba(0.0003)	.0007 *.01*	<.0005 -----	<.0005 -----	.0015 *.03*	<.0005 -----	.003 *.08*	.007 *.04*
Be(0.0001)	0 -----	0 -----	0 -----	.0003 *.006*	0 -----	0 -----	0 -----
Cr(0.0003)	.0003 *.005*	.0003 *.009*	.0003 *.005*	.0003 *.006*	.0003 *.005*	.003 *.08*	.0007 *.004*
Cu(0.00003)	.0015 *.03*	.003 *.09*	.0007 *.01*	.003 *.06*	.007 *.1*	.0015 *.04*	.007 *.04*
Ga(0.0001)	.003 *.05*	.007 *.02*	0 -----	0 -----	0 -----	0 -----	0 -----
Ge(0.0003)	.003 *.05*	.003 *.09*	0 -----	.003 *.06*	.003 *.005*	0 -----	0 -----
Hg(0.3)	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
Li(0.003)	.7 *12*	.7 *20*	.7 *12*	.7 *14*	.7 *12*	0 -----	0 -----
Mo(0.003)	.0015 *.03*	.0015 *.04*	.0015 *.03*	.0015 *.03*	.003 *.05*	0 -----	0 -----
Ni(0.003)	0 -----	.0007 *.02*	0 -----	0 -----	0 -----	.0015 *.04*	.0007 *.004*
Pb(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	.015 *.08*
Sn(0.0003)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	.003 *.02*
Sr(0.0003)	0 -----	0 -----	0 -----	<.0005 -----	0 -----	.07 *2*	.0015 *.008*
V(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	.003 *.08*	0 -----
W(0.003)	.015 *.3*	.015 *.4*	.015 *.3*	.015 -----	.015 -----	0 -----	0 -----
Y(0.0003)	0 -----	0 -----	0 -----	0 -----	0 -----	.003 *.08*	0 -----
Yb(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	.0003 *.008*	0 -----

TABLE 3.—*Semiquantitative spectrographic analyses,*

	Mammoth Hot Springs area		Norris Geyser Basin				
	YF17 23.0	YF18 21.8	YF19 19.2	YF21 26.9	YF23 10.4	YF24 5.26	YF25 20.1
Al(0.001)	<0.01 -----	<0.01 -----	0.15 *3*	0.015 *.4*	0.15 *2*	3 *16*	0.15 *3*
Fe(0.003)	<.005 -----	<.005 -----	.015 *.3*	<.005 -----	.15 *2*	.3 *.2*	.007 *.1*
Mg(0.00003)	1.5 *35*	3 *60*	.015 *.3*	<.001 -----	.03 *.3*	.07 *.4*	.003 *.06*
Ca(0.0001)	M *>230*	M *>218*	.3 *6*	.7 *20*	.3 *3*	.15 *.8*	.7 *14*
Na(0.01)	7 *140*	7 *145*	M *>192*	M *>270*	M *>100*	3 *16*	M *>200*
K(0.2)	7 *140*	7	7 *140*	7 *170*	7 *70*	3 *16*	7 *140*
Ti(0.0002)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Mn(0.0001)	.0007 *.02*	.0007 *.02*	.007 *.1*	.007 *.2*	.03 *.3*	.015 *.08*	.0007 *.01*
B(0.003)	.007 *.2*	.007 *.2*	.15 *.3*	.3 *8*	.07 *.7*	.03 *.2*	.3 *6*
Ba(0.0003)	.003 *.07*	.003 *.07*	.003 *.06*	.0015 *.04*	.007 *.07*	.015 *.08*	.003 *.06*
Be(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Cr(0.0003)	.0003 *.007*	.0003 *.007*	0 -----	0 -----	0 -----	.0007 *.004*	0 -----
Cu(0.00003)	.0015 *.03*	.003 *.07*	.003 *.06*	.007 *.2*	.0015 *.02*	.015 *.08*	.0015 *.03*
Ga(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Ge(0.0003)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Hg(0.3)	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
Li(0.003)	.15 *4*	.3 *7*	.7 *13*	.7 *20*	.3 *3*	0 -----	.7 *14*
Mo(0.0003)	0 -----	0 -----	.003 *.06*	.007 *.2*	0 -----	0 -----	.003 *.06*
Ni(0.003)	0 -----	0 -----	0 -----	.0007 *.02*	0 -----	0 -----	0 -----
Pb(0.0001)	0 -----	0 -----	0 -----	0 -----	.007 *.07*	.015 *.08*	0 -----
Sn(0.0003)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Sr(0.0003)	.07 *2*	.07 *2*	.0015 *.03*	.0015 *.04*	.0007 *.007*	.0007 *.004*	.003 *.06*
V(0.0001)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
W(0.003)	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----	0 -----
Y(0.0003)	0 -----	0 -----	0 -----	0 -----	.003 *.03*	0 -----	0 -----
Yb(0.0001)	0 -----	0 -----	0 -----	0 -----	.0003 *.003*	0 -----	0 -----

in percent, of evaporated residues—Continued

	Norris Geyser Basin—Continued			Lower Geyser Basin			Beryl Spring
	YF27 5.33	YF28 20.6	YF29 17.6	YF30 9.39	YF34 14.8	YF35 17.2	YF31 19.9
Al(0.001) ------	0.15	0.03	0.07	0.03	0.03	0.07	0.07
	.8	*.6*	*1*	*.3*	*.4*	*1*	*1*
Fe(0.003) -------	.03	<.005	.07	<.005	<.005	<.005	<.005
	.2	-----	*1*	-----	-----	-----	-----
Mg(0.00003) ----	.03	.015	.015	.015	.015	.007	.007
	.2	*.3*	*.3*	*.1*	*.2*	*.1*	*.1*
Ca(0.0001) ------	.15	.15	.15	1.5	.3	.07	.3
	.3	*3*	*3*	*15*	*4*	*1*	*6*
Na(0.01) -------	.7	M	M	M	M	M	M
	35	*>200*	*>175*	*>100*	*>150*	*>170*	*>200*
K(0.2) ----------	0	7	3	3	3	1.5	1.5
		140	*50*	*30*	*40*	*25*	*30*
Ti(0.0002) ------	.0015	0	0	0	0	0	0
	.008	-----	-----	-----	-----	-----	-----
Mn(0.0001) -------	.0007	<.0005	.0015	.07	.007	<.0005	.0007
	.004	-----	*.03*	*.7*	*.1*	-----	*.01*
B(0.003) -------	.03	.3	.3	.03	.03	.07	.07
	.2	*.6*	*.5*	*.3*	*.4*	*1*	*1*
Ba(0.0003) ------	.003	.0007	.007	.003	<.0005	<.0005	<.0005
	.02	*.01*	*.01*	*.03*	-----	-----	-----
Be(0.0001) ------	0	0	0	.0003	0	0	0
	-----	-----	-----	*.003*	-----	-----	-----
Cr(0.0003) ------	.0007	0	0	.0003	.0003	.0003	.0003
	.004	-----	-----	*.003*	*.004*	*.005*	*.006*
Cu(0.00003) ----	.0015	.0007	.0007	.003	.007	.003	.003
	.008	*.01*	*.001*	*.03*	*.01*	*.05*	*.06*
Ga(0.0001) ------	0	0	0	0	0	0	.0007
	-----	-----	-----	-----	-----	-----	*.01*
Ge(0.0003) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Hg(0.3) --------	-----	-----	-----	-----	-----	-----	-----
	-----	-----	-----	-----	-----	-----	-----
Li(0.003) -------	.07	1.5	1.5	.3	.3	.7	.7
	.4	*31*	*25*	*3*	*4*	*12*	*14*
Mo(0.0003) ------	.0015	.003	0	0	.0015	.0015	.007
	.008	*.06*	-----	-----	*.02*	*.03*	*.1*
Ni(0.003) -------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Pb(0.0001) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Sn(0.0003) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Sr(0.0003) ------	0	.0015	.0007	.0015	0	0	0
	-----	*.03*	*.001*	*.01*	-----	-----	-----
V(0.0001) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
W(0.003) -------	0	0	0	0	0.15	.015	0
	-----	-----	-----	-----	*.2*	*.3*	-----
Y(0.0003) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----
Yb(0.0001) ------	0	0	0	0	0	0	0
	-----	-----	-----	-----	-----	-----	-----

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