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Radioactive Springs Geochemical Data Related

to Uranium Exploration--Basic Data and Use of

Multivariate Factor Scores

by

Robert A. Cadigan and J. Karen Felmlee

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ABSTRACT

Radioactive springs and wells at 33 localities in the States of Colorado,
Utah, Arizona, and New Mexico have been studied and sampled to obtain
geochemical data to determine whether such data are useful in a uranium
exploration program. Most samples were collected from mineral-rich springs
probably related to hydrothermal systems of various ages.

Two sets of data were obtained, the first based on the chemical
composition and physical and chemical properties of spring and ground water,
and the second based on the chemical composition of mineral precipitates
deposited by radioactive springs. Multivariate statistical analysis of the
water data suggests four major geochemical factors affecting the 23 parameters
measured. These factors were labeled as total dissolved solids, alkalinity,
temperature, and Fe-U concentration. Multivariate statistical analysis of the
precipitate data suggests five factors affecting the 32 element values
measured. These factors were labeled as mineral contamination, Mn
precipitation, Fe-As-Be precipitation, heavy metals precipitation, and Ba-Ra
precipitation.

Relative intensities of the geochemical processes represented by the
factors were computed using factor scores. Sample localities were ranked on

the basis of relative intensities, and the five localities with the highest intensities were selected as being the most favorable for more intensive exploration for uranium.

Immediate use of such selection would be experimental because of the lack of industry experience at this time in the exploration of active hydrothermal systems for uranium.
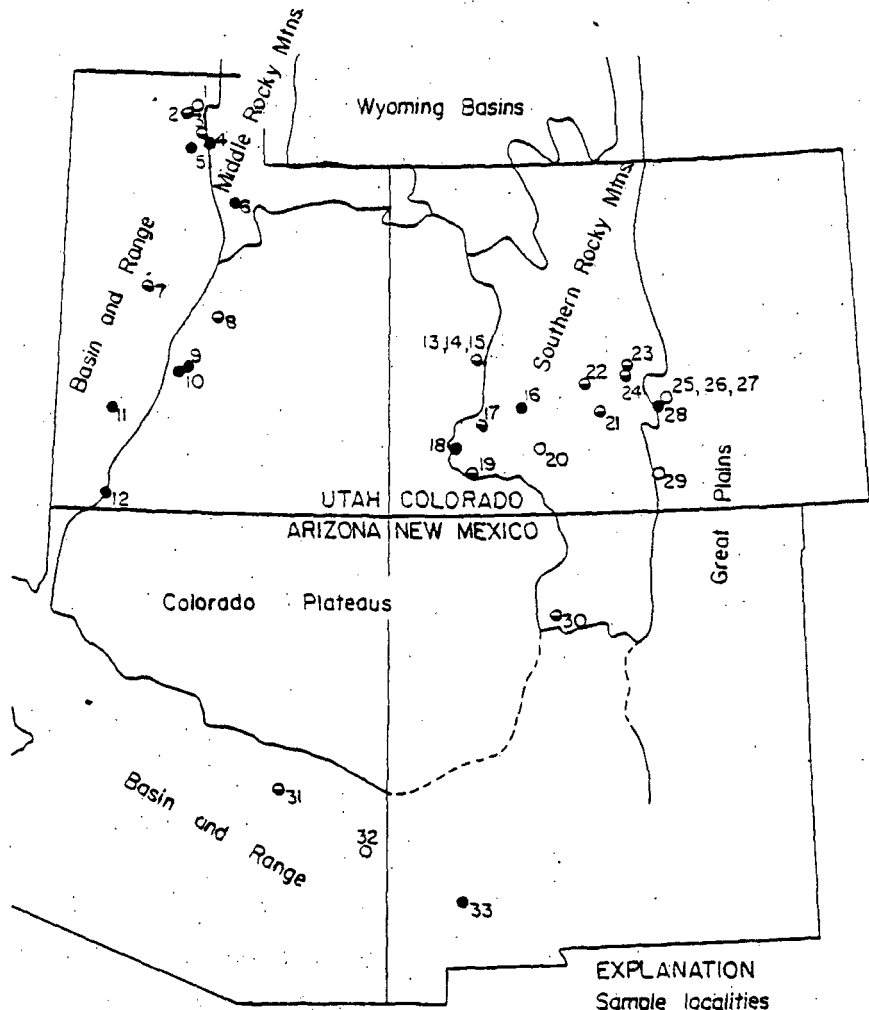
Introduction

The purposes of this report are (1) to present the geochemical data which formed the basis for a previous report and (2) to illustrate the use of multivarite factor analysis for the purpose of evaluating relative favorability of areas containing uranium-bearing mineral springs. The previous report, entitled "Radioactive springs geochemical data related to uranium exploration," was presented at the 25th International Geological Congress in Sydney, Australia, in August 1976, and has since been published (Cadigan and Felmlee, 1977). The reader is referred to the 1977 report for discussions of previous work, sampling and analytical methods, sample bias, mineralogy of precipitates and other related information which for the sake of brevity will be omitted here.

Area of study

The 33 springs whose geochemical characteristics are described in this report are located in the Southern Rocky Mountains of Colorado and New Mexico and in the Basin and Range province of New Mexico, Arizona, and Utah. The Colorado Plateau occupies the center of this area but contains relatively few recognized mineral or thermal springs, and these are located near the margins of the Plateau. Sample localities and kinds of analytical data available from each site for this report are shown on figure 1. Table 1 lists the sample localities by county, State, and geographic longitude and latitude.

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Table 1.--Sample localities

	Locality	County	Latitude	Longitude
		Utah		
1.	Crystal Hot Springs....................	Box Elder	N41.39.34	W112.05.13
2.	Stinking Hot Springs...................	Box Elder	41.34.38	112.13.55
3.	Utah Hot Springs......................	Box Elder	41.20.20	112.01.44
4.	Ogden Hot Springs....................	Weber	41.14.09	111.55.16
5.	Hooper Hot Springs..................	Davis	41.08.13	112.10.33
6.	Midway Hot Springs.................	Wasatch	40.31.35	111.29.13
7.	Baker Hot Springs....................	Juab	39.36.49	112.43.49
8.	Cold Stinkng Springs..............	San Pete	39.14.19	111.39.19
9.	Redhill Hot Springs...............	Sevier	38.38.26	112.05.53
10.	Joseph Hot Springs.................	Sevier	38.36.52	112.12.07
11.	Thermo Hot Springs................	Beaver	38.10.24	113.12.20
12.	Pah Tempe Hot Springs.............	Washington	37.11.24	113.16.16
		Colorado		
13.	Col. Chinn flowing well............	Delta	38.5022	107.38.22
14.	Doughty Springs.....................	Delta	38.46.12	107.45.34
15.	Alum Gulch (no water)..............	Delta	38.46.00	107.45.53
16.	Cebolla Hot Springs................	Gunnison	38.16.46	107.06.25
17.	Box Canyon Hot Springs............	Ouray	38.01.08	107.40.27
18.	Dunton Hot Springs..................	Dolores	37.46.16	108.05.34
19.	Bakers Bridge Hot Springs..........	La Plata	37.26.58	107.48.23
20.	Wagon Wheel Gap Hot Springs.......	Mineral	37.45.00	106.50.00
21.	Mineral Hot Springs...............	Saguache	38.10.08	105.55.00
22.	Poncha Hot Springs................	Chaffee	38.24.48	106.04.35
23.	Guffey Soda Springs...............	Park	38.44.19	105.31.48
24.	Taylor Soda Springs...............	Fremont	38.36.10	105.33.00
25.	Pumped well (Siloam)..............	Pueblo	38.13.01	104.59.16
26.	Pumped well (Colordo City area)....	Pueblo	37.56.30	104.49.17
27.	Pumped well (Beulah)..............	Pueblo	38.04.35	104.56.21
28.	Lower Red Creek Soda Springs (dry)	Pueblo	38.42.30	105.29.25
29.	La Veta Sulfur Springs............	Huerfano	37.28.00	105.06.00
		Arizona		
31.	Salt Banks Springs.................	Gila	33.49.56	110.35.49
32.	Clifton Hot Springs................	Greenlee	33.04.48	109.18.11
		New Mexico		
30.	Soda Dam Hot Springs..............	Sandoval	35.47.28	106.41.09
33.	Faywood Hot Springs...............	Grant	32.33.17	107.57.42

EXPLANATION
Sample localities
○ Water only
● Precipitate only
◐ Water and precipitate

0 ———— 100 Miles

0 ———— 100 Kilometers

1. Crystal Hot Springs	12. Pah Tempe Hot Springs	23. Guffey Soda Springs
2. Stinking Hot Springs	13. Col. Chinn flowing well	24. Taylor Soda Springs
3. Utah Hot Springs	14. Oughty Springs	25. Pumped well
4. Ogden Hot Springs	15. Alum Gulch	26. Pumped well
5. Hooper Hot Springs	16. Ceballa Hot Springs	27. Pumped well
6. Midway Hot Springs	17. Box Canyon Hot Springs	28. Lower Red Cr. Soda Springs
7. Baker Hot Springs	18. Dunton Hot Springs	29. La Veta Sulfur Springs
8. Cold Stinking Springs	19. Baker's Bridge Hot Springs	30. Soda Dam Hot Springs
9. Redhill Hot Springs	20. Wagon Wheel Gap Hot Springs	31. Salt Banks Springs
10. Joseph Hot Springs	21. Mineral Hot Springs	32. Clifton Hot Springs
11. Thermo Hot Springs	22. Poncha Hot Springs	33. Faywood Hot Springs

Figure 1.- Sample localities of selected springs and flowing or pumped wells. The symbols indicate the kind of samples for which data are available.

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Data

Physical properties and geochemistry of the spring water and precipitate samples vary considerably. Table 2 shows the range of values and the median value for each measured parameter. The data used for statistical analysis in this report are given in tables 3 and 4. Data on water (table 3) were compiled from analyses of our samples and from analyses published in other reports since 1962 by the U.S. Geological Survey and by other organizations. Data on precipitates, table 4, are entirely from our own samples.

Mineralogy

The term "travertine" (properly a field term) has been used to describe the hard crystalline precipitates associated with many mineral springs. Travertine may consist of almost pure calcite or a mixture of minerals that can be differentiated by X-ray diffraction. Calcite most commonly composes 10 percent or more of each of the samples of precipitate that we collected. Other minerals present that compose 10 percent or more of at least one sample are barite, manganite, hematite, goethite, gypsum, fluorite, romanechite $(BaMn^{+2}Mn_8^{+4}O_{16}(OH)_4)$, and pyrolusite. Quartz, feldspar, dolomite, and mica are among the minerals identified that represent detrital grains and rock fragments in the samples. X-ray diffractometer traces do not account for the significant amounts of As or W known to be present, as shown in tables 2 and 4. This discrepancy suggests that these two metals are present in amorphous or noncrystalline forms. Some precipitates contain native sulfur in minor to major amounts. At some springs, deposits of Fe and Mn minerals as well as S have been mined as ores. Parts of the Stinking Hot Springs travertine deposit were found to be composed almost entirely of barite; part of it has been mined, first as a possible uranium ore (because of its high radioactivity), then later as a soil conditioner.

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Table 2.--Summary of analytical results for samples from localities
shown on figure 1

[27 water samples from 21 sites; 54 precipitate samples from 25 sites.]

	Water				Precipitate		
Parameter	Min.	Max.	Median	Parameter	Min.	Max.	Median
Temperature(°C)....	7	78	30	Data in parts per million			
pH.................	2.9	9.6	7.1	Ca.........	10,000	>100,000	>100,000
Alkalinity[1]........	0	1,610	--	Mg.........	200	>20,000	5,000
Specific conductance				Fe.........	300	100,000	20,000
(μmhos/cm at 25°	170	52,000	3,200	Mn.........	30	100,000	700
Data in milligrams per liter				Si.........	700	>100,000	20,000
Dissolved solids				Al.........	200	>100,000	5,000
(sum)..............	87	43,500	2,120	Na.........	500	>100,000	7,000
SiO_2..............	.7	86	36	K..........	<7,000	100,000	<7,000
Ca.................	3.9	930	110	Ti.........	1	5,000	150
Mg.................	.4	330	24				
Na.................	15	15,000	560	As.........	<1,000	>100,000	<1,000
				B..........	<20	200	<20
K..................	1.6	870	36	Ba.........	3	>100,000	1,000
HCO_3..............	0	4,330	323	Be.........	<1.5	500	10
CO_3..............	0	13	0	Co.........	<5	200	<5
SO_4..............	1.9	1,500	160				
Cl.................	3.4	26,000	320	Cr.........	<1	150	5
				Cu.........	<1	150	5
F..................	.3	12	2.4	Mo.........	<3	50	<3
NO_3..............	<.1	.48	<.1	Nb.........	<10	20	<10
PO_4..............	<.01	.77	.03	Ni.........	<5	50	<5
Data in micrograms per liter				Pb.........	<10	1,500	10
Fe..................	<10	47,000	120	Sb.........	<200	700	<200
Mn.................	<1	2,200	130	Sc.........	<5	100	<5
Ba.................	6	7,600	100	Sr.........	200	15,000	5,000
Sr.................	24	38,000	2,500	V..........	<1	150	<7
Mo.................	<.5	760	18				
				W..........	<100	10,000	<100
Li.................	7	14,000	1,500	Y..........	<10	500	<15
B..................	4	23,000	780	Zr.........	<10	500	20
Al.................	10	10,000	50	Ga.........	<5	150	<5
Ra.................	.52	420	9.1	Ge.........	<10	100	<10
U..................	<.4	95	<.4				
				Li.........	<100	300	<100
				eU.........	<10	6,010	250
				RaeU[2]......	435	8,500	--
				U[2]........	<.20	38.32	--
				Th[2]........	<4	11.61	--

[1]Only 16 samples.
[2]Only 17 of the most radioactive samples.

Table 3.--Analytical data for water samples from localities shown on Figure 1.

[Major ions were analyzed by wet chemical method; trace metals, by emission spectrography; radium by radiochemical method; and uranium, by extraction fluorometry   Data for locs. 20-24 and 29 are from Mallory and Barnett (1973) and V. J. Janzer (written commun., 1974); major ion data for location 7 are from Mundorff (1970), and radium and uranium values for loc. 19 are from Scott and Voegeli (1961) and for loc. 1 are from O'Connell and Kaufmann (1976).]

Locality No.	Sample No.	Temperature (°C)	pH	Dissolved solids (calculated) (mg/l)	Bicarbonate + Carbonate ($HCO_3 + CO_3$) (mg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Chloride (Cl) (mg/l)	Sulfate (SO_4) (mg/l)	Fluoride (F) (mg/l)
1	76MSW-8	56	6.3	43500	471	800	180	15000	780	26000	470	1.3
2	76MSW-5	43	6.6	27900	443	740	330	9000	490	17000	79	.9
3	76MSW-15	54	7.4	20400	195	910	25	6300	870	12000	180	3.7
7	75MSW-18	78	7.1	3630	160	345	68	816	48	1450	756	4.1
8	76MSW-19	11	7.8	3120	1420	45	23	1200	19	1100	16	2.7
13	75MSW-6	41	6.6	2000	1540	110	34	610	36	370	58	2.4
14	75MSW-4	15	6.5	3200	2150	110	43	1100	47	720	94	2.5
14	75MSW-5	14	2.9	2120	0	170	98	180	22	25	1500	.7
14	75MSW-3	13	6.3	2450	1290	98	140	560	28	320	620	1.6
17	75MSW-27	45	7.9	1680	129	380	9	120	10	43	1000	3.1
19	75MSW-28	30	7.2	3670	162	350	54	830	71	1500	720	2.7
20	MIN-1	50	6.7	1490	976	66	15	448	44	199	132	8.7
20	MIN-2	57	7.0	1500	976	65	14	462	46	231	165	8.0
21	SAG-5	62	7.2	655	323	57	13	146	14	38	165	4.3
21	SAG-4	58	7.2	649	323	58	13	146	13	38	159	4.3
22	CHA-7	68	7.4	657	195	16	.4	196	7.6	49	193	12
22	CHA-6	68	7.5	649	189	18	.6	198	8.0	47	188	10
23	PAR-4	10	6.7	4840	2930	110	96	1600	71	1330	134	1.9
24	FRE-1	9	6.8	9940	4330	45	125	3650	200	3930	113	2.3
25	75MSW-10	20	6.5	1950	1440	130	46	520	41	240	230	1.8
26	75MSW-11	18	9.6	87	84	3.9	7	19	2.5	3.4	1.9	.3
27	75MSW-13	13	6.9	245	161	48	13	15	2.9	4	67	.6
29	HUE-5	7	7.5	304	267	33	4.5	75	1.9	9.5	42	.5
29	HUE-4	7	7.2	297	256	31	4.4	74	1.6	10	49	.5
30	75MSW-8	29	6.7	3330	721	230	23	980	190	1500	43	.4
31	76MSW-1	21	7.3	34200	1960	520	220	12000	260	19000	1100	2.8
32	75MSW-2	56	7.5	10500	136	930	24	3000	21	6400	43	2.2

Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.

[All data are in parts per million. All elements were determined by semiquantitative spectrographic method by H. G. Nieman and M. Solt; eU was done by beta-gamma radiometric method by I. C. Frost. Letters indicate qualified values: G, greater than the upper limit of determination; L, detected in concentration below the lower limit of determination; N, not detected. The sample from loc. 15 also contains Ce, Nd, and Sm; one sample from loc. 22 also has Zn; and several samples from loc. 31 contain Zn, Tl, Ce, or Nd.]

Loc.	Sample No.	Iron (Fe)	Magnesium (Mg)	Calcium (Ca)	Titanium (Ti)	Manganese (Mn)	Arsenic (As)	Boron (B)	Barium (Ba)	Beryllium (Be)	Cobalt (Co)
2	75MS-102B	3000	7000	100000G	700	200	1000N	20N	100000	1.5N	5N
2	75MS-103B	5000	20000	100000G	700	150	1000N	30	70000	1.5N	5N
2	75MS-101B	700	3000	100000G	70	100	1000N	20N	100000G	1.5N	5N
3	75MS-105	50000	200	100000G	5000	10000	1000N	20N	1000	20	5N
3	75MS-104	50000	1000	100000G	70	20000	1000N	30	1500	20	5N
4	75MS-106B	50000	2000	100000G	300	10000	1000N	20N	1000	15	5N
5	75MS-107	20000	7000	50000	700	50000	1000N	150	30000	1.5N	5
6	75MS-108	1000	5000	100000G	70	70	1000N	20N	200	1.5L	5N
7	75MS-109B	100000G	2000	100000G	150	10000	1000N	20N	5000	15	5N
7	75MS-111B	100000G	7000	100000G	200	50000	1000	20N	10000	20	5N
7	75MS-110	20000	10000	100000G	100	200	1000N	20N	200	1.5	5N
8	75MS-112	10000	15000	100000G	1000	100	1000N	30	10000	1.5N	5N
9	75MS-113B	100000G	1000	100000	150	50000	100000G	20N	7000	50	5N
9	75MS-115	15000	3000	100000G	100	700	1000N	20N	300	3	5N
9	75MS-114	20000	500	100000G	10	5000	1000	20N	1500	5	5N

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Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.--Continued

Loc.	Sample No.	Iron (Fe)	Magnes-ium (Mg)	Calcium (Ca)	Titanium (Ti)	Manganese (Mn)	Arsenic (As)	Boron (B)	Barium (Ba)	Beryl-lium (Be)	Cobalt (Co)
10	75MS-116	30000	7000	100000G	200	20000	1000	20N	2000	10	5N
11	75MS-117	7000	10000	70000	500	150	1000N	100	500	10	5N
12	75MS-118	300	3000	100000G	7	50	1000N	20N	100	1.5N	5N
14	75MS-34	3000	2000	100000G	200	1500	1000N	20L	100000G	5	5N
14	75MS-33	3000	500	50000	200	500	1000N	20N	100000G	5	5N
15	75MS-35	1000	1000	100000G	20	30	1000N	20N	3	1.5N	5N
16	75MS-29	1500	15000	100000G	30	700	1000N	20N	500	7	5N
17	75MS-30	100000G	200	10000	5000	100000G	7000	20N	15000	200	7
17	75MS-122B	7000	300	100000G	70	100000G	1000N	20N	15000	50	20
18	75MS-119	3000	3000	100000G	15	3000	1000N	20N	70	1.5N	5N
19	75MS-123	10000	2000	100000G	5000	1000	1000N	20N	70	7	5N
21	75MS-20	15000	3000	100000G	50	1000	1000N	20N	5000	3	5N
21	75MS-21	10000	5000	100000G	70	150	1000N	20N	2000	5	5N
21	75MS-22	2000	10000	100000G	10	200	1000N	20N	500	3	5N
22	75MS-25	100000G	1000	30000	50	100000G	1000N	20N	100000	100	5
22	75MS-27	10000	1500	70000	150	100000G	1000N	20N	100000G	50	5N
22	75MS-26	5000	1500	100000G	20	1000	1000N	20N	500	7	5N
23	75MS-1	100000G	3000	70000	150	150	3000	20N	700	70	5N
23	75MS-4	100000G	7000	100000G	200	200	2000	20N	500	50	5N
23	75MS-2	20000	7000	100000G	150	200	1000N	20N	150	20	5N

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Loc.	Sample No.	Iron (Fe)	Magnes- ium (Mg)	Calcium (Ca)	Titanium (Ti)	Manganese (Mn)	Arsenic (As)	Boron (B)	Barium (Ba)	Beryl- lium (Be)	Cobalt (Co)
23	75MS-5	10000	3000	100000G	20	300	1000N	20N	100	10	5N
23	75MS-3	5000	10000	100000G	50	300	1000N	20N	150	7	5N
24	75MS-17	100000G	3000	70000	200	70	20000	200	1000	300	5N
24	75MS-14	100000G	3000	70000	150	70	100000	50	1000	300	5N
24	75MS-11	100000G	3000	50000	100	150	100000	50	1000	300	5N
24	75MS-15	100000G	7000	100000G	200	700	30000	70	1000	300	5N
24	75MS-13	20000	5000	100000G	70	500	1000	20N	150	30	5N
28	75MS-19	3000	10000	100000G	5	100	1000N	20N	150	7	5N
30	75MS-40	20000	2000	100000G	300	50000	3000	20N	10000	30	5N
31	76CD-5B	100000G	15000	20000	3000	7000	100000	50	700	200	100
31	76CD-9B	100000G	5000	100000G	300	500	100000G	150	200	500	5N
31	76CD-7	100000	10000	100000G	150	3000	50000	100	200	100	30
31	76CD-6B	100000G	5000	100000G	15	10000	100000G	70	1000	200	100
31	76CD-2	15000	3000	15000	150	50000	1500	150	1500	15	200
31	76CD-3	20000	20000	100000	500	700	1000N	50	300	2	10
31	76CD-4	30000	7000	100000G	1500	1500	1000N	150	500	10	30
31	76CD-8	15000	20000	100000G	1500	1500	1000N	20N	300	1.5	5
31	76CD-10	20000	7000	100000G	200	1000	3000	20L	70	30	5
33	76CD-1B	5000	5000	100000G	2	700	1000N	20N	500	5	5N

Table 4.--Analytical data for precipitate samples from localities shown on Figure 1--Continued

Loc.	Chromium (Cr)	Copper (Cu)	Lanthanum (La)	Molybdenum (Mo)	Niobium (Nb)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Scandium (Sc)	Strontium (Sr)	Lithium (Li)
2	20	15	50N	3N	10N	5N	10N	200N	5N	7000	100N
2	30	10	50N	3N	10N	5L	20	200N	5N	7000	100L
2	2	2	50N	3N	10N	5N	10N	200N	5N	15000	100N
3	1N	1N	50N	3N	10N	5N	10N	200N	5N	3000	100N
3	1	5	50N	7	10N	5N	10N	200N	5N	5000	100N
4	15	5	50N	3N	10N	5L	10N	200N	5N	2000	100N
5	20	30	50N	30	10N	5	10N	200N	5N	3000	150
6	3	2	50N	3N	10N	5N	10N	200N	5N	3000	100N
7	3	1.5	50N	3N	10N	5N	10N	300	5N	1500	100N
7	7	10	50L	3N	10	5L	10N	500	5N	15000	100N
7	2	1N	50N	3N	10N	5N	10N	200N	5N	5000	100L
8	15	7	50N	3N	10N	5L	10N	200N	5N	5000	100N
9	1	10	50N	3N	10	5N	10N	700	5N	2000	100N
9	5	5	50N	3N	10N	5L	10N	200N	5N	15000	100N
9	1N	1N	50N	3N	10N	5N	10N	200N	5N	2000	100N
10	1	10	50N	7	10N	5L	10N	200N	5N	15000	100N
11	10	5	50N	3N	10N	5L	10	200N	5N	3000	300
12	1N	1N	50N	3N	10N	5N	10N	200N	5N	3000	100N
14	5	3	50N	7	10N	5N	10N	200N	70	15000	100N
14	2	1.5	50N	3N	10N	5N	10N	200N	100	10000	100N

Table 4.--Analytical data for precipitate samples from localiites shown on Figure 1. -Continued

Loc.	Chromium (Cr)	Copper (Cu)	Lantha-num (La)	Molyb-denum (Mo)	Niobium (Nb)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Scandium (Sc)	Strontium (Sr)	Lithium (Li)
15	1	3	300	3N	10N	5N	10N	200N	5N	2000	100N
16	1N	1N	50N	3N	10N	5N	10N	200N	5N	7000	100N
17	1N	1N	50N	15	20	5L	1500	700	5N	7000	100N
17	1N	1.5	50N	20	15	5N	10N	200	5N	15000	100N
18	1N	1N	50N	3N	10N	5N	10N	200N	5N	3000	100N
19	1N	1N	50N	3N	10N	5N	10N	200N	5N	5000	100N
21	1N	1N	50N	3N	10N	5N	10N	200N	5N	1000	100N
21	1	1N	50N	3N	10N	5N	10N	200N	5N	1500	100N
21	1N	1N	50N	3N	10N	5N	10N	200N	5N	2000	100N
22	2	3	50N	20	15	5N	10N	200N	5N	1500	100N
22	2	7	50N	50	20	5L	50	200N	5N	5000	100N
22	1N	1N	50N	3N	10	5N	10N	200N	5N	3000	100N
23	3	20	50N	3N	10N	5L	20	200N	7	5000	100N
23	7	5	50N	3N	10N	7	10N	200N	5L	10000	100N
23	3	5	50N	3N	10N	5N	10N	200N	5N	10000	100N
23	1N	1N	50	3N	10N	5N	10N	200N	5N	10000	100N
23	2	1.5	50N	3N	10N	5N	10N	200N	5N	10000	100N
24	5	15	50N	3N	10N	5N	15	200N	5L	5000	300
24	1.5	5	50N	3N	10N	5N	15	200N	5N	7000	100N
24	1.5	3	50L	3N	10N	5N	10N	200N	5N	3000	100N

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Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.-Continued

Loc.	Chromium (Cr)	Copper (Cu)	Lantha- num (La)	Molyb- denum (Mo)	Niobium (Nb)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Scandium (Sc)	Strontium (Sr)	Lithium (Li)
24	10	10	50N	3N	10L	5L	10N	200N	5	7000	100N
24	1N	3	50N	3N	10N	5N	10N	200N	5N	1500	100N
28	1N	1N	50N	3N	10N	5L	10N	200N	5N	7000	100N
30	5	10	50N	3N	10N	5	10N	200N	10	700	100N
31	50	20	50N	10	10L	50	30	200N	10	500	100N
31	10	5	50N	3N	10L	5L	1500	200N	50	3000	100N
31	7	15	50N	3N	10N	30	10N	200N	5N	5000	100N
31	3	15	50N	20	10L	50	700	200N	70	2000	100N
31	7	150	50N	20	10L	30	150	200N	5L	300	100N
31	10	15	200	3N	10N	7	70	200N	7	500	100N
31	15	20	50N	5	10L	10	70	200N	7	200	100N
31	15	15	50N	3N	10N	10	10N	200N	5L	2000	100N
31	5	7	50N	3N	10N	5	15	200N	7	10000	100N
33	2	3	50N	3N	10L	5N	10N	200N	5N	700	100N

Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.-Continued

Loc.	Vanadium (V)	Tungsten (W)	Yttrium (Y)	Zirconium (Zr)	Silicon (Si)	Aluminum (Al)	Sodium (Na)	Potassium (K)	Gallium (Ga)	Germanium (Ge)	Equivalent Uranium (eU)
2	15	100N	10L	50	50000	15000	5000	10000	5L	10N	710
2	30	100N	10	70	70000	20000	15000	15000	5	10N	590
2	7N	100N	10N	30	5000	2000	7000	7000N	5N	10N	6010
3	7N	100N	10N	10N	5000	200	20000	7000N	5N	20	80
3	7N	100N	10N	10N	10000	1500	30000	7000N	5N	30	410
4	10	100N	20	30	50000	15000	5000	7000	5L	10	430
5	30	100N	10L	70	100000G	15000	10000	30000	5	15	1040
6	7N	100N	10N	10N	5000	1000	1500	7000N	5N	10N	5
7	7N	200	15	50	20000	7000	5000	7000N	10	10N	250
7	10	300	15	15	30000	15000	7000	7000N	10	10N	250
7	7N	100N	10N	10N	20000	5000	2000	7000N	5N	10N	5
8	10	100N	10	70	100000G	15000	10000	20000	7	15	370
9	7N	1000	20	10N	15000	5000	10000	7000N	15	100	2300
9	3	100N	10N	10N	1500	1500	5000	7000N	5N	10N	30
9	7N	100	10N	10N	1000	500	2000	7000N	5N	10N	190
10	15	100N	50	15	30000	20000	10000	7000	5N	15	290
11	15	100N	10N	70	100000G	15000	10000	15000	15	30	50
12	7N	100N	10N	10N	1000	200	7000	7000N	5N	10N	60
14	10	100N	15	100	20000	15000	3000	7000N	5L	10N	2010
14	20	100N	20	70	20000	10000	2000	7000N	5L	10N	2940

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Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.-Continued

Loc.	Vanadium (V)	Tungsten (W)	Yttrium (Y)	Zirconium (Zr)	Silicon (Si)	Aluminum (Al)	Sodium (Na)	Potassium (K)	Gallium (Ga)	Germanium (Ge)	Equivalent Uranium (eU)
15	7N	100N	150	10N	3000	2000	2000	7000N	5N	10N	5
16	7N	100N	10N	10N	2000	1000	2000	7000N	5N	10N	5
17	7N	7000	15	15	10000	1500	500	7000N	15	50	790
17	7N	3000	10N	10N	10000	1000	700	7000N	5N	10N	2370
18	7N	100N	10N	10N	3000	500	1500	7000N	5N	10N	5
19	7N	100N	10N	10N	1500	200	20000	7000N	5N	10N	40
21	7N	100L	10N	10N	5000	1000	500	7000N	5L	10N	160
21	7N	100L	10N	10N	5000	1000	3000	7000N	5L	10N	200
21	7N	100N	10N	10N	7000	300	2000	7000N	5N	10	50
22	7N	5000	500	10N	50000	10000	3000	7000N	150	30	2000
22	7N	10000	200	500	30000	7000	30000	7000N	70	10N	1970
22	7N	100N	15	10N	3000	2000	500	7000N	5	10N	10
23	10	100N	150	50	70000	7000	30000	7000	5	30	590
23	10	100N	100	10	70000	5000	20000	7000	5	15	300
23	7N	100N	15	20	20000	3000	10000	7000N	5N	10N	100
23	7N	100N	10	20	2000	500	7000	7000N	5N	10N	70
23	7N	100N	10N	10N	3000	700	20000	7000N	5N	10N	60
24	15	100N	30	20	30000	10000	100000G	20000	5	15	2540
24	7N	100N	30	20	20000	7000	30000	7000	7	20	3830
24	7N	100N	50	30	30000	3000	20000	7000	5	30	2010

Table 4.--Analytical data for precipitate samples from localities shown on Figure 1.-Continued

Loc.	Vanadium (V)	Tungsten (W)	Yttrium (Y)	Zirconium (Zr)	Silicon (Si)	Aluminum (Al)	Sodium (Na)	Potassium (K)	Gallium (Ga)	Germanium (Ge)	Equivalent Uranium (eU)
24	30	100N	30	70	50000	20000	20000	10000	10	30	790
24	7N	100N	10N	20	5000	3000	10000	7000N	5N	10N	790
28	7N	100N	10N	10N	1500	500	2000	7000N	5N	10N	30
30	20	1000	20	30	15000	10000	5000	7000N	5N	20	4480
31	100	100N	50	150	100000G	50000	15000	30000	30	10N	2380
31	100	100N	150	70	30000	10000	70000	7000N	5N	100	510
31	15	100N	20	70	30000	15000	10000	7000N	5	50	200
31	100	100N	150	10	7000	3000	15000	7000N	5N	70	1520
31	100	100N	30	20	100000G	5000	700	7000N	5L	10N	5
31	150	100N	20	70	100000G	100000G	7000	100000	20	10N	50
31	150	100N	20	100	100000G	100000G	7000	100000	30	10N	5
31	50	100N	10N	15	15000	15000	10000	7000N	5L	10N	10
31	20	100N	10N	10	7000	5000	20000	7000N	5L	10N	140
33	7N	100N	10N	10N	500	500	5000	7000N	5N	10N	180

Factors controlling the geochemistry of
waters and precipitates

Some of the geochemical factors that affect the measured parameters can be identified and their effects evaluated by using statistical multivariate factor analysis. Geochemical factor analysis is a matter of establishing, mathematically, cause and effect relationships in which the causes may be identified with geochemical factors or processes and the effects are the variations in parameter values. Three to six factors commonly account for more than 50 percent of the variation in a set of associated parameters. Conventionally the factors (causes) that can be identified are selected for interpretation, even though the number selected does not account for all the variation (effects). The first factor to come out of the analysis accounts for more variance than any subsequently derived factor, and for this reason it is identified as the most important factor affecting the parameters (variables). The second factor is second most important in its effects, and so forth.

For further discussions of factor analysis applied to data matrices, the reader should consult detailed papers by Imbrie (1963), Steiner (1965), Cadigan (1972), and a comprehensive text by Harman (1967).

Factor analysis of water sample data

The results of the R-mode factor analysis of the water sample data, table 3, are shown in table 5. Factor matrices for two to ten rotated varimax factors were studied, and the four-factor matrix was selected as most adequately establishing the order of importance and identifying the major causes of variation in the variables listed. The four factors account for 77 percent of the variance in the data for in the 27 water samples.

Table 5.--Reordered varimax factor matrix for water sample data

[Data are from samples collected at 21 of the 33 selected sample localities. A data matrix of 27 samples and 23 variables was used]

Variable	Total dissolved solids Factor 1 loading	Alkalinity Factor 2 loading	Temperature Factor 3 loading	Fe-U concentration Factor 4 loading	Communality
Cl..................	0.975	0.100	0.077	0.027	0.97
Na..................	.956	-.038	.090	.039	.93
Dissolved solids...	.953	-.185	.108	.117	.97
K...................	.923	-.080	.102	.185	.90
Li..................	.904	.012	.155	.117	.86
Sr..................	.897	-.180	.249	-.051	.90
B...................	.877	-.055	.091	.090	.79
Ca..................	.798	(-.394)	.165	-.014	.82
Mg..................	.699	(-.276)	-.241	(.361)	.75
Ra..................	.596	.121	(-.469)	(.289)	.67
Mo..................	.511	.068	.125	-.012	.28
pH..................	-.023	.837	-.038	(-.308)	.80
HCO$_3$+CO$_3$.............	(.406)	.796	-.045	-.031	.80
NO$_3$...............	.171	-.463	-.072	.029	.25
Mn..................	.018	-.518	(.384)	(-.279)	.49
Al..................	(.428)	-.804	-.109	.120	.86
F...................	.117	.261	.889	-.057	.77
SiO$_2$..............	.216	-.124	.810	(.311)	.82
Temperature........	.222	.034	.686	(-.371)	.66
SO$_4$...............	.234	(-.407)	.667	(.440)	.86
Fe..................	.194	(-.406)	.110	.804	.86
U...................	(.458)	-.048	-.149	.756	.81
Ba..................	(.600)	-.099	-.069	-.645	.79

Note: Underlined factor loadings are those for variables most affected by the factor under which they are listed. If a variable is significantly affected by a second or third factor, its loading for that factor is shown in parentheses. Communalities are the sums of the squares of the factor loadings for each variable. They represent the proportion of variance in each variable accounted for by the four factors; thus, four factors account for 67% and 81%, respectively, of the variance in Ra and U concentrations in the waters.

We identified the four geochemical factors or processes as total dissolved solids (TDS), alkalinity, temperature, and Fe-U concentration. Table 5 variables and their numerical factor loadings, which represent the correlation between the variable and the respective factors, are divided into four blocks, representing factor groups. The upper block, for example, contains the variables most affected by increases and decreases in TDS. The second block contains variables most affected by variation in alkalinity; the third, variables most affected by variation in temperature; and the fourth block contains three interacting elements, Fe, U, and Ba.

With an increase or decrease of amounts of TDS in solution, most of the variables tend to increase or decrease in proportion to the squares of their factor loadings. Increases in alkalinity of the waters (factor 2) not only increase the concentrations of ions used as an indicator of alkalinity, HCO_3 + CO_3, but also increase pH. Decreases in alkalinity tend to be marked by increased values for Al, Mn, NO_3, SO_4, Fe, and Ca, and decreased values for HCO_3 + CO_3 and pH. Increases in temperature of the waters (factor 3) are marked by increased values for F, SiO_2, SO_4, and Mn; decreases in temperature tend to be marked by increased amounts of Ra. The effect of Fe-U concentration (factor 4) is more subtle. Increases in amounts of Fe and U in solution are marked by the presence of increased amounts of SO_4, Mg, SiO_2, and Ra. Decreased amounts of Fe and U in solution are marked by increased values for Ba, temperature, pH, and Mn. This complicated relationship occurs because Ba tends to remove SO_4 from solution and to precipitate as barite, which coprecipitates Ra. The loss of the SO_4 ion may cause an increase in pH, which brings about precipitation of Fe, U, Mg, SiO_2, and Mn.

Factor analysis of precipitate sample data

Multivariate R-mode factor analysis was also done on data from 54
precipitate samples collected at 24 mineral spring localities (table 4).

We selected the first five factors as best identifying the major causes
of variation in concentration of the elements listed. The five factors shown
in table 6 account for 69 percent of the variance. The five major factors in
order of importance are mineral contamination; Mn precipitation, Fe, As, and
Be precipitation; heavy metals precipitation; and Ba precipitation. Table 6
variables and their loadings are divided into five blocks representing what
might be called factor groups, as was done with the water data factor
analysis.

The factor identified as mineral contamination is the most important
single process affecting the variation of parameter values studied. Mineral
contamination represents contributions of detrital grains, rock fragments,
clay particles, and mineral dust transported by wind, water, or gravity from
adjacent terrain, and soluble mineral salts from within the spring area
deposited by transpiration and evaporation. This contamination process is
negatively related to the precipitation of Ca mostly as $CaCO_3$. The loadings
suggest that precipitation of Ca and contamination represent opposing
processes occurring at mineral spring sites. The second factor or process,
the deposition of black and reddish-black Mn-rich precipitates, character-
istically includes deposition of W, Mo, Sb, and Nb and to some extent Ga and
Ba, and is inversely related to the deposition of Ca, Mg, and Na. The third
factor, deposition of reddish-brown Fe-As-Be precipitates, characteristically
includes deposition of Ge, Na, Y, and Ra(eU). Radium, represented by eU
(total radiation count stated in terms of equivalent uranium), As, and related
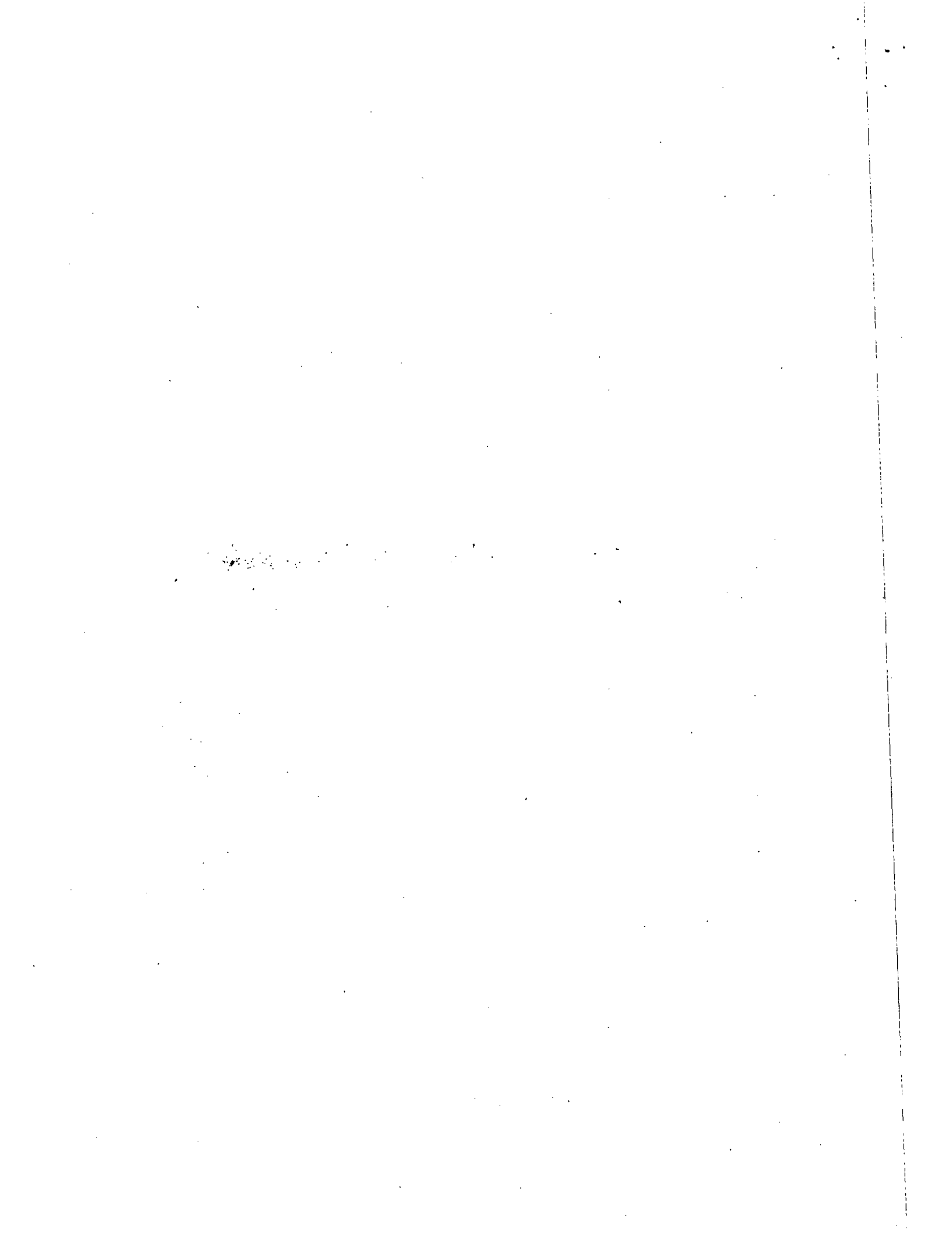elements are coprecipitated by $Fe(OH)_x$. The fourth factor, precipitation of

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Table 6.--Reordered varimax factor matrix for precipitate sample data

[Data are from samples collected at 24 of the 33 selected sample localities. A data matrix of 54 samples and 32 variables was used]

Variable	Mineral contamination Factor 1 loading	Mn precipitation Factor 2 loading	Fe-As-Be precipitation Factor 3 loading	Heavy metals precipitation Factor 4 loading	Ba-Ra precipitation Factor 5 loading	Communality
Si..........	0.883	0.156	0.152	0.220	-0.002	0.88
Al..........	.848	.053	.107	.301	.069	.83
K...........	.830	-.142	.064	.067	-.229	.77
Cr..........	.807	-.170	.057	(.322)	.124	.80
Zr..........	.703	.001	.177	(.359)	(.317)	.76
Cu..........	.670	-.015	-.221	(.424)	.125	.69
Ga..........	.639	(.554)	.165	.019	-.111	.76
Ti..........	.596	.161	.133	.058	.081	.41
B...........	.559	-.157	(.385)	(.403)	-.188	.68
Li..........	.503	-.121	.036	-.262	-.141	.36
W...........	-.077	.885	.069	-.123	.157	.83
Nb..........	-.044	.824	.165	.181	.010	.74
Mn..........	-.012	.791	.067	.256	.164	.72
Mo..........	.139	.643	-.034	(.460)	.133	.66
Sb..........	<-.058	<.638	<.189	<.215	<.017	<.49
Ca..........	(-.312)	-.567	-.236	-.187	.170	.54
Mg..........	(.417)	-.568	-.142	.180	-.181	.58
As..........	.062	.017	.861	.277	.035	.82
Be..........	-.048	.270	.828	.182	.075	.80
Fe..........	.274	.270	.800	.080	-.010	.79
Ge..........	.150	.124	.777	-.007	.075	.67
Na..........	(.361)	(-.476)	.617	-.080	.150	.77
Y...........	(.345)	.278	.491	.288	.055	.52
Ni..........	(.344)	-.001	.168	.799	-.137	.80
Co..........	.166	.305	.052	.793	-.234	.80
V...........	(.612)	-.175	.122	.688	.035	.90
Sc..........	.127	-.170	.236	.636	(.378)	.65
Pb..........	.179	.230	(.372)	.581	-.128	.58
Ba..........	(.360)	(.505)	-.177	-.064	.664	.86
eU(Ra)......	.267	.277	(.435)	-.052	.661	.78
Sr..........	-.155	-.166	.053	(-.416)	.542	.52
La..........	.075	-.078	-.032	-.028	-.488	.25

Note: Underlined factor loadings are those for variables most affected by the factor under which they are listed. If a variable is significantly affected by a second or third factor, its loading for that factor is shown in parentheses. Communalities are the sums of the squares of the factor loadings for each variable. They represent the proportion of variance in each variable accounted for by the five factors; thus five factors account for 54% and 78%, respectively, of the variance in Ca and eU concentrations.

the heavy metals Co, Ni, U, Pb, Mo, Cu, Zr, and Cr, a classically hydrothermal suite of metals, is possibly related to igneous source rocks and TDS in the transporting solution. The fifth factor is precipitation of Ba as barite and coprecipitation of Ra and Sr.

Factor 5 confirms the strong association between Ba and Ra precipitation previously observed. The Mn and Fe-As-Be precipitation factors are also positively related to the occurrence of high eU (Ra). Spring localities where Mn- and Fe-rich precipitates are being deposited are typically, and in part conspicuously, radioactive. The factor groups are compatible with field observations and support the validity of our sampling procedures. In other words, the results of the statistical analysis of the sample data support what we think we see in the field.

Older precipitate deposits of extinct radioactive springs (or of springs which have migrated to new outlets) and the older parts of deposits of active springs lose most of their radioactivity in about 5,000 years. This loss of radioactivity is caused by radioactive decay of ^{226}Ra, which has a half life of 1,600 years. The phenomenon may be used as semiquantitative evidence to help estimate the cumulative period of activity of some modern springs and to identify older travertine deposits of active radioactive spring systems.

Factor scores for water samples

The intensity of the effects of the processes or factors determined in factor analysis can be measured by factor scores as computed by Steiner (1965). Algebraically the process of factor analysis can be visualized as a system of linear equations of the form:

$$Z_{ji} = a_{jk}f_k$$

in which i stands for the observations (samples) from 1 to N; j, for the variables from 1 to n; and k, for the factors from 1 to p. The problem is to

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calculate the a's (factor loadings) and the f's (factor scores); Z_{ji} represents the Z scores (Dixon and Massey, 1951, p. 24) of each variable (j) for each sample (i). Tables 5 and 6 show the factor loadings for each variable.

The equation for computing factor scores is

$$f_{ki} = b_{kj}Z_{ji}.$$

b can be computed several ways, but the simplest way to obtain factor scores according to Steiner (1965), is to substitute factor loadings a for the b values. Thus the formula would be:

$$f_{ki} = a_{kj}Z_{ji}.$$

The factor scores are calculated by converting all data matrix natural log values to Z scores. Then a factor score is computed for each sample for each factor. For example, to compute a factor score for one sample for factor 1 in table 5, the standard score value for each variable is multiplied by the appropriate factor loading, and the results, added algebraically, yield a single score for the sample for factor 1. When this procedure is applied to all water samples for all factors the result is the factor score matrix of table 7. This matrix was computed from the data in table 3 and the factor loadings in table 5.

The scores are a quantitative measure of the intensity of the effects of the four factors. The high factor 1 scores for localities 1, 2, 3, 24, 30, and 31 suggest that the total dissolved solids effect is highest in samples collected from these locations (Crystal Hot Springs, Stinking Hot Springs, Utah Hot Springs, Taylor Soda Springs, Soda Dam Hot Springs, and Salt Banks Springs). Highest alkalinity effect (factor 2) is found in samples from a pumped well in Pueblo County (loc. 20) and from Poncha Hot Springs (loc. 22).

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Table 7.--Computed factor scores (as defined by Steiner, 1965) for water sample data (table 3)

Locality number	Sample number	Total dissolved solids Factor 1	Alkalinity Factor 2	Temperature Factor 3	Fe-U concentration Factor 4
1	76MSW8	16.19	-4.34	1.04	3.15
2	76MSW5	14.17	-3.75	-.02	-.59
3	76MSW15	12.86	-2.58	2.84	1.70
7	75MSW18	2.60	-.78	3.89	-.42
8	76MSW19	.66	1.76	-2.67	-2.06
13	75MSW6	.76	1.06	.29	-3.77
14	75MSW4	2.75	.61	-.43	-2.29
14	75MSW5	-2.62	-13.54	.33	5.85
14	75MSW3	-1.06	-.79	.97	2.15
17	75MSW27	-2.49	-1.00	3.34	-.80
19	75MSW28	4.96	-1.82	2.47	2.99
20	MIN-1	-0.75	-.07	2.86	-.70
20	MIN-2	-.97	1.37	3.28	-.70
21	SAG-4	-5.05	2.24	1.40	-1.52
21	SAG-4	-5.43	2.31	1.31	-.L59
22	CHA-7	-9.59	3.13	3.76	-3.10
22	CHA-6	-.930	2.89	3.48	-2.88
23	PAR-4	3.92	1.74	-1.31	+3.89
24	FRE-1	8.23	.87	-2.01	+5.31
25	75MSW10	1.83	.10	-.86	2.03
26	75MSW11	-19.59	6.75	-8.88	-3.52
27	75MSW13	-11.13	.70	-4.47	1.76
29	HUE-5	-13.45	2.57	-4.69	-3.31
29	HUE-4	-14.00	1.67	-4.72	-2.93
30	75MSW8	5.29	1.22	-3.79	-.55
31	76MSW1	13.86	-1.36	2.00	4.66
32	76MSW2	7.33	-.96	.58	-2.77

Highest temperature effect (factor 3) is found at Baker Hot Springs, Poncha Hot Springs, and Box Canyon (Ouray) Hot Springs. Highest Fe-U effect (factor 4) is found at Doughty Springs (Alum Spring), Taylor Soda Springs, and Salt Banks Springs.

In contrast, the samples showing lowest intensity effects of any factor are indicated by the large negative values for that factor. Thus, the sample with the least alkalinity effect is from Doughty Springs (Alum Spring). The sample with the lowest Fe-U effect is from the Col. Chinn well.

The four factors represent in a broad sense four new variables, and the scores are quantitative measures of the effects of these variables on the parameters measured.

Linear correlation coefficients (r) among the factors, using the scores in table 7, are calculated to be:

Factors	1	2	3	4
1 TDS..................	1.0			
2 Alkalinity............	-.49	1.0		
3 Temperature..........	.42	-.32	1.0	
4 Fe-U concentration....	.53	-.61	.15	1.0

Coefficients of $r > \pm .38$ are significant at the 95-percent level, and those $> \pm .49$ are significant at the 99-percent level. All computed coefficients are significant except the ones between alkalinity and temperature and between Fe-U and temperature. Highest correlations are between alkalinity and Fe-U concentration (-.61), between TDS and Fe-U concentration (.53), and between TDS and alkalinity (-.49). The high correlations are interpreted to mean that Fe-U and TDS are generally both lower in waters of high alkalinity.

A scatter diagram of alkalinity factor scores and corresponding Fe-U factor scores (fig. 2) confirms the generally negative relationship between
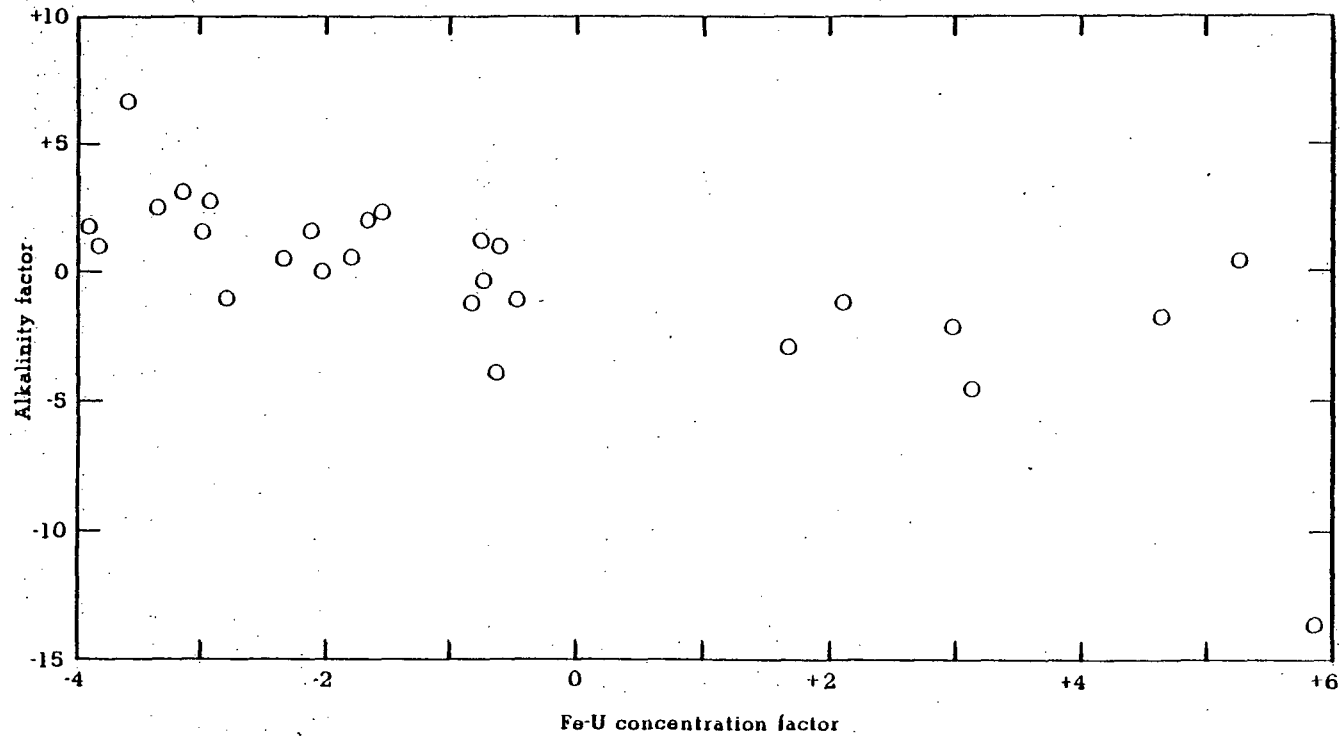
Figure 2.--Scattergram of alkalinity factor scores plotted against iron-uranium concentration factor scores for 27 spring- and well-water samples.

the two. The extreme Fe-U high score is for a sample collected at Doughty Springs (Alum Spring), which has acidic water. On the other hand, the next highest Fe-U score is from Taylor Soda Springs, which has moderately alkaline waters. Of the springs studied, the higher Fe-U scores tend to occur in waters with alkalinity scores in the range of +1.0 to - 5.0. The lower Fe-U scores tend to occur in water with alkalinity scores in the range of +5.0 to -1.0.

Factor Scores for precipitate samples

Trace element data from table 4 and the factor loadings in table 6 were used to calculate factor scores for the 57 precipitate samples. The factor score matrix is shown in table 8.

As with the water samples, if the factors are considered to be geochemical processes, and the factor loadings an indication of the effects on the parameters measured, the factor scores are measures of intensity of the total effect of each process on each sample. Negative scores indicate low intensities, high positive scores indicate relatively high intensities.

Computed linear correlation coefficients (r) of the factor scores using all possible pairs are shown below:

Factors	1	2	3	4	5
1 Mineral contamination........	1.0				
2 Mn precipitation.............	.21	1.0			
3 Fe-As-Be precipitation.......	.71	.45	1.0		
4 Heavy metals precipitation...	.84	.33	.71	1.0	
5 Ba-Ra precipitation..........	.19	.43	.35	.07	1.0

Coefficient values of .27 or greater are significant at the 95-percent level, values of .35 or greater are significant at the 99-percent level.

Table 8.--Computed factor scores (as defined by Steiner, 1965)
for prcipitate sample data (table 4)

Locality number	Sample number	Mineral contamination Factor 1	Mn precipitation Factor 2	Fe-As-Be precipitation Factor 3	Heavy metals precipitation Factor 4	Ba-Ra precipitation Factor 5
2	75MS102B	4.89	-2.71	-3.82	-.99	2.23
2	75MS203B	9.41	-3.77	-1.63	-1.27	1.14
2	75MS101B	-3.61	-3.01	-5.52	-4.85	3.40
3	75MS105	-7.54	.01	-.67	-5.33	.12
3	75MS104	-3.57	-.02	.73	-4.67	1.08
4	75MS106B	3.47	-.32	.58	.65	.58
5	75MS107	12.98	1.83	1.06	4.86	.58
6	75MS108	-6.87	-4.74	-6.99	-5.13	-2.33
7	75MS109B	-.37	3.99	-.01	-2.54	.96
7	75MS111B	2.20	5.82	1.81	-.77	1.85
7	75MS110	-4.26	-4.45	-5.34	-4.81	-2.53
8	75MS112	8.00	-3.34	-.84	.62	.64
9	75MS113B	-.77	9.75	7.04	-2.06	1.98
9	75MS115	-5.53	-3.80	-3.99	-3.56	-.35
9	75MS114	-10.59	.10	-3.97	-5.31	-.41
10	75MS116	2.31	-.33	1.18	.80	1.73
11	75MS117	9.87	-2.95	1.38	.98	-2.10
12	75MS118	-11.29	-5.48	-7.56	-3.90	-2.07
14	75MS34	2.21	.09	-1.64	1.47	5.13
14	75MS33	.84	.79	-1.44	.53	4.68
15	75MS35	-7.33	-4.97	-5.89	-3.90	-5.88
16	75MS29	-9.37	-4.18	-6.58	-5.24	-1.97
17	75MS30	-1.33	18.90	6.73	2.12	1.54
17	75MS122B	-7.59	11.02	-2.30	-2.19	2.78
18	75MS119	-10.42	-3.44	-7.45	-5.30	-2.81
19	75MS123	-8.38	-3.32	-5.34	-5.62	-1.23
21	75MS20	-7.74	.04	-5.55	-4.65	-1.14
21	75MS21	-6.36	-1.86	-4.56	-4.67	-.94
21	75MS22	-9.10	-3.80	-3.53	-5.15	-1.95
22	75MS25	2.57	14.48	4.25	1.53	1.99
22	75MS27	3.96	13.51	1.89	2.75	4.14
22	75MS26	-8.63	1.05	-5.05	-4.13	-2.02
23	75MS1	5.47	-.68	6.26	2.72	1.29
23	75MS4	3.87	-2.37	3.91	1.11	.79
23	75MS2	-2.24	-3.73	-1.65	-2.81	.17
23	75MS5	-8.23	-3.80	-3.53	-5.13	-1.86
23	75MS3	-6.47	-5.09	-3.87	-4.71	-0.72
24	75MS17	9.59	-2.69	8.61	1.26	.44
24	75MS14	3.27	-.51	7.32	-.15	.95
24	75MS11	2.89	-.26	6.86	-.39	-.51
24	75MS15	7.60	-.73	7.27	3.38	1.63
24	75MS13	-5.13	-3.27	-1.35	-4.00	.84
28	75MS19	-10.14	-4.72	-5.85	-4.91	-2.04
30	75MS40	1.93	2.53	2.57	2.62	3.00
31	76CD5B	16.52	4.86	8.96	14.37	-.79
31	76CD9B	5.48	2.77	10.37	13.57	1.41
31	76CD7	5.87	-1.12	6.21	6.21	-.55
31	76CD6B	6.75	-1.43	11.66	8.08	1.58
31	76CD2	7.93	6.32	2.13	13.19	-3.36
31	76CD3	13.46	-2.16	1.13	8.56	-4.98
31	76CD4	14.38	1.12	2.39	11.35	-3.23
31	76CD8	3.07	-3.88	-2.63	3.30	-1.37
31	76CD10	.37	-3.49	1.00	2.55	-.01
33	76CD1B	-8.30	-2.53	-4.66	-3.65	-1.52

Levels of Fe-As-Be and heavy metals precipitation correlate highly with mineral contamination, and levels of Fe-As-Be and Ba-Ra precipitation correlate highly with Mn precipitation. Thus there appear to be two groups of significantly intercorrelating factors: 1, 3, and 4; and 2, 3, and 5. The first group seems related to mineral contamination and heavy metals deposition. The second group seems related to Ra deposition. Factor 3 is included in both groups. The intercorrelations emphasize the fact that the effects of some of the geochemical processes tend to overlap to a highly significant degree. Thus, for example, the factor identified by us as mineral contamination is affected by the factors indentified as Fe-As-Be precipitation and heavy metals precipitation, and the latter two factors are similarly related. Calcium precipitation (a factor?) may be a process competitive with the first four factors. Magnesium may occur both in mineral contaminants and in precipitates. Note its apparent negative relationship with Ca in factor 1 and its positive relationship with Ca in factor 2 in table 6.

Ranking of localities

Factor scores were used to rank the various sample localities in terms of the intensity with which each of the identified geochemical processes operated. This was done by using the highest sample score at each locality. For example, ranking of the water-sample localities in terms of scores for factor 4, the Fe-U concentration factor, produced the following six highest ranking localities and scores:

1. Doughty Springs   5.85
2. Taylor Soda Springs   5.31
3. Salt Bank Springs   4.61
4. Guffey Soda Springs   3.89
5. Crystal Hot Spring   3.15

6. Bakers Bridge Hot Springs 2.99

The six highest ranking localities for precipitate samples in terms of scores for factor 5, the Ba-Ra precipitation factor, are:

1. Doughty Springs   5.13
2. Poncha Hot Springs   4.14
3. Stinking Hot Springs   3.40
4. Soda Dam Hot Spring   3.00
5. Box Canyon Hot Springs   2.78
6. Red Hill Hot Springs   1.98

The five highest ranking localities based on a composite of the scores of the four factors for water samples and the five factors for precipitate samples are shown in the following list and in figure 3:

1. Poncha Hot Springs
2. Salt Banks Hot Springs
3. Taylor Soda Springs
4. Crystal Hot Springs
5. Box Canyon Hot Springs

Based on the higher intensity of geochemical processes involving radioactive elements, these localities are considered to be the ones most likely to be associated with uranium mineralization.

Conclusions

The data presented in this report indicate that samples of water and precipitates from radioactive mineral springs and wells can supply a considerable amount of geochemical information of value in a uranium exploration program.

Multivariate statistical analysis and the computation of factor scores yield reproducible evidence regarding the relative intensities of geochemical
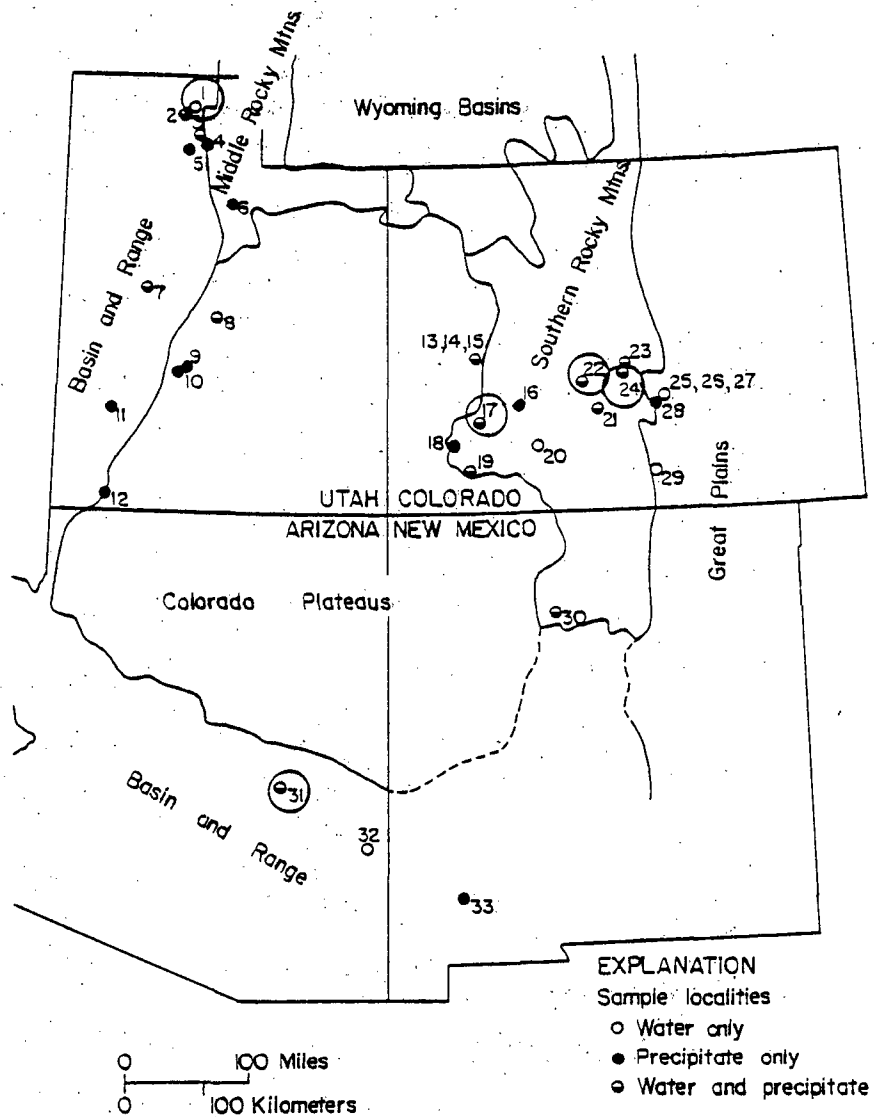
Figure 3.-Localities (circled) suggested by multivariate analysis
methods and ranked scores to have the greatest uranium mineral-
ization potential.

processes operating at the sampled localities. Based on the relative intensities of geochemical processes involving uranium and radium as measured by factor scores, localities may be selected as sites for further exploration for uranium deposits associated with active hydrothermal systems.

The immediate value of using radioactive mineral spring data for uranium exploration purposes cannot be demonstrated. Little exploration for uranium in hydrothermal systems has been attempted, owing to unevaluated risks related to depths of ore and a lack of knowledge concerning possible ore grades and size of deposits. Further geochemical study of the radioactive springs may provide additional information needed to decrease the risks involved in exploratory drilling of the uranium-rich hydrothermal systems.

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