Uranium Content of Ground and Surface Waters in a Part of the Central Great Plains

By E. R. LANDIS

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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URANIUM CONTENT OF GROUND AND SURFACE WATERS IN A PART OF THE CENTRAL GREAT PLAINS

By E. R. Landis

ABSTRACT

The uranium content of water from various rock units and geologic terranes has been determined in an attempt to locate areas in which large amounts of uranium in the water might indicate the presence of nearby accumulations of uranium in the rocks of the central Great Plains.

Water samples were collected from three geologic terranes in the report area: The tuffaceous-rocks terrane, of Tertiary and Quaternary age; the shale terrane, of Cretaceous age; and the sandstone terrane, of late Permian through Early Cretaceous age. The average uranium content of 179 water samples from tuffaceous fluviatile rocks ranging in age from Pliocene to Pleistocene is 6.7 parts per billion (ppb). A total of 48 samples from Cretaceous shale and limestone of marine origin contain an average of 20.4 ppb uranium. Sandstone, siltstone, and claystone of terrestrial and near-shore marine origin are the predominant rocks of the sandstone terrane, and the 83 water samples collected from or related to these rocks contain an average of 10.2 ppb. The average uranium-content figure derived for the shale terrane may not be representative of the uranium content of waters from this unit throughout the report area because most of the samples were collected from a small area in which the uranium content of the waters may be abnormally large. Compared to the shale terrane, the tuffaceous-rocks terrane and the sandstone terrane are both represented by a greater number of samples collected over a much larger area, and the data on the average uranium content derived for them are believed to be representative of the uranium content in the report area.

The data on average uranium content of the different rock units, or groups of rock units, are listed according to the source from which the samples were collected (well, spring, stream, municipal water system, reservoir, or lake), and for some samples by geographic parts of the report area. They are believed to be of more potential use in any future hydrogeochemical exploration in the area than are the data on average uranium content derived for the three geologic terranes. The average uranium content of ground-water samples from 12 individual rock units or groups of rock units ranges from less than 1.0 to 38 ppb. Several rock units were sampled over areas large enough to indicate that waters from the same rock unit in different parts of the report area may range widely in average uranium content.

Most or all the water samples from certain rock units wherever present in the area, particularly those of Permian and Triassic age, contain large amounts of uranium. Also, relatively large amounts of uranium are present in water samples from some parts of the report area, such as the Cimarron River area of westernmost Oklahoma and northeastern New Mexico, and the Rule Creek area of Bent and Las Animas Counties, Colo. Further exploration to determine the source of the uranium in the water from these rock units and areas may be worth while.

INTRODUCTION

PURPOSE OF STUDY

During 1954, 1955, and 1956, water samples for determination of uranium content were collected in western Kansas, southeastern Colorado, northeastern New Mexico, and the Panhandle of Oklahoma by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission.

Fix (1956), Saukoff (1956), and Denson, Zeller, and Stephens (1956), have discussed the uranium content of natural waters and the value of water sampling in prospecting for uranium deposits and in evaluating the potential of an area, a geologic terrane, or an individual rock unit, as a source of uranium or as a host for uranium deposits.

Fix (written communication, 1954) and Denson, Zeller, and Stephens (1956, p. 673–680) found differences in uranium content in waters from different geologic environments. Three widespread geologic terranes are present in the area covered in this report and samples were collected to determine the average uranium content of waters from each of the terranes. The number of samples is sufficient to show preliminary data on the average uranium content of ground water from some rock units of different ages in the area, and to indicate some areas in which water samples contain relatively large amounts of uranium.

SAMPLING

Wells were the sources for more than half the samples, but streams and springs were sampled at selected localities, and some reservoirs and lakes were sampled where other sources were not available. An effort was made to obtain clear samples of water. Wells were sampled extensively, both to obtain water from specific aquifers and as a necessity in areas that lack surface water. Of the sources sampled, reservoirs are considered to furnish the least representative samples because of the effects of evaporation and the periodicity and volume of rainfall. Stream samples are affected by the presence of reservoirs upstream and by the periodicity and volume of past rainfall. The most representative samples are from wells obtaining water from acquifers deep enough to be relatively unaffected by surface conditions. A total of 324 samples were collected from 319 sources: 73 stream samples from 72 localities; 5 samples from lakes; 23 samples from 21 reservoirs; 168 samples from 166 wells; 18 samples from springs; and 37 samples from municipal water systems. The samples from Kansas were collected between July 10 and September 21, 1954, and those from Colorado and Oklahoma, between September 21 and November 4, 1954. Three samples from New Mexico were collected in April 1956.

In Kansas, the samples from Wallace, Logan, Gove, Scott, Finney, Lane, Ness, Hodgeman, Ford, and Gray Counties were collected during and after a period of several months in which little or no rain fell in the collection area, whereas those from Clark, Meade, Seward, Haskell, Grant, Stanton, Hamilton, and Kearny Counties and the northeastern part of Stevens County were collected during a period when rain fell generally throughout the area, with quantities ranging from a trace to several inches. The samples from Colorado, Oklahoma, and from Morton County and the western part of Stevens County, Kans., were collected during a period of prevailing dryness in which only a few scattered rains fell. The samples from New Mexico were collected early in spring after a period of scattered but heavy rainfall.

PRESENTATION OF DATA

Table 4 shows the location, source, estimated flow in gallons per minute, the rock unit from which the water was obtained (aquifer), the uranium content in parts per billion, the acidity (pH), and the terrane affiliation pertinent to the individual samples. Samples are listed by county and land subdivision. The flow in gallons per minute is estimated for most of the samples, but in a few cases definite information was available, either orally from interested parties or in the geologic literature.

Tables 1 and 2 show the average (arithmetic mean) uranium content of ground-water samples from selected rock units and areas in the report area. Table 3 summarizes all the analytical data and shows, according to source, the number and average uranium content of water samples that were obtained from or whose uranium content is related to stratigraphic units of different age. For purposes of calculating average uranium content, those samples with less than 1.0 part per billion (ppb) uranium were considered to contain 0 ppb. For comparative purposes the averages are shown to 0.1 part per billion (10^9) but are significant only to the first whole number.

Plate 26 and figure 25 show the areal distribution and uranium content of all water samples collected in the area by the author during this investigation. The source type of each sample is indicated by symbol. Plate 26 shows the general geology of the report area, as modified from State and U.S. Geological Survey maps. Rocks that crop out in the area are grouped into five units that are differentiated by patterns. Figure 25 shows the locations and source types of water samples that were collected in part of Wallace County, Kans., that could not all be shown at the scale on the map on plate 26.

METHOD OF ANALYSIS

The water samples were collected in pint polyethylene bottles, and all were analyzed within 6.5 months after collection. The acidity of the water was determined in the laboratory with a pH meter having a glass electrode. The uranium content was determined by the ethyl acetate extraction method in the following procedure: An acidified aliquot of the sample, commonly 100–500 ml, was evaporated to an almost dry residue, to which was then added a dilute solution of nitric acid. To an aliquot of this solution was added recrystallized aluminum nitrate. The uranium was extracted from solution by use of ethyl acetate and then roasted in a platinum dish. The residue was fused with a sodium fluoride-carbonate flux. A sensitive fluorimeter was used to compare the fluorescence of the fused residue with standard uranium compounds treated in a similar manner, and the uranium content was calculated in parts per billion. The probable limits of accuracy of this method range from about 1 ppb for samples containing 10 ppb uranium, to about 3 ppb for samples containing 100 ppb. All analyses were made in U.S. Geological Survey laboratories by J. Johnson, J. McClure, D. Stockwell, J. Patton, H. Lipp, J. Schuch, J. Wilson, H. Bivens, G. Burrow, and R. Cox, under the supervision of L. F. Rader, Jr.

GEOLOGIC TERRANES

In the area in which samples were collected for this report, rock units ranging in age from Permian to Recent are present at or near the surface. The units may be grouped for convenience according to age, lithologic character, structural relationship, and genesis, in three geologic terranes for comparison of the uranium content of water obtained from the rocks included in each terrane. The most widespread is the sequence of tuffaceous fluviatile sediments of Tertiary and Quaternary age, but the shale terrane of Cretaceous age occupies large areas in Colorado and Kansas, and the sandstone terrane of late Permian through Early Cretaceous age occupies extensive areas in southeastern Colorado, southern Kansas, northeastern New Mexico, and the Oklahoma Panhandle.

Although many samples of both ground and surface water are listed in table 4 as having been obtained from alluvium of Recent age, the uranium in the samples is believed to be related to the older rocks that are either overlain by the alluvium or drained by waters that subsequently furnished the samples from nearby alluvium. As used in the tables "alluvium" also includes colluvium, soils, and thin eolian sediments. The terrane affiliations of the samples collected from alluvium, where determinable, are noted in the tables.

SANDSTONE TERRANE

The sandstone terrane includes all the rocks of Permian, Triassic, and Jurassic age in the area of this report and all the rocks of Cretaceous age below the top of the Dakota sandstone. The rock units included are the Whitehorse sandstone, Day Creek dolomite, the Taloga formation of Cragin (1897), and the Cloud Chief formation, all of Permian age; the Lykins formation, of Permian(?) and Triassic(?) age; the Dockum group, of Triassic age; the Entrada sandstone of Jurassic age; the Purgatoire formation, consisting of the Cheyenne sandstone and the Kiowa shale members; and the Dakota sandstone, all of Early Cretaceous age. Although several of the rock units of this terrane are chiefly shale, which normally yields little or no water, the sandstones of the terrane are among the important aquifers of the Great Plains region.

This terrane occupies a large area in southeastern Colorado but is not well represented at the surface in western Kansas. However, in many areas where the rocks of this terrane underlie rocks of the other two terranes, samples of water were obtained from deep wells drawing water from the formations belonging to this unit.

SHALE TERRANE

The shale terrane includes all formations of Cretaceous age above the Dakota sandstone that are exposed in the northern part of the Kansas and Colorado parts of the report area. The shale terrane includes the Graneros shale of Early and Late Cretaceous age, and the Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale of Late Cretaceous age. These rock units yield water to very few wells and springs, and many of the samples from this terrane are stream samples or samples from shallow wells obtaining water at the contact of the relatively impermeable shales and the overlying thin valley and gully fill.

TUFFACEOUS-ROCKS TERRANE

The tuffaceous-rocks terrane consists of tuffaceous rocks ranging in age from Pliocene to Recent. Rock units that are included are the Laverne, Ogallala, and Meade formations. The lower portion of the Ogallala and its correlative, the Laverne formation, are considered to be early Pliocene in age, although Moore and others (1951, p. 20) considered them also to be possibly late Miocene in age. The upper and most widespread part of the Ogallala is Pliocene in age, but in eastern

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Colorado some of the units ordinarily mapped with the Ogallala may be Pleistocene in age. Frye and Leonard (1952, p. 66) refer to certain rocks in southwestern Kansas formerly included in the Ogallala to the Blanco formation that they believe to be of Pleistocene age. In the present report they are mapped with the Ogallala. The Meade formation is of Pleistocene age (Moore and others, 1951, p. 14). Also included in this terrane are dune sand and terrace deposits of Pleistocene and Recent age and the wide belt of thick alluvium along the Arkansas River.

URANIUM CONTENT OF WATER FROM INDIVIDUAL ROCK UNITS

Table 1 shows the average uranium content of selected samples of well and spring water from individual rock units in the report area and the location of the averaged samples within the area. The averages

TABLE 1.—*Uranium content of samples of well and spring water from selected individual rock units and areas*

Rock unit and age	Location of samples	Number of samples	Uranium content (ppb)	
			Range	Average
Sandstone terrane				
Permian:				
Undifferentiated rocks	Meade and Morton Counties, Kans.; Texas County, Okla.	5	11–28	16.0
Triassic:				
Undifferentiated rocks	Baca County, Colo.; Texas County, Okla.	2	35–41	38.0
Jurassic:				
Entrada sandstone	Baca County, Colo.	1	----------	4.0
Cretaceous:				
Cheyenne sandstone member of Purgatoire formation.	do	3	11–50	27.0
Dakota sandstone	Baca County, Colo.; Morton, Stanton, and Hamilton Counties, Kans.	11	<1–18	7.5
Do	Lane, Ness, Hodgeman, and Ford Counties, Kans.	7	<1–14	5.1
Shale terrane				
Cretaceous:				
Graneros shale	Kearny County, Kans.	1	----------	<1.0
Codell sandstone member of Carlile shale.	Kiowa County, Colo.	2	1–2	1.5
Niobrara formation	Finney County, Kans.	3	11–14	12.7
Tuffaceous-rocks terrane				
Pliocene:				
Ogallala formation including the Laverne formation.	Total area, average	69	<1–88	10.4
Ogallala formation and (or) Meade formation.	do	9	<1–7	3.7
Pleistocene:				
Meade formation	Meade, Seward, and Grant Counties, Kans.	11	2–7	3.2

for those rock units that are represented by only a few samples are indicative only of the order of magnitude of the uranium content of waters from these units in the immediate area of the sample source. Average uranium-content figures were derived for each of the two areas in which water samples were collected from the Dakota sandstone. In table 1 samples that are derived from either or both the Ogallala and Meade formations, but cannot be definitely attributed to one or the other, are grouped as the Ogallala and (or) Meade formations. Samples from wells that obtain water both from the Laverne formation and from the Ogallala formation are included in table 1 with the samples of water derived solely from the Ogallala formation.

Waters from the Ogallala and Meade formations were sampled over large parts of the report area and the data on average uranium content shown in table 1 are broad generalizations that may not be applicable throughout the area. Table 2 shows the average uranium content of water samples from these rock units in small parts of the report area. The subdivision was made on the basis of geologic and geographic setting and the time the sample was collected. Because the source of some samples is uncertain, the Laverne and Ogallala formations are

TABLE 2.—*Uranium content of grouped samples of well and spring water from rock units of Tertiary and Quaternary age in various parts of the report area.*

Location of samples	Number of samples in group	Uranium content (ppb)	
		Range	Average
Ogallala formation			
Cheyenne, Crowley, Kiowa and Lincoln Counties, Colo	7	3-88	26.4
Baca County, Colo.; Morton County, Kans; and Cimarron and Texas Counties, Okla	10	6-15	11.4
Western Kansas north of the Arkansas River, except northern Hamilton and Kearny Counties, Kans	27	4-40	10.9
Meade and Clark Counties and the part of Ford County south of the Arkansas River, Kans	13	1-21	7.3
Stanton County, Kans	6	1- 4	2.0
Hamilton County, Kans	4	<1- 4	1.8
Laverne and Ogallala formations			
Meade County, Kans	2	7- 7	7.0
Ogallala formation and (or) Meade formation			
Meade County and the parts of Gray and Ford Counties south of the Arkansas River, Kans	5	3- 7	5.2
Seward, Stevens and Stanton Counties, Kans	4	<1- 3	1.8
Meade formation			
Meade County, Kans	2	7- 7	7.0
Seward and Grant Counties, Kans	9	2- 4	2.3

considered as a unit for Meade County, Kans., and the Ogallala and Meade formations are so considered for parts of southwestern Kansas.

AREAS HAVING A LARGE CONTENT OF URANIUM IN WATER

Appraisal of the results of the water sampling allows delineation of several areas in which most or all the water samples contain uranium in quantities larger than do samples from the same terrane or rock unit in the report area as a whole.

VALLEY OF THE SMOKY HILL RIVER

One of the areas in which most of the water samples contain large amounts of uranium is the valley of the Smoky Hill River in Wallace, Logan, and Gove Counties, Kans. The valley is cut in shale and limestone beds of Cretaceous age that are overlain by thin deposits of fluviatile and eolian sediments of Pleistocene and Recent age. The Ogallala formation of Pliocene age unconformably overlies the Cretaceous rocks on the upland plains and interstream divides on each side of the valley of the Smoky Hill River.

Interpretation of the analyses of water from the area is complicated by the fact that samples were collected during two dry periods separated by a period of rainfall. For convenience, the samples collected in early July and those collected in late August and early September are hereinafter referred to as July samples and September samples, respectively. No large variation in uranium content is apparent in well and spring samples of water from the Ogallala formation collected during both time periods, and samples taken during both time periods from a well in Logan County obtaining water at the contact of Pleistocene(?) sediments and Cretaceous shale showed essentially no variation in uranium content (table 4, samples 210708 and 217643). July and September samples obtained from reservoirs dug in the Cretaceous shale beds showed a large difference in uranium content. One reservoir in Wallace County, Kans., sampled in July, had a uranium content of 380 ppb, but samples collected from it in September indicated a content of only 5 ppb (table 4, samples 210704 and 215044), and many of the reservoirs sampled during the "September" period contained less than 1 ppb (fig. 25). The great difference in uranium content is probably attributable largely to two causes—concentration through evaporation during the dry period preceding the July sampling period and the flow of surface waters into the reservoirs during the wet period between sampling periods in contrast to subsurface flow only, prior to the July sampling.

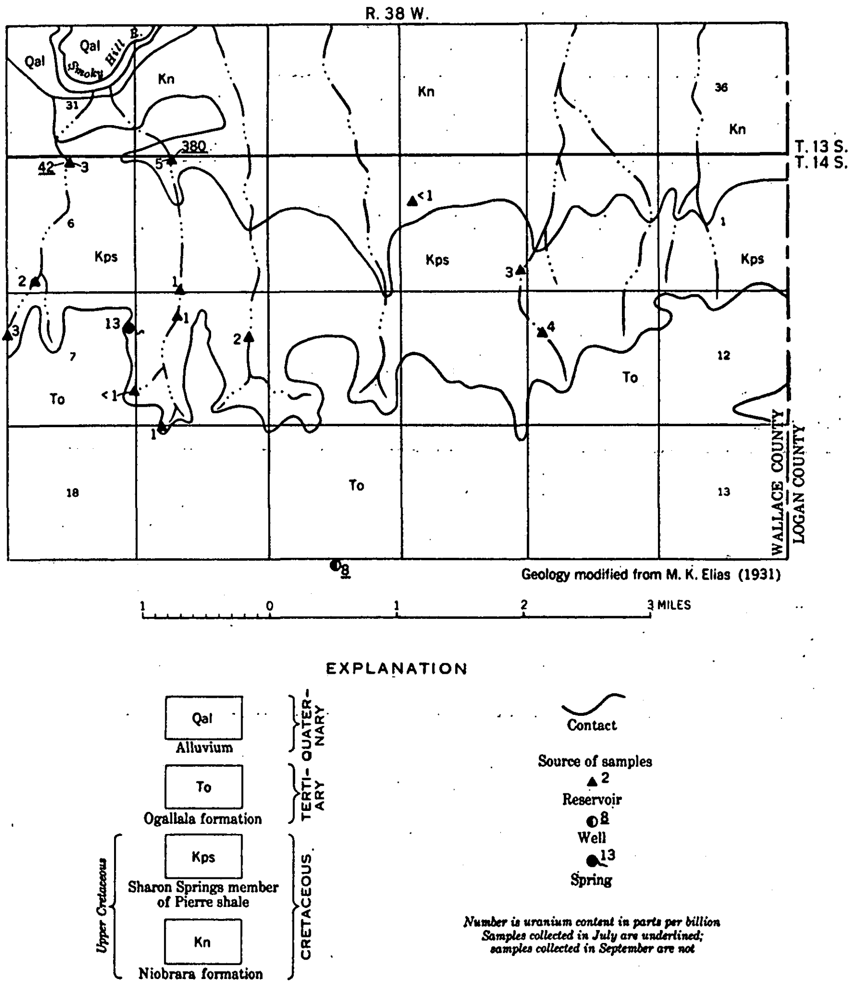

FIGURE 25.—Map showing location and uranium content of water samples collected in Tps. 13 and 14 S., R. 38 W., Wallace County, Kans.

Chemical and spectrographic analyses of the residue obtained by evaporation of 5 gallons of water from the well in sec. 2, T. 13 S., R. 35 W., Logan County, are shown on page 232.

Chemical analyses of the residue from 5 gallons of water froma well in sec. 2, T. 13 S., R. 35 W., Logan County, Kans.

[Sample serial No. 219171. Analysts: J. Wilson, W. Mountjoy, J. H. McCarthy, and G. C. Campbell. Residue: 26.65 grams, equals 0.141 percent of sample]

Element	Concentration in residue (percent)	Concentration in water (approximate ppb)	Element	Concentration in residue (percent)	Concentration in water (approximate ppb)
Calcium	16.5	232,000	Phosphorus	<.003	<40
Zinc	.005	70	Arsenic	.002	30
Uranium	.004	60	Selenium	.001	10

Semiquantitative spectrographic analyses of the residue from 5 gallons of water from a well in sec. 2, T. 13 S., R. 35 W., Logan County, Kans.

[Sample serial No. 219171, spectrographic plate No. II-1177. Analyst: P. J. Dunton. Looked for but not detected, as the amount present was below the threshold amount of the element: Ag, As, Au, Be, Bi, Cd, Ce, Co, Cr, Dy, Er, Ga, Gd, Ge, Hf, Hg, In, Ir, La, Mn, Nb, Nd, Ni, Os, P, Pb, Pd, Pt, Re, Rh, Ru, Sb, Sc, Sm, Sn, Ta, Te, Th, Ti, Tl, U, W, Y, Yb, Zn, and Zr. Residue: 26.65 grams, equals 0.141 percent of sample. Concentration in water: approximate values obtained by use of subgroup midpoints, which are logarithmic means. The concentrations of the elements are determined by semiquantitative spectrographic analysis are bracketed into groups, each of approximately one-third of an order of magnitude, X+ indicating the higher portion (10–15 percent); X, the middle portion (5 to 2 percent); and X−, the lower portion (2 to 1 percent). Comparisons of this type of semiquantitative results with those obtained by quantitative methods, either chemical or spectrographic, show that the assigned group includes the quantitative value in about 60 percent of the analyses.]

Element	Concentration in residue (percent)	Concentration in water (approximate ppb)	Element	Concentration in residue (percent)	Concentration in water (approximate ppb)
Calcium	xx.	>100,000	Lithium	0.0x−	210
Sodium	x.+	96,000	Molybdenum	.00x	45
Magnesium	x.	45,000	Iron	.00x	45
Potassium	.x+	9,600	Aluminum	.00x−	21
Silicon	.x	4,500	Barium	.00x−	21
Strontium	.x−	2,100	Copper	.000x+	9.6
Boron	.0x+	960	Vanadium	.000x+	9.6

Samples from 5 wells and 2 springs obtaining water from the Ogallala range in uranium content from 8 to 20 ppb and average 10.1 ppb. Thirteen samples of well and stream water and water from municipal systems were obtained from thin alluvium overlying Cretaceous shale in the valley. Nine well samples contain an average of 36.1 ppb uranium, two stream samples contain an average of 24 ppb, and two water-system samples contain an average of 18 ppb. In contrast, samples of water from or related to rock units of the shale terrane in Ness, Lane, Finney, Hodgeman, and Ford Counties, Kans., contain far less uranium. Seven samples of well and spring water and water from municipal systems contain an average of 9.4 ppb uranium and three stream samples contain an average of 6.3 ppb. This difference in the uranium content of the water samples may be a reflection of a difference in average uranium content between the younger Upper Cretaceous rocks in the valley of the Smoky Hill River and the slightly older rocks that crop out to the southeast.

SCOTT COUNTY-FINNEY COUNTY AREA

Samples collected along a north-south line in Scott and Finney Counties, Kans., indicate an area in which water from the Ogallala formation has a more than normal content of uranium. Three of the samples contain from 12 to 23 ppb uranium, whereas other samples to the north, south, and east contain no more than 8 ppb.

The water table is much nearer the surface along the north-south sample-collection line than it is east or west of it (Waite, 1947, p. 56). Possibly loss of water through evaporation has resulted in a greater concentration of uranium in the ground water.

VALLEY OF THE CIMARRON RIVER

In Cimarron County, Okla., and Union County, N. Mex., 6 samples obtained from the Cimarron River and 1 from a well obtaining water from the river alluvium contain from 13 to 42 ppb uranium. Samples 221356, 221357, and 221364 (table 4) were collected in late October and early November 1954; sample 239713 (table 4) was collected in November 1955; and samples 242831, 242832, and 242833 (table 4) were collected in April 1956.

Fix (1956, p. 790) states that in most uraniferous areas the streams usually contain from 1 to 10 ppb uranium, but (oral communication, 1956) concentrations of as much as 65 ppb uranium have been found. The uranium content of the 7 samples is abnormally large. The Cimarron River rises in an area of extrusive igneous rocks (pl. 26), and the uranium may be derived by leaching of disseminated uranium from these rocks or may be derived from uranium deposits associated with the igneous rocks or the sedimentary rocks of Triassic, Jurassic, and Cretaceous age that underlie the extrusive rocks and are exposed along the valley of the Cimarron River.

RULE CREEK DRAINAGE BASIN

Several samples from streams and springs were collected in the drainage basin of Rule Creek in Bent and Las Animas Counties, Colo. At the confluence of Rule Creek and Muddy Creek, a sample was collected that contains 28 ppb uranium. A reservoir on Muddy Creek, upstream from the collection point, may have affected the uranium content of the sample to some extent in that evaporation of water from the reservoir may have resulted in concentration of uranium in the water reaching Rule Creek. Farther south (upstream) a sample from Rule Creek contains 14 ppb and a sample from Hackberry Creek, a northwestward-flowing tributary, contains 6 ppb. A sample from a spring in the Cheyenne sandstone member of the Purgatoire formation contains 50 ppb uranium. Several low-grade concentrations of uranium in rocks near the headwaters of Rule Creek were examined by the author and the water samples may indicate the presence of other uranium concentrations in the drainage basins of Rule Creek and Muddy Creek.

INDIVIDUAL SAMPLES OF WATER THAT CONTAIN LARGE QUANTITIES OF URANIUM

Several individual water samples contain large amounts of uranium compared to samples from nearby areas or in comparison to the average uranium content of similar samples from the same, or nearby areas.

The sample from a well in the Ogallala in sec. 13, T. 25 S., R. 30 W., Gray County, Kans., contains 40 ppb uranium, whereas other wells obtaining water from the Ogallala formation in the same general area contain from 8 to 14 ppb.

A sample from a spring in sec. 17, T. 32 S., R. 28 W., Meade County, Kans., contains 21 ppb uranium, in contrast to other samples also from the Ogallala formation in the same area that contain less than 8 ppb.

In sec. 21, T. 29 S., R. 36 W., Grant County, Kans., a sample from a spring in the bed of the North Fork of the Cimarron River contains 15 ppb uranium. Other samples of the stream water, above and below the spring in section 21, contain less than 1 ppb, and all samples within 8 miles contain less than 5 ppb.

A sample from a spring in a stream bed in sec. 25, T. 22 S., R. 42 W., Hamilton County, Kans., contains 21 ppb uranium, while water from another spring less than a mile distant in the same stream bed contains only 2 ppb, and no samples within 20 miles contain more than 2 ppb.

A sample from a well in sec. 25, T. 4 N., R. 12 E., Texas County, Okla., contains 41 ppb uranium. The well is believed to obtain water from red beds of Triassic age. A well in sec. 31, T. 29 S., R. 50 W., Baca County, Colo., also supposedly obtaining water from red beds of Triassic age, contains 35 ppb uranium, and a well in sec. 5, T. 34 S., R. 42 W., Morton County, Kans., that may obtain some water from the Dockum group of Triassic age, contains 20 ppb. With the present data it is impossible to determine whether each of the above-cited samples indicates a local concentration of uranium or whether the Triassic rocks contain disseminated uranium in a form that is readily available for solution by ground water. Deposits of uranium minerals in rocks of Triassic age have been reported in northeastern New Mexico (Griggs, 1955, p. 191) and highly radioactive zones are reported to be present in the Dockum group of Triassic age in northern Texas (Eargle and McKay, 1955, p. 262).

The water sample collected from the Purgatoire River in Bent County, Colo., contains 32 ppb uranium. The uranium content of this sample is sufficiently high to indicate that further reconnaissance and hydrogeochemical exploration in that area may be profitable.

The extreme range of uranium content, from 3 to 88 ppb, in the samples from the Ogallala formation in the area north of the Arkansas River in Colorado indicates that more data should be collected and evaluated to determine the possibility of local concentrations of uranium near the sources of samples containing larger amounts of uranium, either in the Ogallala or in the rock units of Cretaceous age that the Ogallala overlies unconformably.

RELATION OF URANIUM CONTENT TO pH

The pH is the logarithm of the reciprocal of the hydrogen-ion concentration when this concentration is expressed as gram ions per liter. A solution having a pH of 7 is neutral. Therefore, an increase in pH represents a decrease in hydrogen-ion concentration, that is, a decrease in acidity, and conversely. At the time of analysis for uranium, determinations of the pH were also made on all but one of the 324 samples. Almost 4 percent had a pH of 7.0 or less, about 28 percent had a pH of 7.1 to 7.5, about 49 percent had a pH of 7.6 to 8.0, and almost 19 percent had a pH of more than 8.0. The pH ranged from 6.5 to 8.5.

Fix (written communication, 1954) has stated that: "Uraniferous waters usually have a pH somewhat greater or less than 7, whereas waters with a pH close to 7 seldom contain anomalous amounts of uranium." Denson, Zeller, and Stephens (1956, p. 799) sampled waters from four areas in the northern Great Plains and Wyoming Basin and concluded that the most highly mineralized water in tuffaceous-rocks terranes has an alkaline pH range of 7.5 to 9.5. The findings of Fix and of Denson, Zeller, and Stephens are substantiated by the results of analyses for this report; in general, the samples with a pH close to the neutral point (pH of 7) do not contain as much uranium as the more alkaline samples with larger pH's.

SUMMARY

Table 3 summarizes the analytical data on which this report is based. The number and average uranium content of samples obtained from or related to rock units of different ages are listed according to the type of source. A total of 324 samples was collected, but one was a bulk sample taken for chemical and spectrographic analyses and the results are not included in table 3.

Almost all the figures for average uranium content in table 3 are greater than the background concentration of uranium in natural waters in the United States, which generally is about 0.1 ppb (Fix, 1956, p. 790). This background figure is very roughly analogous to

TABLE 3.—*Average uranium content of samples of water in western Kansas, eastern Colorado, northeastern New Mexico, and the Oklahoma Panhandle*

Aquifer	Wells		Springs		Streams		Municipal water systems		Reservoirs		Lakes		Total all sources	
	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)	Number of samples	Uranium (ppb)
Recent—alluvium:														
related to tuffaceous-rocks terrane	21	3.4	1	<1	24	4.2	2	4.0	4	7.8	1	5.0	53	4.1
related to shale terrane	11	31.0	2	1.0	9	8.1	3	14.0	14	31.9	1	7.0	40	22.8
related to sandstone terrane	9	9.7			35	9.8							44	9.8
Total related to all terranes	41	12.2	3	<1	68	7.6	5	10.0	18	26.6	2	6.0	137	11.4
Pleistocene—fluviatile and eolian sediments	12	3.4	1	15.0	4	<1			2	1.0			19	3.1
Pliocene and Pliocene and Pleistocene—largely fluviatile	61	10.6	8	9.5			21	6.5	2	<1	2	14.5	94	9.4
Upper Cretaceous—predominantly shale	4	2.3	4	14.8									8	8.5
Lower Cretaceous—predominantly sandstone (Dakota sandstone and Purgatoire formation)	21	7.0	2	25.5			6	8.5					29	8.6
Jurassic (Entrada sandstone)	1	4.0											1	4.0
Triassic—sandstone and red beds (Dockum(?) group)	2	38.0											2	38.0
Permian—sandstone and red beds (Taloga formation of Cragin (1897) and Cloud Chief formation)	5	16.0					1	8.0					6	14.7
Undetermined or more than one aquifer	20	6.5			1	7.0	4	3.8	1	<1	1	3	27	5.7
Total or average	167	9.5	18	11.3	73	7.2	37	7.1	23	20.9	5	8.8	323	9.7

the background intensity of radioactivity and means that any water sample collected in the report area can be expected to contain 0.1 ppb uranium or more.

The average uranium content of the well samples is probably the most useful, potentially, of the averages shown in table 3 for the various source types because wells are the predominant source of water in the report area; water samples from wells are more representative of the uranium content of waters from specific rock units than are waters from other sources because there is less chance of mixing with waters from other rock units; the effects of evaporation are minimized in well samples; and the effects of the volume and periodicity of rainfall is less in well samples than in samples from other sources. With the exception of those samples from thin alluvium overlying the shale terrane in the valley of the Smoky Hill River and the samples from sandstones and red beds of Permian and Triassic age, the average of 9.5 ppb uranium in well samples collected for this report is believed to be representative of the uranium content of most well samples from the report area.

The average uranium content of 11.3 ppb for 18 samples from springs is probably not representative of the uranium content of water samples from springs in the report area as a whole because of the small number of samples. Most of the springs in the report area are small and are subject to evaporation or dilution during dry or wet periods respectively. The fact that the range for spring samples is from less than 1 to 50 ppb will probably be of most value for future comparison.

Streams are second to well samples in being potentially the most useful sources of samples for hydrogeochemical exploration purposes in the report area. However, they are more variable than well samples because within the report area most of the streams, like the springs, are small and are subject to evaporation or dilution, and also to the mixing of waters from different rock units. The fact that the average uranium content of the 73 stream samples does not differ significantly from any of the averages derived for stream samples from alluvium related to the three geologic terranes in the report area may be fortuitous, but the range in uranium content of the stream samples, from less than 1 to 42 ppb uranium, is not excessively large in relation to the number of samples involved. The average uranium content derived for stream samples in the area, 7.2 ppb, is believed to be representative of the uranium content of stream samples from the report area.

The average uranium content of the 37 samples from municipal water systems, 7.1 ppb, is fairly close to the average, 9.5 ppb, derived for wells other than those used for municipal supplies. One of the municipal systems from which samples were collected obtains water from a spring; the others are supplied by wells. The smaller uranium content of water samples from municipal water systems may be due to removal of uranium from the water by rust or other deposits in the the hundreds or thousands of feet of pipe the water passed through between the well-head and the sampling points.

The range for water samples collected from reservoirs is far greater, from less than 1 to 380 ppb uranium, than for samples from any other source. This extreme range may be due to any or all of several causes for each sample. Most of the reservoirs are shallow and consequently the concentration of uranium is greatly affected by evaporation because of the large water-air interface for the volume of water contained. It is also affected by great dilution through an influx of surface waters during and immediately after a period of rainfall. The average uranium content of 20.9 ppb is not representative of the uranium content of samples from reservoirs in the report area because the number of samples is too small in relation to the range of uranium content of the samples and the reservoirs sampled are unevenly distributed through the report area. If necessary, reservoir samples can be used in hydrogeochemical exploration in the report area, but the samples to be compared should be from a small area and should all be collected during a short time period to minimize the effects of changes in weather.

Only five lake samples were collected during this investigation. The average of 8.8 ppb may be representative of the uranium content of the larger, deeper, bodies of water in the report area, for the range in uranium content is not large, from 3 to 18 ppb. Lakes are probably less variable in uranium content than are reservoirs because the much greater volume of water in the lakes minimizes variations in concentration of uranium caused by variations in the volume and periodicity of rainfall. Also, the lakes, in general, are much deeper than are the reservoirs that were sampled and there is less surface area per unit volume of water to be affected by evaporation. Lakes, however, are subject to mixing of waters from different rock units over a relatively large area and the results of lake sampling may for some areas be meaningless for hydrogeochemical exploration purposes, and in others only useful as an average to compare with the results of sampling of waters tributary to the lake.

The average of 9.7 ppb uranium derived from a total of 323 samples is representative of the order of magnitude of the uranium contents of water samples from the report area. With the exception of those rock units that are represented by just a few samples, the averages derived for water samples from the selected rock units in the area (tables 1, 2, and 3) are potentially of greater value to any future hydrogeochemical exploration in the parts of Kansas, Oklahoma, Colorado, and New Mexico from which samples were collected than is the overall total average cited above.

A total of 310 samples were used to derive average-uranium-content figures applicable to the three geologic terranes present in the report area. Terrane relationship of samples, where determinable, can be obtained from table 4. The average uranium content of 179 water samples from the tuffaceous-rocks terrane is 6.7 ppb; 48 samples from the shale terrane contain an average of 20.4 ppb uranium; and the average uranium content of 83 samples from the sandstone terrane is 10.2 ppb.

The tuffaceous-rocks terrane was sampled much more extensively, both in number and areal distribution of samples, than were the other terranes. The average uranium content of 6.7 ppb is probably representative of the uranium content of water samples from this terrane in the report area as a whole, but it is not applicable for hydrogeochemical exploration purposes in small parts of the report area. As an example, the average uranium content of 69 well and spring samples from the Ogallala formation (including the Laverne formation) collected throughout the report area is 10.4 ppb (table 1), but in table 2 the 69 samples are subdivided into seven groups on a geographic basis that was determined by the time period of sample collection. The average uranium content of samples from the seven groups ranges from 1.8 to 26.4 ppb. The difference in average uranium content of the water samples from the various geographic areas may be caused by variations in climatic conditions over the wide area from which the samples were collected, but at least part of the difference may be caused by differences in the amount of uranium available for solution by waters moving through the Ogallala formation.

Water samples related to or collected from rock units of the shale terrane have a large range in uranium content, from less than 1 ppb to 380 ppb. Only 8 of the 48 samples assigned to the shale terrane were collected from rock units of the terrane; the other 40 were collected from water-bearing alluvium related to rock units of the shale terrane. As previously noted, the water samples from the shale terrane in the valley of the Smoky Hill River in Wallace, Logan, and Gove Counties, Kans., contain considerably more uranium than do samples from that terrane in Finney, Ford, Hodgeman, Lane, and Ness Counties, Kans., and they also contain more uranium than do the ramples from rock units of that terrane in other parts of Kansas and Colorado. Of the total of 48 samples assigned to the shale terrane, 27 were collected in the valley of the Smoky Hill River; therefore, the average of 20.4 ppb uranium for samples from the shale terrane is probably too large to be representative of the average uranium content of water from this terrane throughout the report area. The average uranium content of 8 well or spring samples from rock units of the terrane is 8.5 ppb, and this figure may be more nearly representative of the uranium content of samples from the shale terrane.

The average uranium content of 83 water samples from the sandstone terrane is 10.2 ppb. The averages for samples from wells, streams, and water systems agree closely with this figure: 10.1 ppb uranium for 39 well samples, 9.8 ppb for 35 stream samples, and 8.4 ppb for 7 water-system samples. These averages are believed to be representative of the uranium contents of water samples from this terrane.

Water samples from several of the rock units of the sandstone terrane contain more uranium than the averages cited above but the samples are too few to be representative. Of most potential usefulness for future comparison is the average 8.6 ppb derived from 29 samples collected from the Dakota sandstone and the Purgatoire formation of Early Cretaceous age because within the area in which rock units of the sandstone terrane are extensively exposed the Dakota and Purgatoire occupy more outcrop area than any of the other rock units of the terrane, and they are also the source of water for more wells and springs than the others.

Although the figures for average uranium content for water samples from the shale terrane may not be representative, the corresponding figures derived for water samples from the tuffaceous-rocks terrane and the sandstone terrane are believed to be representative of the uranium content of waters from these terranes in the report area. Fix (written communication, 1954) found that water samples from carbonaceous-shale terranes and from acidic-volcanic-rock (including tuff) terranes commonly contain more uranium than water samples from other terranes, and Denson, Zeller, and Stephens (1956, p. 799) report that ground-water samples from acid tuffs and tuffaceous sedimentary rocks in parts of Wyoming and North Dakota contain much more uranium than do samples from other sedimentary rocks in that area. In view of the results obtained by these investigators it is a little surprising that the samples from the sandstone terrane have a slightly higher average uranium content than the samples from the tuffaceous-rocks terrane. Although the Ogallala formation, a unit of the tuffaceous-rocks terrane, has a larger average uranium content in the report area than any of the other rock units that were sampled extensively, water samples collected from some other units of the tuffaceous-rocks terrane contain much less uranium. On the other hand, the average for most of the rock units of the sandstone terrane from which water samples were collected range from slightly less to considerably more uranium than the average for the Ogallala. Though no positive conclusion can be reached until some of the rock units of the sandstone terrane are sampled more extensively, the available data indicate that water samples from the sandstone terrane contain on the average as much or more uranium than samples from the tuffaceous-rocks terrane.

CONCLUSIONS

General conclusions, on the basis of the water-sample data gathered for this report, are (1) the average uranium contents of water samples collected from the geologic terranes and their component rock units in the report area range from about 3 to about 38 ppb, although the uranium content of individual samples ranges from less than 1 to almost 400 ppb; (2) water samples from the sandstone terrane contain on the average as much or more uranium than samples from the tuffaceous-rocks terrane in the report area, though this conclusion may have to be revised as waters from some of the rock units of the sandstone terrane are sampled more extensively; (3) the difference in the uranium content of water samples from specific rock units in different parts of the report area indicates that the uranium content of samples collected for hydrogeochemical exploration purposes should be compared not only to the average uranium content derived for the terrane or the associated rock unit in the report area as a whole but should also be compared to the uranium contents of the samples from the same terrane or the rock unit in the relatively small area of the sample locality; and (4) further exploration and evaluation may be worth while to determine the source of the uranium in waters from those parts of the report area in which most, or all, water samples contain relatively large amounts of uranium, and waters from several rock units, particularly those of late Permian and Triassic age, that have a large uranium content for samples collected from them.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
KANSAS							
Clark County							
12–30S–25W	213931	Minneola water system	100+	Ogallala formation	Tuffaceous-rocks	4	7.3
36–31S–25W	213932	Reservoir		do	do	<1	7.0
8–32S–25W	213935	Stream	1–3	Alluvium	do	8	7.3
10–32S–25W	213934	do	1–3	do	do	2	7.1
	213933	Spring		Ogallala formation	do	1	7.0
Finney County							
25–21S–30W	210690	Spring	2–5	Niobrara formation (fractured limestone).	Shale	11	7.5
26–21S–31W	210689	Well	10	Ogallala formation	Tuffaceous-rocks	7	7.6
2–21S–33W	210686	do	15	do	do	19	7.7
6–22S–27W	210695	State Lake		Alluvium and Carlile shale	Shale	7	7.6
1–22S–29W	210694	Well	1+	Carlile shale	do	6	7.7
34–22S–30W	210691	Spring	10	Niobrara formation (fractured limestone).	do	13	7.5
11–22S–33W	210688	Well	5+	Unknown	Tuffaceous-rocks	6	7.9
9–23S–27W	210696	do	5	Ogallala formation	do	8	7.8
12–23S–29W	210693	do	5	do	do	8	8.0
15–23S–30W	210692	Spring	1+	Niobrara formation (fractured limestone).	Shale	14	7.6
6–23S–32W	210687	Well	5	Ogallala formation	Tuffaceous-rocks	8	7.7
Ford County							
29–25S–22W	213910	Spearville water system	150	Ogallala formation	Tuffaceous-rocks	7	7.6
6–25S–23W	213908	Well	5+	Alluvium	Shale	7	7.6
28–25S–23W	213909	Lake		Ogallala formation	Tuffaceous-rocks	11	7.3
17–26S–21W	213919	Well	5	Ogallala(?) formation	do	4	7.5
15–26S–22W	213920	do	3	Alluvium	Sandstone	4	7.4
	213921	do	5+	Dakota sandstone	do	7	7.3
35–26S–25W	213915	Dodge City water system	2,800+	Ogallala formation	Tuffaceous-rocks	5	7.4
30–27S–21W	213918	Well	250	Dakota sandstone	Sandstone	6	7.4
31–27S–21W	213917	do	5–10	Alluvium and (or) Dakota sandstone.	do	4	7.4

12-27S-24W	213916	Arkansas River	5+	Alluvium	Tuffaceous rocks	16	7.6
5-28S-22W	213922	Ford water system	100+	Alluvium(?)	do	5	7.4
5-29S-21W	213923	Bucklin water system	600	Ogallala formation	do	4	7.3
25-29S-24W	213930	Well	10+	Ogallala(?) formation	do	7	7.5
2-29S-25W	213929	do	10+	Ogallala formation	do	9	7.6
32-29S-26W	213927	Crooked Creek	3-10	Alluvium	do	3	7.3
	213926	Well	10	Meade formation and (or) Ogallala formation.	do	5	7.7
35-29S-26W	213928	do	5-10	Ogallala formation and (or) Dakota sandstone.		6	7.5
Gove County							
29-14S-29W	210718	Well	5+	Alluvium	Shale	16	7.5
Grant County							
27-28S-37W	213997	Ulysses water system	350	Ogallala formation and (or) Meade formation.	Tuffaceous-rocks	1	7.8
26-29S-35W	214002	Well	5-10	Meade formation	do	2	7.7
33-29S-35W	214001	do	5-10	do	do	2	7.6
2-29S-36W	214005	do	50	do	do	2	7.7
7-29S-36W	213998	North Fork of Cimarron River	10	Alluvium and Meade formation	do	<1	7.4
21-29S-36W	213999	Spring in bed of North Fork of Cimarron River.	1+	Meade formation	do	15	7.2
35-29S-36W	214000	North Fork of Cimarron River	5-10	do	do	<1	7.3
6-29S-37W	214006	do	2-10	do	do	<1	7.3
22-29S-38W	214007	do	2-10	do	do	<1	7.3
9-30S-35W	213984	do	15-20	Alluvium	do	1	7.9
16-30S-35W	213983	do	15-20	do	do	5	7.7
24-30S-35W	213982	Pond in a volcanic-ash pit		Meade formation	do	1	7.7
8-30S-36W	213992	Irrigation well	2,000	Ogallala formation and (or) Dakota sandstone.		2	7.6
17-30S-36W	213993	Irrigation and domestic well	500+	do		2	7.5
24-30S-36W	213991	Well	5-10	Alluvium and (or) Meade formation.	do	4	7.3
35-30S-36W	213990	do	10	Meade formation	do	2	7.4
12-30S-37W	213994	Small tributary of Cimarron River.	2-5	Alluvium and Meade formation	do	2	7.1
33-30S-37W	213995	Cimarron River	20+	Alluvium	do	2	7.5
35-30S-37W	213996	Well	10+	Meade formation	do	2	7.6
4-30S-38W	214008	North Fork of Cimarron River	2-5	do	do	<1	7.0

See footnotes at end of table.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
			KANSAS—continued				
			Gray County				
2-25S-28W	213897	Well	5+	Ogallala formation	Tuffaceous-rocks	12	7.6
13-25S-30W	213895	do	5+	do	do	40	7.4
11-26S-28W	213896	Cimarron water system	250	do	do	14	7.6
36-27S-27W	213914	Well	5+	Ogallala formation and (or) Meade formation.	do	3	7.4
7-28S-27W	213913	do	5+	do	do	7	7.6
23-29S-28W	213912	do	5	do	do	5	7.5
			Hamilton County				
25-22S-42W	214035	Spring	1+	Carlile(?) shale	Shale	21	7.5
	214034	do	1+	Carlile shale or alluvium	do	2	7.5
36-22S-42W	214033	Well	2	Dakota sandstone	Sandstone	<1	8.0
7-23S-40W	214032	do	5+	Alluvium	Tuffaceous-rocks	<1	6.5
3-23S-41W	214030	Spring	1+	Alluvium and (or) Carlile shale	Shale	<1	7.1
10-23S-41W	214031	do	1+	Alluvium	Tuffaceous-rocks	<1	7.0
1-23S-42W	214037	Stream	2+	do	do	<1	7.3
2-23S-42W	214036	do	2+	do	do	2	7.2
2-24S-39W	214024	Well	10+	Alluvium and (or) Ogallala formation.	do	2	7.5
25-24S-39W	214025	do	10+	Alluvium and (or) Dakota sandstone.	do	<1	7.7
13-24S-40W	214023	do	10	Alluvium(?)	do	<1	7.8
34-24S-41W	214039	do	10	Ogallala(?) formation	do	<1	7.8
33-24S-42W	214041	Small stream draining Greenhorn and Graneros outcrop.	2-5	Alluvium	Shale(?)	<1	6.9
36-24S-42W	214040	Well	5	Ogallala(?) formation	Tuffaceous-rocks	<1	7.5
1-25S-41W	214038	Small stream draining Greenhorn and Graneros outcrop.	2-5	Alluvium	Shale(?)	<1	7.0
1-25S-43W	214042	do	2-5	do	do	<1	7.2
18-26S-41W	214020	Well	10	Ogallala formation	Tuffaceous-rocks	3	7.5
2-26S-42W	214044	Stream	2-5	Alluvium	do	<1	7.2
5-26S-42W	214043	Well	5-10	do	do	2	7.6
12-26S-42W	214022	Reservoir		Ogallala formation and (or) Dakota sandstone.		<1	7.5
13-26S-42W	214021	Well	5	Alluvium and (or) Ogallala formation.	Tuffaceous-rocks	8	7.4
35-26S-42W	214019	do	10+	Ogallala formation	do	4	7.5

Haskell County							
32-29S-32W	214004	Sublette water system	275	Ogallala formation and (or) Meade formation.	Tuffaceous-rocks	1	7.5
13-30S-34W	214003	Satanta water system	475	Ogallala formation	do	3	7.6
33-30S-34W	213981	Well	5-10	Alluvium	do	5	7.8
Hodgeman County							
25-21S-24W	213905	Well	5	Ogallala formation	Tuffaceous-rocks	6	7.6
8-23S-22W	213906	do	5-10	Alluvium or Dakota sandstone	Sandstone	6	7.4
6-23S-23W	213900	Jetmore water system	50+	Alluvium	Shale	6	7.4
7-23S-24W	213899	Buckner Creek	5+	do	do	5	7.2
7-23S-25W	213898	Well	1+	Ogallala(?) formation	Tuffaceous-rocks	14	7.7
14-24S-23W	213907	Formerly an artesian well	5	Dakota sandstone	Sandstone	14	7.4
Kearny County							
11-24S-35W	214029	Deerfield water system	100+	Alluvium	Tuffaceous-rocks	3	7.8
27-24S-36W	214028	Lakin water system	800	Ogallala formation	do	3	7.6
12-25S-38W	214026	Well	10	Graneros shale	Shale	<1	7.7
	214027	do	5	Alluvium	Tuffaceous-rocks	<1	7.4
Lane County							
3-16S-27W	210722	Well 711 ft deep	5	Dakota sandstone	Sandstone	<1	8.3
20-16S-27W	210721	Well	5	Ogallala formation	Tuffaceous-rocks	4	7.7
32-16S-28W	210720	do	2+	do	do	5	8.0
21-17S-27W	210723	Well	5+	Ogallala formation	do	5	7.7
3-17S-30W	210717	do	5	do	do	8	7.8
28-18S-27W	210724	do	100	Alluvium(?)	Shale	9	7.9
18-18S-28W	210726	Dighton water system	500+	Ogallala formation	Tuffaceous-rocks	10	7.9
14-18S-30W	210682	Well	5	do	do	9	7.6
1-19S-27W	210725	Well approximately 600 ft deep	10+	Dakota sandstone	Sandstone	<1	8.0
30-19S-30W	210683	Well 1,038 ft deep	1+	do	do	1	8.0

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
			KANSAS—Continued				
			Logan County				
22-12S-35W	[1] 217642	Well	2+	Ogallala(?) formation	Tuffaceous-rocks	20	8.2
2-13S-35W	[2] 210708	Well 78 ft deep	2+	Unknown	Shale	49	7.8
	[1] 217643	do	2+	do	do	48	7.8
	[3] 219171	do	2+	do	do		
20-13S-35W	[2] 210707	Smoky Hill River	5+	Alluvium	do	26	7.5
4-13S-36W	[1] 219289	Well	2	do	do	40	7.8
16-13S-36W	[1] 217644	do	2+	do	do	12	7.9
27-13S-36W	[2] 210709	do	2+	do	do	69	7.6
31-13S-36W	[2] 210706	do	2+	do	do	50	7.8
5-14S-36W	[1] 217645	do	5-10	Ogallala formation	Tuffaceous-rocks	10	7.9
14-15S-33W	[2] 210711	Chalk Creek; also called Hackberry Creek.	2-5	Alluvium	Shale	22	7.2
			Meade County				
7-30S-27W	213911	Crooked Creek	5+	Alluvium	Tuffaceous-rocks	2	6.9
6-31S-26W	213925	Fowler water system	800	Ogallala formation	do	5	7.6
2-31S-28W	213944	Well	10	Meade formation and (or) Ogallala formation.	do	6	7.5
2-32S-26W	213937	Reservoir		Alluvium	do	<1	7.3
3-32S-26W	213938	do		Ogallala formation	do	<1	7.3
8-32S-26W	213943	Well	5+	do	do	6	7.6
9-32S-26W	213940	Small tributary of North Branch of Sand Creek.	2+	Alluvium and Ogallala formation.	do	1	7.1
	213942	Well	5+	Ogallala formation	do	8	8.3
10-32S-26W	213939	Stream	2-5	Alluvium	do	5	7.2
12-32S-26W	213936	do	2-5	do	do	2	7.3
16-32S-26W	213941	Well	5+	Ogallala formation	do	4	8.4
11-32S-28W	213924	Meade water system	900+	Ogallala formation and Meade formation.	do	5	7.6
17-32S-28W	213949	Big Spring	20	Ogallala formation	do	21	7.5
16-33S-26W	213958	Sand Creek	10+	Alluvium	Sandstone	3	7.2
35-33S-26W	213957	Well	5-10	Ogallala formation	Tuffaceous-rocks	6	7.7
35-33S-27W	213950	do	10+	do	do	7	7.5
4-33S-28W	213945	Crooked Creek	10	Alluvium	do	4	7.4
20-33S-28W	213946	do	10+	do	do	3	7.5

34-33S-28W	213959	Well	5+	Ogallala formation	do	8	8.1
15-33S-29W	213948	Spring	10+	do	do	7	7.6
	213968	Artesian well	200	do	do	7	7.8
24-33S-29W	213947	State Lake		Alluvium and Ogallala formation.	do	5	7.4
25-33S-29W	213962	Small tributary of Shorts Creek	2+	Alluvium	do	1	7.2
13-34S-26W	213956	Tributary of Sand Creek	2+	do	Sandstone	4	7.4
19-34S-26W	213951	Well	5+	Unknown	do	17	8.0
24-34S-26W	213955	do	5	do	do	13	7.9
32-34S-26W	213952	do	5	do	do	11	7.6
14-34S-28W	213960	Crooked Creek	10+	Alluvium	do	4	7.3
32-34S-28W	213961	Well	5+	Meade formation	Tuffaceous-rocks	7	7.4
30-34S-29W	213965	do	10+	do	do	7	7.5
9-34S-30W	213967	do	5	Laverne formation and Ogallala formation.	do	7	7.9
20-34S-30W	213966	do	5	do	do	7	7.8
2-35S-26W	231954	do	5+	Ogallala formation	do	4	7.4
1-35S-27W	213953	do	10+	Alluvium	Sandstone	3	7.8
4-35S-29W	213964	Reservoir		Meade formation	Tuffaceous-rocks	1	7.3
9-35S-29W	213963	Cimarron River	20+	Alluvium	do	7	7.3
Morton County							
30-31S-39W	221289	Well	2-5	Ogallala formation	Tuffaceous-rocks	12	8.4
	221290	do	2-5	do	do	12	8.1
10-31S-42W	221283	do	2-5	Morrison formation, Dockum group, or Taloga formation of Cragin (1897).	Sandstone	1	8.3
16-31S-42W	221284	do	2-5	Ogallala formation	Tuffaceous-rocks	9	8.1
18-31S-43W	221285	do	2-5	Dakota sandstone	Sandstone	8	8.0
34-32S-40W	221291	do	2-5	Ogallala formation	Tuffaceous-rocks	12	8.2
35-32S-40W	221312	Dug well in alluvium bordering Cimarron River.	2+	Alluvium	do	7	8.3
28-32S-41W	221287	Artesian well 610 ft deep	2-3	Permian red beds	Sandstone	28	8.0
9-32S-43W	221286	Well	5+	Dakota sandstone	do	18	8.5
2-34S-40W	221311	Rolla water system	200	Ogallala formation	Tuffaceous-rocks	7	8.1
5-34S-42W	221308	Well	2-5	Ogallala formation or Dockum group.		20	8.2
6-34S-42W	221309	Reservoir: some of the water is runoff, some is spring or seep water; there may be some concentration due to evaporation.		Alluvium and Ogallala formation.	Tuffaceous-rocks	29	7.9
16, 17, 20, 21-35S-42W	221310	Elkhart water system	306	Ogallala formation	do	12	8.5
Ness County							
30-18S-23W	213901	Ness City water system	50+	Dakota sandstone	Sandstone	11	7.3
31-18S-23W	213902	North Walnut Creek	2-5	Alluvium	Shale	10	7.7
32-19S-23W	213903	Well	5	Dakota sandstone	Sandstone	8	7.8
32-20S-23W	213904	Pawnee River	5+	Alluvium	Shale	4	7.0

See footnotes at end of table.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
			KANSAS—continued				
			Scott County				
2-16S-33W	210716	Scott Lake; fed mainly by two springs sampled in this township.	200+	Ogallala formation	Tuffaceous-rocks	18	7.6
12-16S-33W	210715	Old Steele Home Spring	50	do	do	8	7.8
13-16S-33W	210714	Big Spring	400+	do	do	8	7.8
2-17S-32W	210719	Well	10+	do	do	8	7.9
13-18S-33W	210713	Scott City water system	2,100+	do	do	12	7.9
32-19S-31W	210684	Well	5	do	do	8	7.8
25-19S-33W	210685	do	5	do	do	23	7.7
			Seward County				
6-31S-34W	213980	Well	5-10	Meade formation	Tuffaceous-rocks	2	7.9
19-31S-34W	213979	Reservoir		Alluvium	do	1	7.5
21-32S-33W	213975	Well	5-10	do	do	7	7.5
3-32S-34W	213977	do	2-5	do	do	3	7.9
13-32S-34W	213976	do	5+	Meade formation	do	4	7.9
30-33S-31W	213985	do	10+	Alluvium	do	2	7.3
31-33S-31W	213986	do	5-10	Meade formation and (or) Ogallala formation.	do	<1	6.9
6-33S-32W	213978	do	5-10	Alluvium	do	4	7.7
19-33S-32W	213974	do	5	Alluvium(?)	do	3	7.9
28-33S-32W	213972	do	5	Alluvium	do	3	8.1
30-33S-32W	213973	do	5-10	Meade formation	do	2	7.7
9-34S-31W	213987	do	10	Alluvium	do	<1	7.6
15-34S-31W	213988	do	5-10	do	do	4	7.5
22-34S-31W	213970	do	10+	do	do	3	8.1
22-34S-31W	213971	Pond in bed of Cimarron River; probably mostly runoff.		do	do	1	7.4
33-34S-31W	213969	Well	5-10	Meade formation	do	3	7.6
			Stanton County				
22-27S-40W	214016	Well	10+	Ogallala formation	Tuffaceous-rocks	2	7.5
26-27S-40W	214017	do	1,000+	Ogallala formation and (or) Dakota sandstone.		2	7.8
12-27S-41W	214015	do	5-10	Ogallala formation	Tuffaceous-rocks	4	7.4
35-28S-39W	214009	do	100	do	do	2	7.5

11-28S-41W	214014	do	10+	do	do	1	7.8
36-28S-41W	214013	Johnson water system	110	do	do	2	8.1
21-29S-39W	214010	Well	5-10	Meade formation and (or) Ogallala formation.	do	3	7.5
25-29S-40W	214011	do	10	do	do	2	7.7
26-29S-41W	214012	do	10+	Ogallala formation	do	2	7.7
2-29S-42W	214018	do	10+	do	do	1	7.5
15-29S-43W	221277	Bear Creek	25	Alluvium and Dakota sandstone.	Sandstone	2	7.8
5-30S-43W	221271	Well	5	Dakota sandstone	do	<1	8.1
Stevens County							
26-31S-36W	213989	Well	10+	Ogallala formation and (or) Meade formation.	Tuffaceous-rocks	2	7.7
29-31S-38W	221313	Cimarron River; no flow here, sample from pool.		Alluvium	do	7	7.9
16-33S-37W	221314	Hugoton water system	100+	Ogallala formation and Meade formation.	do	8	8.3
Wallace County							
14-12S-42W	[2] 210700	Well	1+	Ogallala formation	Tuffaceous-rocks	11	7.8
6-13S-38W	[1] 219288	do	1-2	Alluvium	Shale	11	7.6
21-13S-38W	[2] 210702	do	1+	Alluvium (may obtain some water from Pierre shale).	do	30	7.8
25-13S-39W	[2] 210703	Wallace water system	100	Alluvium	do	26	8.1
27-13S-40W	[2] 210712	Sharon Springs water system	50-100	do	do	10	7.8
11-13S-42W	[2] 210699	Stream	2+	Alluvium (water mainly from base of Ogallala formation).	Tuffaceous-rocks	13	7.8
3-14S-38W	[1] 217639	Reservoir		Alluvium	Shale	3	7.6
	[1] 217638	do		do	do	<1	7.6
5-14S-38W	[2] 210704	do		do	do	380	6.9
	[4] 215044	do		do	do	5	7.3
6-14S-38W	[2] 210710	do		do	do	42	7.0
	[5] 215046	do		do	do	3	7.1
	[1] 217634	do		do	do	2	7.6
7-14S-38W	[1] 217635	do		do	do	3	7.7
	[1] 217636	do		do	do	<1	7.4
	[1] 217633	Spring	1-5	Ogallala formation	Tuffaceous-rocks	13	8.1
8-14S-38W	[1] 217631	Reservoir		Alluvium	Shale	1	7.5
	[1] 217632	do		do	do	1	7.5
	[1] 217641	do		do	do	2	7.7
11-14S-38W	[1] 217640	do		do	do	4	7.6
17-14S-38W	[1] 217637	do		do	do	1	7.7
21-14S-38W	[2] 210705	Well	1	Ogallala formation	Tuffaceous-rocks	8	7.6
8-14S-39W	[2] 210701	Spring	1	do	do	10	7.7
5-14S-41W	[2] 210698	Well	5+	do	do	9	7.9
11-14S-41W	[2] 210697	do	2	Alluvium	do	9	7.6

See footnotes at end of table.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
				COLORADO			
				Baca County			
32-28S-44W	221300	Two Buttes water system (well 180 ft deep).	100	Dakota sandstone	Sandstone	6	8.0
	221299	Well 160 ft deep	2-25	Ogallala formation or Dakota sandstone.		8	8.1
1-28S-46W	221303	Well	2-5	Entrada sandstone	Sandstone	4	8.2
	221302	Two Buttes Lake	(?)	Alluvium (water from runoff, Ogallala formation, Dakota sandstone, Cheyenne sandstone member of Purgatoire formation, Morrison formation, and Entrada sandstone).		3	7.7
6-28S-46W	221292	Two Buttes Creek	2-5	Alluvium	Sandstone	2	8.0
10-29S-42W	221275	Buffalo Creek	1-3	do	do	<1	7.4
33-29S-43W	221274	Horse Creek	10	do	do	7	8.0
27-29S-44W	221301	Former artesian well	1,500	Cheyenne sandstone member of Purgatoire formation.	do	11	8.1
5-29S-46W	221298	Well	2-25	Dakota(?) formation	do	6	8.0
10-29S-49W	221358	Two Buttes Creek	3	Alluvium	Shale	6	7.8
31-29S-50W	221332	Well	2-3	Dockum(?) group (probably in limestone).	Sandstone	35	8.1
3-30S-42W	221276	Bear Creek	25	Alluvium	do	6	7.8
	221278	Well	5+	Dakota sandstone	do	9	8.0
15-30S-42W	221270	do	5-10	do	do	15	7.9
21-30S-43W	221273	Bear Creek	1-2	Alluvium	do	2	8.1
32-30S-43W	221269	Walsh water system	1,300	Cheyenne sandstone member of Purgatoire formation.	do	6	8.2
30-30S-45W	221272	Well	5+	do	do	20	8.0
30-30S-46W	221365	Springfield water system	600+	Dakota sandstone	do	4	8.1
2-30S-50W	221331	Freezeout Creek	2+	Alluvium	do	5	8.1
5-31S-41W	221288	Sand Arroyo	1-2	do	do	16	8.0
1-31S-45W	221267	Well 90-100 ft deep	2-5	Ogallala formation	Tuffaceous-rocks	12	8.1
	221268	Well 125-135 ft deep	2-5	Dakota sandstone	Sandstone	2	8.1
6-31S-48W	221335	Pritchett water system	100	do	do	20	8.0
28-31S-50W	221334	Well	2-5	do	do	12	8.0
5-32S-42W	221281	Domestic well at Stonington	2-5	do	do	7	8.0
29-32S-46W	221279	Well	2-5	Dakota sandstone or Cheyenne sandstone member of Purgatoire formation.	do	2	8.2

10-32S-50W	221336	do	5-10	Dakota sandstone or Ogallala formation.		10	8.2
19-33S-42W	221282	Domestic well at Midway	2-5	Ogallala formation	Tuffaceous-rocks	14	8.0
28-33S-43W	221280	Well	3	do	do	11	7.9
27-33S-50W	221340	East Carrizo Creek (water may be partially runoff).	10+	Alluvium	Sandstone	9	8.2
31-33S-50W	221354	Tributary of West Carrizo Creek.	100+	do	do	8	7.9
10-34S-46W	221307	Campo water system	100+	Cheyenne sandstone member of Purgatoire formation (principal aquifer) and Dakota sandstone.	do	4	8.1
10-34S-50W	221352	East Carrizo Creek	2-5	Alluvium	do	11	8.1
12-35S-50W	221355	Carrizo Creek	25-50	do	do	6	8.1
15-34S-50W	221353	West Carrizo Creek	25+	do	do	6	7.9
Bent County							
23-23S-52W	221361	Purgatoire River	[6] 750	Alluvium	Sandstone	32	8.1
6-26S-51W	221362	Rule Creek	15+	do	do	28	8.0
19-26S-51W	221359	do	2-3	do	do	14	7.9
15-27S-51W	221363	Hackberry Creek	2	do	do	6	7.7
Cheyenne County							
20-14S-44W	219290	Cheyenne Wells water system	500	Ogallala formation	Tuffaceous-rocks	6	7.9
22-14S-46W	219291	Domestic well at First View	2-5	do	do	3	7.9
6-16S-45W	219292	Well	2-5	Ogallala formation (basal 8 ft)	do	16	7.7
Crowley County							
32-21S-59W	221266	Spring	0.1	Ogallala formation (seep at base)	Tuffaceous-rocks	8	7.9
Kiowa County							
8-18S-44W	219297	Well 570 ft deep (water is clear but has sour, sulfurous (H_2S) odor).	2-5	Codell(?) sandstone member of Carlile shale.	Shale	1	8.4
25-18S-44W	219293	Domestic well in Sheridan Lake (reaches shale at 65 ft; water is very hard, probably from Ogallala formation).	2-5	Ogallala(?) formation	Tuffaceous-rocks	88	7.8

See footnotes at end of table.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
COLORADO—Continued							
Kiowa County—Continued							
13-18S-46W	219296	Well approximately 500 ft deep	2	Codell(?) sandstone member of Carlile shale.	Shale	2	8.2
22-18S-48W	219294	Eads water system	500	Ogallala formation	Tuffaceous-rocks	3	8.3
9-18S-50W	210302	Well	5	do	do	28	8.2
29-18S-51W	219298	Haswell water system	50?	Ogallala(?) formation	do	11	7.5
1-19S-47W	219295	Well (water now is clear and hard; formerly was black, soft, full of asphaltic material; may now be from Ogallala formation).	1	Codell sandstone member of Carlile shale or Ogallala fortion.		40	7.8
Las Animas County							
34-28S-51W	221360	Spring	1	Cheyenne sandstone member of Purgatoire formation.	Sandstone	50	8.1
2-30S-51W	221333	Well	2-3	Alluvium or Dakota sandstone	do	10	7.9
26-32S-52W	221337	Stream	2-5	Alluvium	do	<1	7.6
9-33S-52W	221338	Spring	2+	Dakota(?) sandstone (crossbedded sandstone).	do	1	8.0
14-33S-52W	221339	Tecolote Creek (no flow visible, probably partly runoff).	(?)	Alluvium	do	<1	7.7
13-33S-57W	221366	Chacuaco Creek	3	do	do	2	7.9
18-33S-58W	221367	Alkali Creek	2	do	do	5	8.2
33-33S-59W	221368	Trinchera Creek	10	do	do	7	8.2
Lincoln County							
18- 9S-54W	219299	Genoa water system (spring at base of Ogallala formation).	25+	Ogallala formation	Tuffaceous-rocks	3	7.7
5-11S-56W	219300	Well	2-5	do	do	4	7.7
22-15S-55W	219301	Well at store south side of road at Karval (previous analysis—quality of water—showed large quantity of nitrate).	2-5	do	do	38	8.0

Prowers County

7-25S-46W	221306	Clay Creek	10+	Alluvium	Sandstone	7	8.0
13-26S-47W	221304	do	10+	do	do	6	7.9
21-26S-47W	221305	Well	2-5	Alluvium and (or) Dakota sandstone.	do	10	8.3
4-27S-44W	221297	North Butte Creek	1-3	Alluvium	do	1	7.4
4-27S-45W	221296	Stock well in NE1/4, depth unknown.	1-3	Alluvium and (or) Dakota sandstone.	do	18	8.1
20-27S-45W	221293	Well	2-5	Alluvium, Ogallala formation, or Dakota sandstone.		5	8.0
27-27S-45W	221294	Two Buttes Creek	5-10	Alluvium	Sandstone	4	8.0
7-27S-46W	221295	Water from tank	2-5	Dakota(?) sandstone	do	<1	7.5

OKLAHOMA

Cimarron County

25-2N-6E	221329	Well	2-5	Alluvium	Tuffaceous-rocks	5	8.0
31-2N-8E	221330	do	2-5	Ogallala formation	do	6	8.2
15-3N-5E	221328	Boise City water system	153	do	do	6	8.5
12-4N-7E	221327	Keyes water system	70-90	do	do	7	8.2
4-5N-1E	221356	Cimarron River	100+	Alluvium	Sandstone	25	8.0
	[7] 239713	do	100+	do	do	19	8.0
11-5N-2E	221357	do	100+	do	do	13	8.3
5-5N-5E	221364	Well (water from Cimarron River alluvium).	2-5	do	do	26	8.2

Texas County

11-1N-18E	221318	Well (probably does not enter Permian red beds).	2-5	Alluvium and Cloud Chief formation.	Sandstone	6	8.0
	221319	Well (water brackish)	2-5	Cloud Chief formation (red beds).	do	11	8.0
26-2N-17E	221320	Hardesty water system	100?	Cloud Chief (?) formation	do	8	8.1
2-3N-10E	221326	Well	2-5	Ogallala formation	Tuffaceous-rocks	15	8.3
22-3N-13E	221323	North Canadian River	25+	Alluvium		7	7.9
13-3N-15E	221316	do	5-10	do	Tuffaceous-rocks	7	8.3
31-3N-15E	221322	Guymon water system	536	Ogallala formation	do	8	8.2
35-3N-16E	221321	Well	2-5	do	do	11	8.1
26-3N-17E	221317	North Canadian River	25+	Alluvium	do	7	8.3
19-4N-11E	221325	Well	40	Triassic red beds and (?) Ogallala formation.		1	8.0
25-4N-12E	221324	do	3	Red beds (?) of the triassic	Sandstone	41	7.9
34-5N-17E	221315	Hooker water system	300+	Ogallala formation	Tuffaceous-rocks	5	8.5

See footnotes at end of table.

TABLE 4.—*Uranium content and physical factors pertaining to samples of water collected in Kansas, Colorado, Oklahoma, and New Mexico*—Continued

Location of sample (Sec., T., R.)	Sample No.	Source	Estimated flow (gpm)	Aquifer	Terrane	Uranium content (ppb)	pH
NEW MEXICO							
Union County							
28-31N-29E	242831	Cimarron River	20	Alluvium	Sandstone	42	7.9
12-31N-31E	242832	do	20	do	do	23	8.0
36-32N-34E	242833	do	15-20	do	do	19	7.9

1 September sample.
2 July sample.
3 Sample taken for analysis of residue; collected with sample 217643.
4 September sample; collected at same point as sample 210704.
5 September sample; collected at same point as sample 210710.
6 Records of the U.S. Geological Survey show a flow of 1.7 cfs on Nov 1, 1954.
7 Collected November 1955 from same point as sample 221356.

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