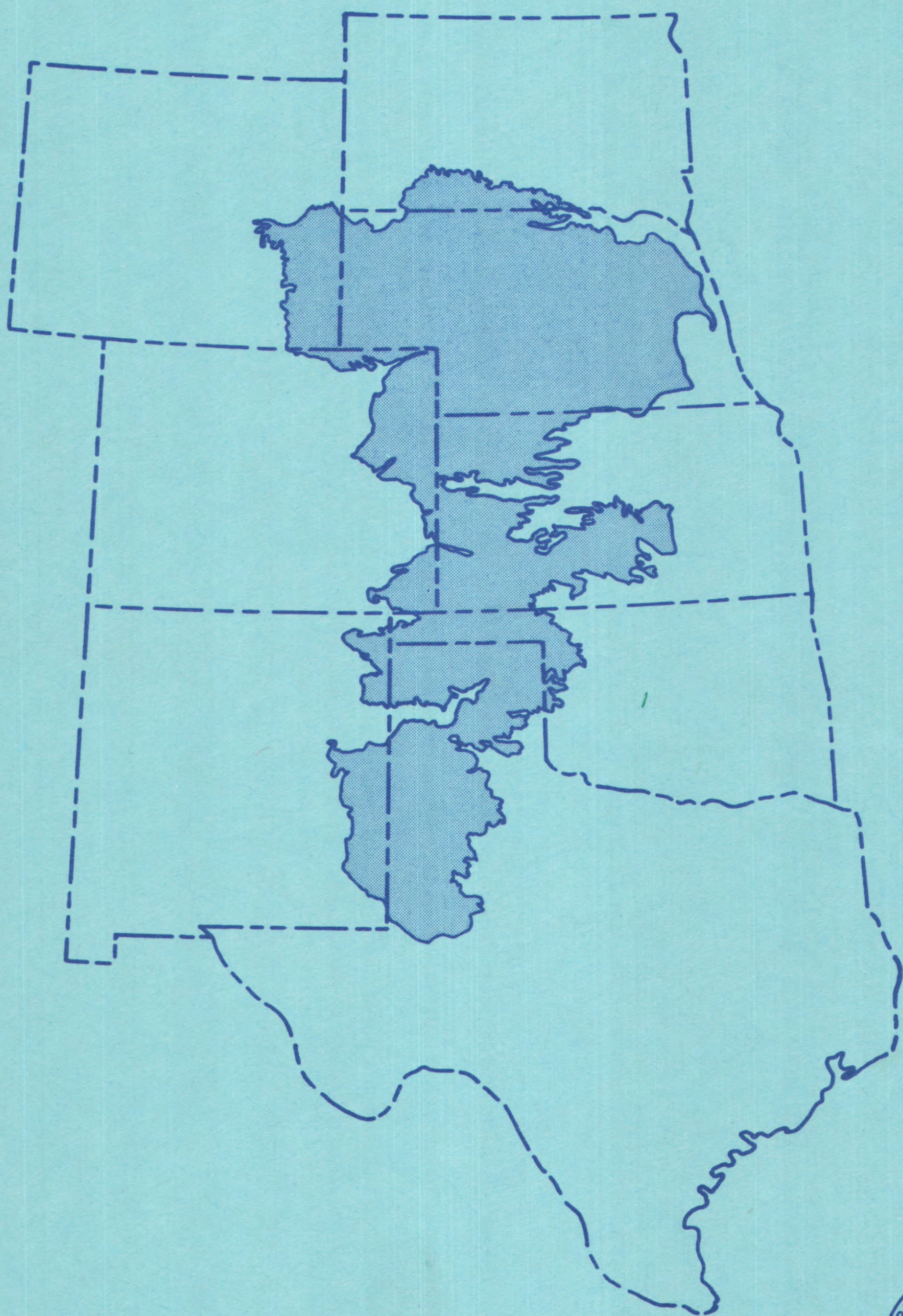
RESULTS OF A RECONNAISSANCE WATER-QUALITY SAMPLING PROGRAM OF THE OGALLALA AQUIFER IN COLORADO, KANSAS, NEBRASKA, OKLAHOMA, SOUTH DAKOTA, AND TEXAS



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Unusually large silica concentrations in many of the water samples probably were due to the presence of amorphous silica in relatively young volcanic-ash deposits present in the aquifer. Because the greatest silica concentrations (as much as 65 milligrams per liter) occurred in the Northern part of the aquifer, the volcanic source was probably from the northwest.

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RESULTS OF A RECONNAISSANCE WATER-QUALITY SAMPLING PROGRAM OF THE OGALLALA AQUIFER IN COLORADO, KANSAS, NEBRASKA, OKLAHOMA, SOUTH DAKOTA, AND TEXAS

By G. L. Feder and N. C. Krothe

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ABSTRACT

Results of a reconnaissance water-quality sampling program of the Ogallala aquifer indicates the water generally is suitable for most uses. Fluoride and selenium were the only chemical constituents found to exceed the National Interim Primary Drinking Water Regulations in water from some of the wells.

Unusually large silica concentrations in many of the water samples probably were due to the presence of amorphous silica in relatively young volcanic-ash deposits present in the aquifer. Because the largest silica concentrations (as much as 65 milligrams per liter) occurred in the northern part of the aquifer, the volcanic source was probably from the northwest.

INTRODUCTION

The Ogallala aquifer consisting of rocks of late Tertiary age is an important source of water for residents of the High Plains Region of the western United States (fig. 1). In addition to providing irrigation water for farming, water from the Ogallala aquifer provides much of the water supply for municipalities, industries, and rural residents in the area. Because of the importance of the Ogallala aquifer to residents of the High Plains, the U.S. Geological Survey is doing an intensive study of the aquifer as part of the Regional Aquifer System Analysis Program. The project includes studies on the hydraulic properties and water-quality characteristics of the aquifer. As part of the water-quality study, an initial reconnaissance of the Ogallala aquifer was made to estimate the means and variances of major and minor chemical constituents in the water. This report describes the results of this program.

SAMPLING

The southern Kansas, Oklahoma, and Texas area was sampled during the summer of 1980. The Colorado, central Kansas, Nebraska, and South Dakota area was sampled during the fall of 1980. To obtain water-quality data from the southernmost part of the Ogallala Formation in Texas, two chemical analyses obtained for other studies were used. One chemical analysis from Hansford County, Tex., was obtained from Bassett and others (1981). The chemical analysis from Lubbock County, Tex., was obtained from W. W. Wood (U.S. Geological Survey, unpublished data, 1981). Water samples for northwest Texas and western Oklahoma were collected by J. W. Oliver of the U.S. Geological Survey. All samples were collected from wells cased into the Ogallala Formation, and the samples were collected after pumping the well for at least 10 minutes.

RESULTS

The water-quality data obtained from the reconnaissance study of the Ogallala aquifer indicates that the ground water generally is suitable for most uses. A statistical summary of the data is shown in table 1; results of the laboratory analysis are shown in table 2. Examination of the data in table 2 shows that the only chemical constituents that exceed the 1976 U.S. Environmental Protection Agency's National Interim Primary Drinking Water Regulations were fluoride and selenium. Gross alpha activity of some of the wells sampled was relatively high, but the method of determination did not exclude the contribution to gross alpha activity from uranium and radon. The 1976 National Interim Primary Drinking Water Regulations call for a maximum contaminant level due to gross alpha activity (incluing radium-226, but excluding radon and uranium) of 15 pCi/L (picocuries per liter); therefore, it is not known if the water contained gross alpha activity in excess of the standard.

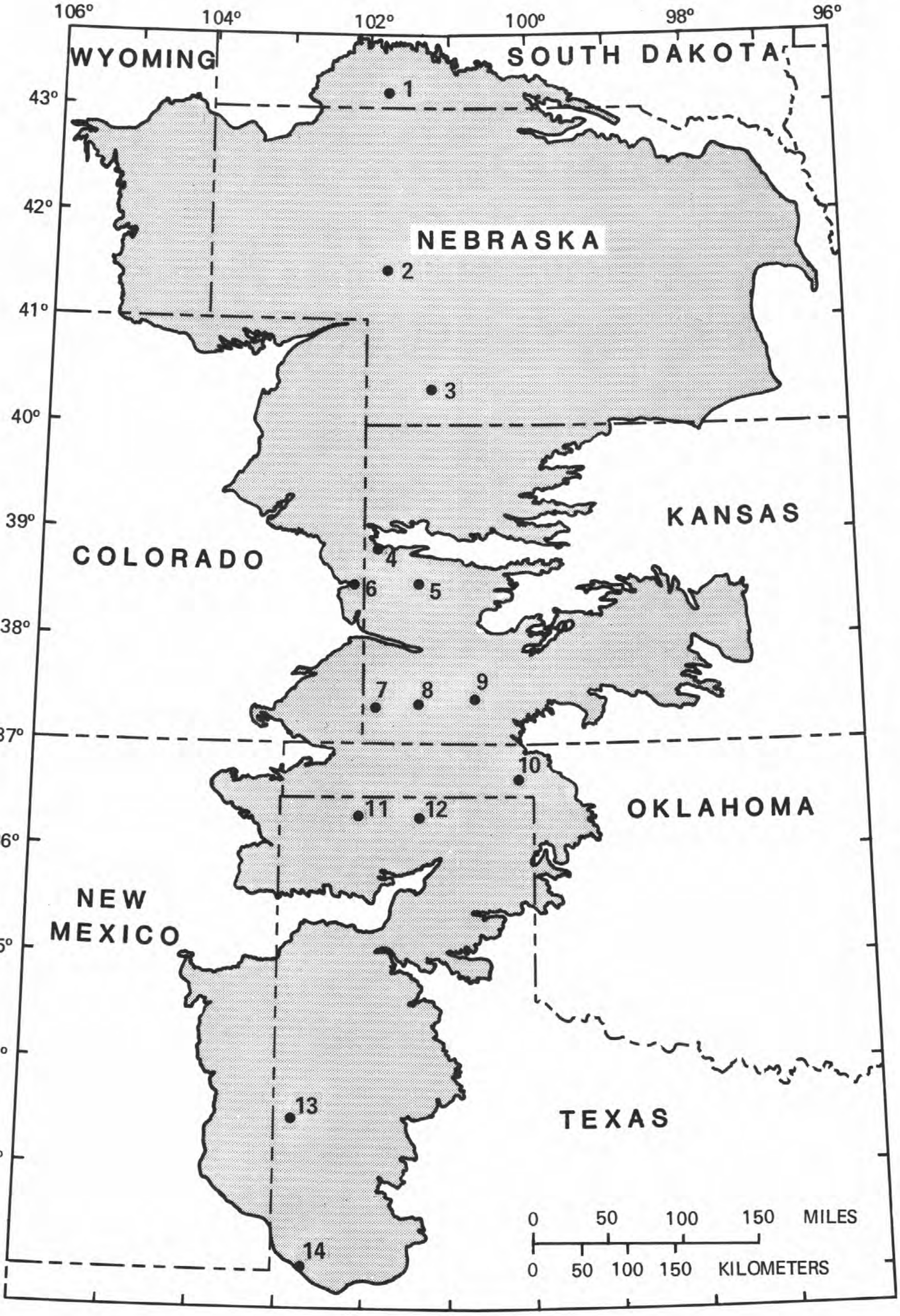

Figure 1.--Location of water-quality sampling sites in the Ogallala aquifer. (Circles indicate sampling sites.)

Table 1.--*Statistical summary of water-quality data from the Ogallala Formation*

[Data expressed as milligrams per liter (mg/L), micrograms per liter (μg/L), and picocuries per liter (pCi/L); GM is geometric mean; GD is geometric deviation; Range is maximum and minimum values obtained; Detection ratio is the number of samples in which the constituent was present in concentrations greater than the detection limit.]

Constituent	Units	GM	GD	Range	Detection ratio
Arsenic (As)	μg/L	4.9	0.23	2-9	6:6
Barium (Ba)	μg/L	71	.21	30-140	12:12
Beryllium (Be)	μg/L	<1	--	<1	0:12
Bicarbonate (HCO_3)	mg/L	175	.30	28-326	14:14
Boron (B)	μg/L	80	.57	<10-270	12:14
Bromide (Br)	μg/L	110	.28	<100-700	11:13
Cadmium (Cd)	μg/L	<1	--	<1-2	2:12
Calcium (Ca)	mg/L	40	.25	7.6-99	14:14
Chloride (Cl)	mg/L	13	.57	0.4-100	14:14
Cobalt (Co)	μg/L	<3	--	<3	0:12
Copper (Cu)	μg/L	<10	--	<50	0:13
Fluoride (F)	mg/L	1.1	.33	0.2-2.8	13:13
Hardness (total as $CaCO_3$)	mg/L	174	.30	25-460	14:14
Iodide (I)	μg/L	--	--	<10-50	8:12
Iron (Fe)	μg/L	--	--	<5-190	3:14
Lead (Pb)	μg/L	--	--	<10-12	1:6
Lithium (Li)	μg/L	45	.34	7-150	14:14
Magnesium (Mg)	mg/L	17	.41	1.4-50	14:14
Manganese (Mn)	μg/L	--	--	<1-470	3:14
Molybdenum (Mo)	μg/L	--	--	<10-22	5:12
Nitrate plus nitrite ($NO_3 + NO_2$)(as N)	mg/L	2.3	.32	.6-7.0	14:14
pH[1]	[1]	7.7	.27	7.0-8.0	14:14
Potassium (K)	mg/L	6.6	.23	3.6-20	14:14
Dissolved solids (residue)	mg/L	331	.21	116-875	14:14
Selenium (Se)	μg/L	--	--	<1-15	7:12
Silica (SiO_2)	mg/L	40	.16	23-65	14:14
Sodium (Na)	mg/L	23	.40	3-100	14:14
Strontium (Sr)	μg/L	821	.47	52-3,700	14:14
Sulfate (SO_4)	mg/L	41	.53	2.7-390	14:14
Vanadium (V)	μg/L	--	--	<6-40	10:12
Zinc (Zn)	μg/L	14	.76	<3-370	11:13
Gross alpha (as U natural)	pCi/L	--	--	<1.6-42	9:12
Gross beta (as Cs-137)	pCi/L	7.4	.24	3.6-15	12:12
Dissolved organic carbon (DOC)	mg/L	.6	.21	0.4-1.2	6:6

[1]pH is given in standard units; statistics given are arithmetic mean and standard deviation.

Table 2.--*Chemical analyses of water from the Ogallala aquifer*

[μg/L = micrograms per liter; mg/L = milligrams per liter; pCi/L = picocuries per liter; NA = not analyzed.]

Sample No. - - - - -	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Constituent, in units	South Dakota, Bennett County	Nebraska, Arthur County	Nebraska, Hayes County	Kansas, Scott County	Kansas, Wallace County	Colorado, Kiowa County	Kansas, Stevens County	Kansas, Morton County	Kansas, Seward County	Oklahoma, Beaver County	Texas, Sherman County	Texas, Hansford County	Texas, Lubbock County	Texas, Martin County
Arsenic (As) in μg/L	2	5	9	8	4	5	NA	NA	NA	NA	NA	NA	NA	NA
Barium (Ba) in μg/L	70	130	140	100	90	30	70	40	40	80	60	90	NA	NA
Beryllium (Be) in μg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	NA	NA
Bicarbonate (HCO_3) in mg/L	28	59	244	256	171	183	220	240	220	250	280	260	326	116
Boron (B) in μg/L	<10	<10	80	120	30	270	100	260	170	80	160	140	270	110
Bromide (Br) in μg/L	<100	100	100	100	100	700	100	100	200	100	<100	200	NA	100
Cadmium (Cd) in μg/L	<1	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	1	NA	NA
Calcium (Ca) in mg/L	7.6	24	46	57	33	99	45	39	61	46	41	42	48	37
Chloride (Cl) in mg/L	0.4	22	3.8	17	4.6	49	18	15	14	100	14	6.5	36	19
Cobalt (Co) in μg/L	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	NA	NA
Copper (Cu) in μg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<50	NA
Fluoride (F) in mg/L	0.2	0.3	0.9	1.5	1.0	2.1	0.9	NA	0.9	1.2	1.8	1.6	2.8	1.9
Hardness (total as $CaCO_3$) mg/L	25	79	170	230	120	460	200	250	240	170	250	210	276	187
Iodide (I) in μg/L	<10	<10	<10	10	<10	50	10	20	10	20	50	20	NA	NA
Iron (Fe) in μg/L	<10	<10	<10	<10	<10	11	<10	<10	<10	<10	17	<10	190	<5
Lead (Pb) in μg/L	<10	<10	<10	<10	12	<10	NA	NA	NA	NA	NA	NA	NA	NA
Lithium (Li) in μg/L	7	18	35	59	26	150	39	100	41	35	81	62	80	60
Magnesium (Mg) in mg/L	1.4	4.6	13	22	8.3	50	21	37	21	14	35	24	38	23
Manganese (Mn) in μg/L	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	10	<1	<10	470
Molybdenum (Mo) in μg/L	<10	<10	<10	<10	<10	12	14	22	11	<10	16	<10	NA	NA
Nitrate plus nitrite (NO_3+NO_2) (as N) in mg/L	1.4	7.0	2.7	4.2	2.4	1.7	2.4	2.0	2.9	3.5	0.6	2.1	4.9	0.6
pH, in standard units	7.0	7.3	7.8	7.7	7.9	7.8	7.8	7.9	7.8	7.8	7.8	7.7	7.5	8.0
Potassium (K) in mg/L	4.8	11	12	6.6	4.2	5.5	4.3	4.2	4.6	3.6	9.5	5.1	11	20
Dissolved solids residue in mg/L	116	206	310	385	204	875	310	421	416	480	350	311	454	288
Selenium (Se) in μg/L	<1	<1	<1	<1	<1	15	3	6	9	1	3	2	NA	NA
Silica (SiO_2) in mg/L	63	63	65	55	23	56	33	29	23	35	27	39	40	44
Sodium (Na) in mg/L	3.0	8.8	20	24	18	76	22	45	44	100	24	18	49	8.4
Strontium (Sr) in μg/L	52	140	530	1,300	520	3,700	1,200	1,800	1,400	770	1,300	1,100	1,400	1,400
Sulfate (SO_4) in mg/L	2.7	8.0	26	61	20	390	51	130	130	49	67	32	66	28
Vanadium (V) in μg/L	<6	23	25	30	16	40	17	21	<6	21	26	16	NA	NA
Zinc (Zn) in μg/L	370	240	11	20	12	15	5	5	8	<3	<3	6	110	NA
Gross alpha in pCi/L (as U natural)	<1.6	<2.4	15	24	11	42	13	24	15	<6.4	12	15	NA	NA
Gross beta (as Cs-137) in pCi/L	3.6	9.3	15	8.2	5.8	13	6.9	8.2	7.4	4.2	12	8.1	NA	NA
Dissolved organic carbon (DOC) in mg/L	0.4	0.9	0.4	0.4	0.6	1.2	NA	NA	NA	NA	NA	NA	NA	NA

However, because of the relatively large concentrations in water from the few wells sampled (as much as 42 pCi/L), additional sampling needs to be done using criteria established by the U.S. Environmental Protection Agency to see if the regulation is exceeded.

Excessive fluoride and selenium concentrations in water from the Ogallala Formation have been reported in several publications describing water quality of the area (Bassett and Wood, 1978; Engberg, 1973). Both selenium and fluoride showed large variability in concentration throughout the study area, probably due to variability of the aquifer sediments. Two chemical constituents of geochemical interest that occur in relatively large concentrations in the study area are silica and strontium. Silica concentrations were unusually large for a nongeothermal ground water, with concentrations as much as 65 milligrams per liter obtained in the few samples collected for this study. The greatest silica concentrations were found in the northern part of the area, and probably are related to Quaternary volcanism that occurred to the west in the Rocky Mountains and covered the area with successive ash deposits (Elias, 1931). Volcanic-ash deposits generally are thicker to the north in the area underlain by the Ogallala Formation (E. D. Gutentag, U.S. Geological Survey, oral communication, 1981). Large silica concentrations probably are controlled by solubility of amorphous silica still present in these relatively young volcanic ash deposits (Jordan and others, 1964).

Relatively large strontium concentrations, as much as 3,700 μg/L found in most of the waters sampled in this study also result from the young age of the Ogallala sediments. The large amounts of strontium probably come from carbonate fossils in the formation and also from the sediments in the Ogallala Formation reworked from the underlying Niobrara Formation, Pierre Shale, and Dakota Formation of Cretaceous age. (E. D. Gutentag, U.S. Geological Survey, oral communication, 1981).

SUMMARY AND CONCLUSIONS

Water in the Ogallala Formation of late Tertiary age generally is suitable for most uses. Fluoride and selenium were the only chemical constituents found to exceed National Interim Primary Drinking Water Regulations. The possibility that some water supplies may have exceeded standards for gross alpha activity or radium-226 and radium-228 was indicated by the samples having relatively high gross alpha activity. However, the regulation only includes the contribution to gross alpha activity from radium, and the method used to determine gross alpha activity in this study also included alpha activity from uranium and radon. Therefore, additional sampling in the Ogallala aquifer is needed to determine the type of gross alpha activity present.

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