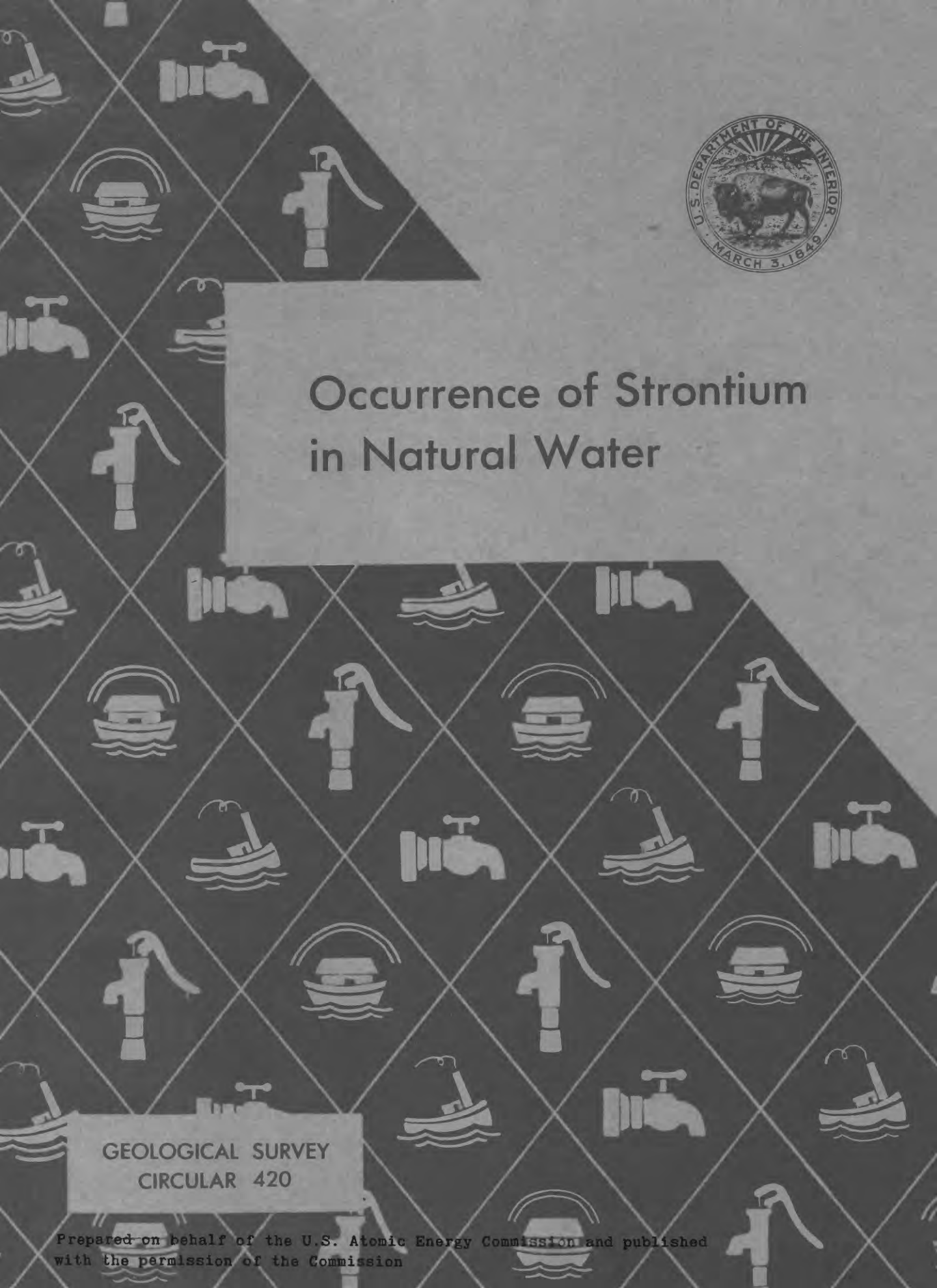

Occurrence of Strontium in Natural Water

GEOLOGICAL SURVEY
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Prepared on behalf of the U.S. Atomic Energy Commission and published with the permission of the Commission

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By M. W. Skougstadt and C. A. Horr

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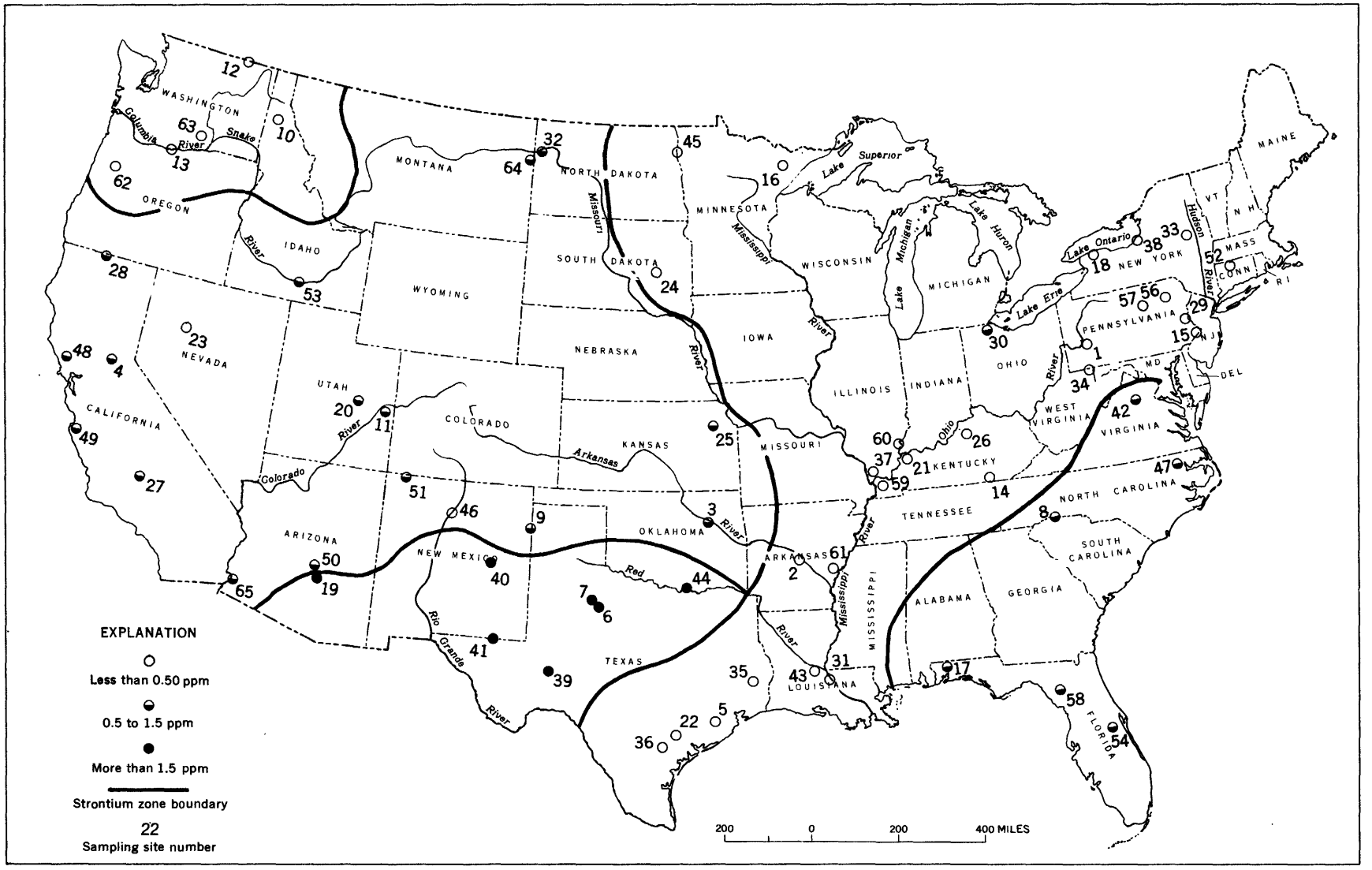

Figure 1.—Map of the United States showing concentration of strontium in surface water at selected sites

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ABSTRACT

The regions where the stable strontium content of surface waters is relatively low (less than 0.50 ppm) include the Pacific Northwest, Northeastern United States, and the Central Lowlands, Particularly the Lower Mississippi basin and the Western Gulf Coast area. Moderate concentrations of strontium (0.50 to 1.5 ppm) are found in streams of Southeastern United States, most of the Great Plains Region, the Western Mountain and Plateau Regions, and California. Relatively high concentrations of strontium occur in the surface waters of an area that includes Northern and Western Texas and Southern New Mexico and Arizona. Exceptions to the above distribution are due to local geologic conditions.

INTRODUCTION

Few data are available on the occurrence of strontium in natural water. Odum (1951) determined the strontium content of certain Florida waters. Alexander, Nusbaum, and MacDonald (1954) measured the strontium content of the public water supplies of many of the major cities through the United States. Nichols and McNall (1957) determined strontium in 380 municipal water supplies in Wisconsin, and reported results for about 100 which contained more than 1.0 ppm (parts per million). Blanchard, Leddicotte, and Moeller (1958) have analyzed the drinking water of seven major cities of the United States by a neutron activation method and have reported their strontium content. These four reports contain about all that is known about the general distribution and occurrence of strontium in fresh water of the United States. This is somewhat surprising considering the fact that the concentration of strontium in sea water (13 ppm) exceeds that of any other cation except the four most common cations: sodium, magnesium, calcium, and potassium.

Certain features of the chemistry of strontium make it easy to understand the lack of available data on strontium occurrence in fresh water. Strontium is present in nearly all fresh water but generally only in trace amounts (1.0 ppm or less). Because strontium closely resembles calcium chemically, and because it is present in much smaller amounts than calcium, the determination of strontium is a difficult analytical problem. The usual analytical procedure for calcium includes any strontium present as a part of the reported calcium. Thus, the analytical result for calcium is in error unless strontium is determined and a correction made for the amount of strontium present. The two elements are so similar in chemical behavior that there is no real need for determining both strontium and calcium, as far as ordinary water use is concerned.

Within recent years, there has been an increased interest in strontium and its occurrence and distribution in nature because of the public health hazards of the radioactive isotope, strontium-90. This isotope, a fission product, has become widely distributed over the earth in minute amounts by nuclear test explosions. Strontium-89 is also produced by nuclear fission. However, its half-life (54 days) compared with the half-life of strontium-90 (28 years) is so small as to make its potential hazard to life almost negligible. Natural, nonradioactive strontium isotopes are possible diluents for the harmful, radioactive isotopes when ingested by animals and by man.

Because of the lack of data on the distribution of natural strontium and because of the current interest in the physiological behavior of strontium, this project was started in October 1957 to survey the occurrence and distribution of stable strontium in natural water of the United States, and to develop an analytical method, or methods, which could be used for the routine laboratory determination of strontium in water.

This study is being made on behalf of the U.S. Atomic Energy Commission and is being carried out under the general direction of S. K. Love, U. S. Geological Survey.

ANALYTICAL METHODS

As an early part of this investigation, an intensive search of the literature was made for analytical methods applicable to the determination of strontium in natural water. The methods reported in publications indicated that either a flame photometric method or a spectrographic method would satisfy the requirements of the present project. These techniques are adequately sensitive and accurate, and also sufficiently rapid so that many samples can be analyzed.

The literature survey and comprehensive bibliography was submitted as an initial report of this project and has been published as Water-Supply Paper 1496-A, Chemistry of strontium in natural water (Horr, 1959).

A flame photometric procedure reported by Skougstad (1957) was modified slightly and adapted to the analysis of all water samples received as a part of the present investigation. The procedure utilizes a Beckman Model DU spectrophotometer with flame attachment, an oxygen-acetylene flame, and a photomultiplier tube attachment. A spectroscopic buffer solution added in equal amount to each sample and to standards minimizes effects of variations in amounts of interfering substances which may be present in the sample solutions.

Because the lower limit of detection of strontium by this procedure is, under optimum conditions, only 0.2 ppm, and because a significant number of the samples contained less than this amount, efforts have been made to develop a routine laboratory method that can be used to determine strontium in water samples in concentrations at least as low as 0.01 ppm. Two methods have been investigated. Work has been directed to the development of a procedure involving concentration of strontium in the sample by means of a cation-exchange resin prior to determination of strontium by flame photometry. The method has not yet been applied to regular analysis of samples, but seems to offer promise of providing a tenfold concentration of strontium which will give close to the desired sensitivity.

More recently, a spectrographic procedure, based on the copper-spark technique originally described by Fred and Nachtrieb (1947) and by Nachtrieb (1950) and employed also by Alexander, Nusbaum, and MacDonald (1954) for the determination of strontium in water, was developed and is now being used for all samples in which the values by flame photometric procedure are less than 0.2 ppm of strontium. In addition, samples containing 0.2 to 1.0 ppm of strontium are being checked by both procedures. The spectrographic method requires approximately 30 ml of water sample and is capable of detecting 0.005 ppm of strontium. The probable error of an analysis is about 10 percent of the amount present.

SAMPLING PROGRAM

Surface water samples from about 65 points in the United States have been collected by the District Offices of the Water Resources Division of the U. S. Geological Survey. Nearly all points were regular sampling stations of the Geological Survey and were selected to represent, insofar as possible, the major streams and drainage areas of the country. At each point, three samples were obtained at intervals of several months to a year, to obtain water during high, low, or median flow conditions for the stream.

A comprehensive chemical analysis was made according to standard and accepted procedures by the district laboratory collecting the sample, and a portion of the sample was sent to the U. S. Geological laboratory in Denver for determination of strontium.

The streams sampled are listed in table 1, and the location of the sampling site for each stream is indicated in figure 1.

STRONTIUM CONTENT OF WATER

SURFACE WATER

Table 1 lists the strontium content of samples received and analyzed from May 1958 through August 1959. All samples have been analyzed by the flame photometric procedure without prior concentration of the sample. Where strontium has also been determined spectrographically, the results for both procedures are given. Note that for a number of samples the results by the two independent

Table 1—*Strontium content of surface water*

No.	River	Location	Concentration of strontium, ppm					
			Flame photometer			Spectrograph		
			Flow stage			Flow stage		
			High	Median	Low	High	Median	Low
1	Allegheny	Kittanning, Pa	<0.2	<0.2	<0.2	0.077	0.063	0.098
2	Arkansas	Little Rock, Ark	.4	.4	.4	-------	--------	---------
3	-----do	Tulsa, Okla	2.0	1.0	1.8	-------	--------	---------
4	American	Fair Oaks, Calif	-------	--------	1.4	-------	--------	---------
5	Brazos	Richmond, Tex	<.2	2.2	.4	>.1	--------	---------
6	Brazos, Dbl. Mountain Fork	Aspermont, Tex	-------	--------	5.4	-------	--------	---------
7	Brazos, Salt Fork	-----do	-------	--------	9.8	-------	--------	---------
8	Broad	Boiling Springs, N. C	.8	.8	.8	-------	--------	---------
9	Canadian	Logan, N. Mex	.8	.8	.8	-------	--------	---------
10	Coeur d'Alene	Cataldo, Idaho	-------	--------	.4	-------	--------	.030
11	Colorado	Cisco, Utah	.4	2.0	1.4	-------	--------	---------
12	Columbia	International Boundary	-------	--------	<.2	-------	--------	.072
13	-----do	Rufus, Oregon	<.2	<.2	<.2	-------	.092	.21
14	Cumberland	Williamsburg, Ky	<.2	<.2	.8	.041	.051	.13
15	Delaware	Morrisville, Pa	<.2	<.2	<.2	.053	.042	.061
16	Embarrass	Embarrass, Minn	-------	.8	<.2	-------	.025	.041
17	Escambia	Century, Fla	-------	.6	.8	-------	--------	---------
18	Genessee	Rochester, N. Y	-------	--------	.8	-------	--------	.38
19	Gila	Kelvin, Ariz	3.0	--------	2.8	-------	--------	---------
20	Green	Green River, Utah	.8	.6	.6	-------	--------	---------
21	-----do-----	Spottsville, Ky	<.2	<.2	.8	.080	.14	.12
22	Guadalupe	Victoria, Tex	<.2	--------	-------	>.1	--------	---------
23	Humboldt	Rye Patch, Nev	.2	<.2	<.2	-------	--------	---------
24	James	Huron, South Dak	<.2	.6	.4	.23	--------	---------
25	Kansas	Topeka, Kansas	1.2	.8	.8	-------	--------	---------
26	Kentucky	Frankfort, Ky	<.2	.4	.8	.044	.081	.12
27	Kern	Bakersfield, Calif	-------	--------	1.4	-------	--------	---------
28	Klamath	Klamath, Calif	-------	--------	1.4	-------	--------	---------
29	Lehigh	Glendon, Pa	<.2	<.2	<.2	.065	.059	.19
30	Maumee	Waterville, Ohio	1.0	1.0	1.4	-------	--------	---------
31	Mississippi	St. Francisville, La	.5	--------	<.2	-------	--------	.22
32	Missouri	Williston, N. Dak	.8	--------	.8	-------	--------	---------

Table 1—*Strontium content of surface water*—Continued

No.	River	Location	Concentration of strontium, ppm					
			Flame photometer			Spectrograph		
			Flow stage			Flow stage		
			High	Median	Low	High	Median	Low
33	Mohawk	Cohoes, N. Y	-------	<0.2	-------	-------	>0.1	-------
34	Monongahela	Charleroi, Pa	<0.2	<.2	<0.2	0.087	.102	0.097
35	Neches	Evadale, Tex	<.2	1.0	-------	.088	---------	-------
36	Nueces	Mathis, Tex	.8	-------	<.2	.31	---------	.33
37	Ohio	Golconda, Ill	.4	<.2	.8	.15	.17	.23
38	Oswego	Minetto, N. Y	-------	.8	-------	-------	>.3	-------
39	Pecos	Girvin, Tex	-------	-------	7.6	-------	-------	-------
40	-----do	Puerto de Luna, N. Mex	<.2	5.0	5.0	>.4	-------	-------
41	-----do	Red Bluff, N. Mex	3.4	4.8	8.0	-------	-------	-------
42	Rappahannock	Remington, Va	.6	.8	.8	-------	-------	-------
43	Red	Alexandria, La	.4	-------	<.2	-------	-------	.44
44	-----do	Gainesville, Tex	1.0	1.6	2.2	-------	-------	-------
45	-----do	Grand Forks, N. Dak	.2	.8	<.2	-------	-------	.20
46	Rio Grande	San Ildefonso, N. Mex	.8	<.2	.8	-------	.31	-------
47	Roanoke	Jamesville, N. C	.8	-------	<.2	-------	-------	.49
48	Russian	Guerneville, Calif	-------	-------	1.4	-------	-------	-------
49	Salinas	Spreckles, Calif	-------	-------	1.4	-------	-------	-------
50	Salt	Stewart Mountain Dam, Ariz	-------	.8	-------	-------	-------	-------
51	San Juan	Archuleta, N. Mex	-------	2.0	.8	-------	-------	-------
52	Scantic	Broad Brook, Conn	-------	-------	.8	-------	-------	.22
53	Snake	King Hill, Idaho	.4	<.2	<.2	.47	-------	>.4
54	St. John's	Cocoa, Fla	-------	2.0	.8	-------	-------	-------
55	St. Lawrence	Thousand Island Park, N. Y	-------	-------	-------	-------	-------	-------
56	Susquehanna	Danville, Pa	<.2	<.2	.2	.12	.086	-------
57	Susquehanna, West Br	Lewisburg, Pa	<.2	<.2	<.2	.103	.090	.097
58	Suwannee	Branford, Fla	.6	.8	-------	-------	-------	-------
59	Tennessee	Paducah, Ky	<.2	<.2	.8	.074	.037	-------
60	Wabash	New Haven, Ill	<.2	<.2	.8	.11	.38	.14
61	White	Clarendon, Ark	.4	.2	<.2	.033	.035	.039
62	Willamette	Salem, Oreg	-------	<.2	2.8	-------	.046	.045
63	Yakima	Kiona, Wash	-------	.8	2.8	-------	.063	-------
64	Yellowstone	Sidney, Mont	.8	-------	-------	-------	-------	-------
65	Yuma Main Canal	Yuma, Ariz	-------	.8	-------	-------	-------	-------

methods do not give satisfactory agreement. The lack of agreement is attributed to the lack of sensitivity of the flame photometric procedure. When samples containing less than 1.0 ppm of strontium are analyzed, it is necessary to work in the extreme lower range of the calibration curve and also in the extreme lower range of the transmission-scale of the spectrophotometer. At this very low range, it is difficult to distinguish a reading difference of one scale division or less which corresponds to several tenths of a part per million strontium. The presence of interfering ions in the sample may also cause an error proportionally greater at strontium concentrations near the limit of sensitivity of the flame photometric method.

For these reasons, then, reported analyses of less than 1.0 ppm by the flame photometric procedure without preliminary concentration of the sample must be recognized as being subject to considerable error.

Where discrepancies exist, the samples are being rechecked by an ion-exchange concentration step prior to the flame photometric determination.

The streams selected for sampling have been classified on the basis of their strontium content. A stream at its sampling point is considered to be relatively low in strontium if it contains less than 0.50 ppm; relatively high if it contains more than 1.5 ppm; and moderate if it contains between 0.50 and 1.50 ppm of strontium.

The geographical areas or regions where streams have been found to contain strontium at relatively low, moderate, or high levels of concentration are also shown in figure 1. Thus, the regions where the strontium content of surface waters is relatively low (less than 0.50 ppm) includes the Pacific Northwest, Northeastern United States, and the Central Lowlands, including the Lower Mississippi Basin and the western Gulf Coast area. Moderate amounts of strontium (0.50 to 1.5 ppm) are found in streams of Southeastern United States, most of the Great Plains Region, the Western Mountain and Plateau Regions, and California. Relatively high concentrations of strontium occur in the surface water of an area that includes northern and western Texas and southern New Mexico and Arizona.

The data so far obtained reveal three exceptions to this geographical distribution. The Maumee River at Waterville, Ohio, contains relatively more strontium than other streams sampled in this area. This is probably due to localized geologic conditions that supply considerable amounts of strontium to ground and surface waters of the area. It is known, for example, that there are extensive deposits of celestite in northern Ohio.

Two other streams do not fall within the above classification for the region in which they are located. Preliminary results show that the Humboldt River at Rye Patch, Nev., and the Rio Grande at San Ildefonso, N. Mex., contain somewhat less strontium than the other streams in those regions. This, again, is probably due to specific localized geologic conditions.

GROUND WATER

In addition to the surface water sampling program, about 150 samples of ground water have been analyzed for strontium. These samples represent ground water sources in California, Colorado, Iowa, Kansas, Maine, Minnesota, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Washington, West Virginia, Wisconsin, and Wyoming. Most of these samples were taken from public water supplies.

The strontium concentration of these samples ranged from less than 0.2 ppm to 36 ppm. Samples from two wells in the known high-strontium area of East-central Wisconsin contained 24 and 36 ppm, respectively. Several well samples from Iowa contained from 2.0 to 3.0 ppm, and one well sample contained 8.8 ppm. One sample from Kansas contained 9.2 ppm; and certain samples from Colorado, Minnesota, Nevada, and North Dakota contained moderate amounts. A great proportion of the samples analyzed contained less than 0.50 ppm of strontium.

Although the strontium content of individual samples is not included here, table 2 lists the maximum strontium concentration found in any one sample from each State. The number of different sources sampled in each State is included in the table.

Table 2—*Maximum concentration of strontium in ground waters sampled*

State	Maximum concentration of strontium, (ppm)	Number of samples
California	0.2	7
Colorado	1.6	15
Iowa	[1]8.8	6
Kansas	9.2	2
Maine	.2	2
Minnesota	1.3	8
Mississippi	.1	2
Montana	.8	4
Nebraska	.8	9
Nevada	1.8	17
New Mexico	.2	9
North Dakota	1.2	2
Oklahoma	.2	2
Oregon	.2	19
Washington	.2	10
West Virginia	[2]116	1
Wisconsin	36	2

[1] 2.4 to 3.0 ppm of strontium found in five samples.

[2] Oil well brine.

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