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CHEMICAL AND ISOTOPIC COMPOSITIONS OF SELECTED SODA AND HOT SPRING WATERS AND GASES, COLORADO

By T. S. Presser, W. C. Evans, L. D. White and Ivan Barnes

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ABSTRACT

Results of chemical and isotopic analyses of water and gases of twelve soda springs and two hot springs of Colorado are reported.

As part of the investigations of ground water by the U.S. Geological Survey, soda springs of Colorado have been sampled and analyzed. Two hot springs were also analyzed for comparison. The locations of the springs (or wells) and the geologic material from which they issue are given in table 1.

The methods of sample collection and field determinations of pH and alkalinity are given in Presser and Barnes (1974). Water samples were immediately pressure-filtered through a 0.1 μm (micrometer) membrane filter using compressed nitrogen. Samples collected for Group II metals were acidified with concentrated hydrochloric acid to pH 2. Twenty-five milliliters of filtered sample were diluted to 50 ml. (milliliters) with deionized water to slow the polymerization of silica. Two samples of untreated water were collected in 15 ml glass bottles with polyseal caps for stable isotope analysis of hydrogen and oxygen. Dissolved carbon dioxide species were precipitated for carbon isotope ratio determination by adding 20 ml. of saturated ammoniacal strontium chloride solution through a 0.45 μm filter to 100 ml. of untreated sample (Gleason, 1969). Samples of gases escaping from the spring were collected in evacuated glass sample bulbs.

Sodium, potassium, calcium and magnesium were determined by atomic absorption spectrophotometry (AAS). Methods for the analysis of boron, silica and the anions are described in Skougstad and others (1979). Specifically the methods are: dianthrimide (0.1 to 1.0 mg/L) and carmine (1.0 to 10 mg/L) for boron; molybdate blue and AAS for silica (duplicate analyses); mohr (>12 mg/L) and ferric thiocyanate (1 to 12 mg/L) for chloride; thorin for sulfate; specific ion electrode for fluoride; and hypochlorite oxidation for bromide and iodide. These methods were modified to overcome interferences from iron hydroxide and calcite precipitates and hydrogen sulfide.

Isotopic ratios of $^{18}O/^{16}O$, D/H, $^{13}C/^{12}C$ and $^{15}N/^{14}N$ were measured on a modified Nier double-collecting 6-inch 60° sector mass spectrometer. The methods of sample preparation were: CO_2-equilibration method of Cohn and Urey (1938) for oxygen; the uranium technique of Bigeleisen and others (1952) for hydrogen; and the phosphoric acid technique of McCrea (1950) for carbonates. The $SrCO_3$ precipitate for carbon isotope analysis had been previously filtered and washed with CO_2-free water. The filtration and washing were done in a glove box with an argon atmosphere. The dried precipitate was homogenized by grinding in a ball mill. The chemical and isotopic data for the waters and CO_2 gas are given in table 2.

Gases were analyzed by gas chromatography as soon as possible after returning to the laboratory, always within two weeks of collection. Linde Molecular Sieve 5A[1/] was used to separate and quantify He, H_2, O_2, Ar, N_2 and CH_4, while Porapak Q was used for C_2H_6 and CO_2. Helium was used as the carrier gas except in the analysis for He and H_2 where argon carrier was employed. The results of chemical analyses and the $\delta^{15}N$ compositions of the gases are given in table 3.

1/ The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

REFERENCES CITED

Bigeleisen, Jacob, Perlman, M. L., and Prosser, H. C., 1952, Conversion of hydrogenic materials to hydrogen for isotope analysis: Anal. Chemistry, v. 24, p. 1356-1357.

Cohn, Mildred, and Urey, H. C., 1938, Oxygen exchange reactions of organic compounds and water: Am. Chem. Soc. Jour., v. 60, p. 679.

Epis, R. C., Wobus, R. A., and Scott, G. R., 1979, Preliminary geologic map of the Black Mountain Quadrangle, Fremont and Park Counties, Colorado. U.S. Geol. Survey Open-File Report 79-652.

Gleason, J. D., Friedman, Irving, and Hanshaw, B. B., 1969, Extraction of dissolved carbonate species from natural water for carbon-isotope analysis: U.S. Geol. Survey Prof. Paper 650-D, p. D248-D250.

Hail, W. J., Jr., 1972. Reconnaissance geologic map of the Cedaredge Area, Delta County, Colorado. U.S. Geol. Survey Miscellaneous Geologic Investigations Map I-697.

Hedlund, D. C. and Olson, J. C., 1975. Geologic map of the Powderhorn Quadrangle, Gunnison and Saguache Counties, Colorado. U.S. Geology Survey Geologic Quadrangle Map GQ 1178.

McCrea, J.M,, 1950. The isotopic chemistry of carbonates and a paleotemperature scale: J. Chem Phys., 18, p. 849-857.

McKnight, E. T., 1974. Geology and ore deposits of the Rico District, Colorado. U.S. Geol. Survey Prof. Paper 723, 100 p.

Presser, T. S. and Barnes, Ivan, 1974, Special techniques for determining chemical properties of geothermal water: U.S. Geol. Survey Water-Resources Inv. 22-74, 11 p.

Scott, G. R., Van Alstine, R. E., and Sharp, W. N., 1975, Geologic map of the Poncha Springs Quadrangle, Chaffee County, Colorado, U.S. Geol. Survey Miscellaneous Field Studies Map MF-658.

Scott, G. R. and Wobus, R. A., 1973, Reconnaissance geologic map of Colorado Springs and vicinity, Colorado. U.S. Geol. Survey Miscellaneous Field Studies Map MF-482.

Skougstad, M. W., Fishman, M. J., Friedman, L. C., Erdmann, D. E., and Duncan, S. S., 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geol. Survey Techniques of Water-Resources Inv., book 5, chap. A1, 626 p.

Steven, T. A., Lipman, P. W., Hail, W. J., Jr., Barker, Fred and Luedke, R. G., 1974, Geologic map of the Durango Quadrangle, Southwestern Colorado. U.S. Geol. Survey Miscellaneous Investigations Series Map I-764.

Tweto, Ogden, 1976A. Geologic map of the Craig 1° x 2° Quadrangle, northwestern Colorado, U.S. Geol. Survey Miscellaneous Investigations Series Map I-972.

Tweto, Ogden, 1976B. Preliminary geologic map of Colorado. U.S. Geol. Survey Miscellaneous Field Studies Map 788.

Tweto, Ogden, Moench, H. and Reed, J. C., Jr., 1976. Preliminary geologic map of the Leadville 1° x 2° Quadrangle, northwestern Colorado, U.S. Geol. Survey Miscellaneous Field Studies Map MF 760.

Tweto, Ogden, Steven, T. A., Hail, W. J., Jr. and Moench, R. H., 1976, Preliminary Geologic map of the Montrose 1° x 2° Quadrangle, southwestern Colorado. U.S. Geol. Survey Miscellaneous Field Studies Map MF 761.

Table 1. Names of springs, rock types, ages of known or inferred bedrock and locations.

Name	Rock Type	Age	Reference	Location: Latitude	Location: Longitude
Steamboat Springs	Limestone	Jurassic	Tweto (1976A)	40°29.3'N	106°50.45'W
Juniper Hot Spring	Sandstone	Mesozoic	Tweto (1976A)	40°28.02'N	107°57.17'W
Idaho Springs	Biotite gneiss	Proterozoic	Tweto (1976B)	39°44.37'N	105°30.72'W
Glenwood Springs	Sandstone	Pennsylvanian	Tweto, Moench and Reed (1976)	39°33.0'N	107°19.0'W
Manitou Springs Iron Geyser	Granite	Proterozoic	Scott and Wobus (1973)	38°51.42'N	104°55.7'W
Manitou Springs Seven Minute Spring	Fountain arkose	Permian and Pennsylvanian	Scott and Wobus (1973)	38°51.6'N	104°55.0'W
Mineral Spring	Dakota sandstone	Cretaceous	Hail (1972)	38°47.33'N	107°56.20'W
Yellow Soda Spring	Biotite gneiss	Proterozoic	Epis and others (1979)	38°44.3'N	105°31.72'W
Princeton Hot Spring	Quartz monzonite	Oligocene to Eocene	Scott and others (1975)	38°44'N	106°10'W
Hortense Hot Spring	Quartz monzonite	Oligocene to Eocene	Scott and others (1975)	38°44.00'N	106°10.43'W
Cimarron Spring	Biotite gneiss and granite	Proterozoic	Tweto, Steven and others (1976)	38°27'N	107°33'W
Powder Horn Hot Spring	Ash flow on felsite	Oligocene, Precambrian	Hedlund and Olson (1975)	38°17'N	107°7'W
Rico, Iron Draw	Hermosa Formation (marine clastic sediments and limestone)	Pennsylvanian	McKnight (1974)	37°41'N	108°0'W
Trimble	Sandstone	Pennsylvanian	Steven and others (1974)	37°23.5'N	107°50.9'W

Table 2. Chemical and isotopic compositions of water from selected CO_2-rich springs of Colorado. Concentrations are in mg/L. Isotopic compositions are permil relative to SMOW (^{18}O and D) and PDB (^{13}C). Two hot springs (Hortense and Princeton) are given for comparison.

Name	Field Number	$\delta^{18}O$	δD	T°C	pH	SiO_2	Ca	Mg	Na	K	$H_2CO_3^1$	HCO_3^2	$\delta^{13}C$ $SrCO_3$	$\delta^{13}C$ $CO_2(g)$	Cl	SO_4	F	B	Br	I
Steamboat Spring	CQ75IB77	-17.77	-136.7	26.	6.55	24.	110.	31.	2200.	130.	1670.	3430.	-4.41	-7.30	1400.	540.	3.5	5.4	3.6	0.3
Juniper Spring	CQ74IB77	-18.93	-141.3	37.	7.98	36.	3.0	0.33	470.	2.0	21.	1100.	-2.21		93.	2.	3.4	0.56		
Idaho Spring	CQ77IB77	-15.90	-117.4	50.	6.33	68.	130.	39.	515.	73.	1100.	1470.	-4.66	-6.22	68.	400.	4.2	0.40		
Glenwood Spring	CQ76IH77	-17.73	-133.9	51.	6.32	33.	460.	88.	6750.	160.	410.	782.	-5.72	-8.08	10500.	1100.	2.3	1.0	2.3	0.4
Manitou Iron Geyser	CQ80IB77	-12.11	-84.5	10.	6.03	75.	185.	31.	495.	82.	3500.	1600.	-3.30	-5.08	195.	210.	4.7	1.2		
Manitou 7-Minute Spr.	CQ81IB77	-11.91	-84.6	11.	6.28	22.	460.	125.	470.	50.	2900.	2540.	-2.87	-5.33	330.	240.	1.4	0.96		
Mineral (Delta, CO)	CQ86IB77	-11.59	-108.5	15.	6.55	10.	170.	50.	4550.	120.	2300.	4570.	-4.70	-8.50	3900.	1400.	2.4	12.	13.0	0.6
Yellow Soda Spring	CQ78IB77	-11.59	-86.0	8.	6.64	78.	240.	150.	1500.	60.	1600.	3060.	-1.45	-7.07	1300.	120.	2.5	1.0	6.0	<0.1
Princeton Hot Spring	CQ82IB77	-15.65	-116.9	55.	8.50	63.	9.6	0.27	57.	1.9	0.31	68.	-11.5		5.1	61.	9.4	0.35		
Hortense Hot Spring	CQ83IB77	-15.80	-118.8	83.	8.58	79.	4.1	<.1	90.	2.8	0.24	80.	-8.54		8.4	95.	16.2	0.17		
Cimarron	CQ85IB77	-16.31	-126.6	13.	6.15	12.	130.	34.	495.	71.	2100.	1320.	-6.43	-6.81	155.	340.	3.7	1.4		
Powder Horn Hot Spring	CQ84IB77	-15.89	-127.1	41.	6.53	80.	120.	49.	305.	63.	590.	1170.	-3.42	-6.27	120.	120.	4.7	1.2		
Rico, CO	CQ87IB77	-15.86	-112.4	35.5	6.65[3] 6.0	120.	690.	98.	75.	29.	590. 2668.	1730.	-1.96	-6.13	3.0	890.	2.3	0.12		
Trimble Spring	CQ88IB77	-14.45	-106.2	43.	5.98	74.	470.	37.	420.	40.	1700.	1090.	-5.80	-6.28	200.	1100.	3.0	1.3		

[1] Calculated
[2] Total alkalinity as HCO_3
[3] Geysering spring: pH recorded after eruption and shortly before eruption, respectively.

Table 3. Chemical compositions of gases from selected CO_2-rich springs of Colorado and the $\delta^{15}N$ of the N_2-rich gases. Concentrations are in volume percent; the $\delta^{15}N$ in parts per thousand is referred to air. The gases from two hot springs (Hortense and Princeton) are given for comparison.

	Juniper Spring CQ74IB77	Steamboat Spring CQ75IB77	Glenwood Spring CQ76IB77	Idaho Spring CQ77IB77	Yellow Soda Spring CQ78IB77	Manitou Iron Geyser CQ80IB77	Manitou 7-Minute Spring CQ81IB77
He	0.22	<0.02	0.90	<0.02	0.06	0.02	<0.02
H_2	0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Ar	0.38	<0.02	0.78	0.06	0.17	0.03	0.02
O_2	<0.02	0.04	<0.02	0.11	0.38	<0.02	0.30
N_2	20.53	0.20	35.57 $\delta^{15}N = 0.96$	2.60	7.04 $\delta^{15}N = 1.94$	1.58	0.75
CH_4	77.18	0.02	0.27	<0.005	0.005	0.005	<0.005
CO_2	1.41	98.00	61.56	96.73	91.97	98.04	98.88
C_2H_6	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
H_2S		∿0.4					
	99.78	98.66	99.08	99.50	99.62	99.69	99.95

(Continued)

Table 3. Chemical compositions of gases from selected CO_2-rich springs of Colorado and the $\delta^{15}N$ of the N_2-rich gases. Concentrations are in volume percent; the $\delta^{15}N$ in parts per thousand is referred to air. The gases from two hot springs (Hortense and Princeton) are given for comparison. (continued)

	Princeton Hot Spring CQ82IB77	Hortense Spring CQ83IB77	Powder Horn Hot Spring CQ84IB77	Cimarron CQ85IB77	Delta, CO CQ86IB77	Rico, CO CQ87IB77	Trimble Spring CQ88IB77
He	0.02	0.06	<0.02	0.07	<0.02	<0.02	<0.02
H_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ar	1.31	2.10	0.07	0.21	0.02	<0.02	0.02
O_2	8.53	0.05	0.31	<0.02	<0.02	<0.02	0.04
N_2	88.48 $\delta^{15}N = 1.19$	96.60 $\delta^{15}N = -0.21$	2.32 $\delta^{15}N = -0.08$	5.77 $\delta^{15}N = -0.93$	0.45	0.04	0.74
CH_4	<0.01	<0.01	0.01	0.01	0.01	<0.005	<0.005
CO_2	0.16	0.28	96.30	92.34	97.85	99.23	98.47
C_2H_6	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	98.50	99.09	99.01	98.40	98.33	99.27	99.27