Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

URANIUM CONTENT OF GROUND AND SURFACE WATERS IN WESTERN KANSAS, EASTERN COLORADO, AND THE OKLAHOMA PANHANDLE *

By

E. R. Landis

July 1956

Trace Elements Investigations Report 624

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

USGS - TEI-624

GEOLOGY AND MINERALOGY

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URANIUM CONTENT OF GROUND AND SURFACE WATERS IN WESTERN KANSAS, EASTERN COLORADO, AND THE OKLAHOMA PANHANDLE

By E. R. Landis

ABSTRACT

During 1954, 1955, and 1956, 324 water samples were collected in western Kansas, eastern Colorado, the Oklahoma Panhandle, and northeastern New Mexico, to determine the uranium content of water from the various rock units and geologic terranes in the region, and to locate areas in which large amounts of uranium in the water might reflect the presence of nearby uranium accumulations.

Three geologic terranes are present in the report area: the Tertiary-Quaternary tuffaceous terrane, the Upper Cretaceous shale terrane, and the upper Permian through Lower Cretaceous sandstone terrane. The average uranium content of 179 water samples from the tuffaceous terrane, which is composed primarily of tuffaceous, fluviatile rocks ranging in age from Pliocene to Pleistocene, is 6.7 parts per billion. A total of 48 samples from the Upper Cretaceous shale terrane, which is composed almost entirely of shale and limestone of marine origin, contain an average of 20.4 parts per billion uranium. Sandstone, siltstone, and claystone of terrestrial and near-shore marine origin are the predominant constituents of the upper Permian through Lower Cretaceous sandstone terrane, and the 83 water samples collected from, or related to, rock units of this terrane contain an average of 10.2 parts per billion uranium. The average uranium

content figure derived for the Upper Cretaceous shale terrane may not be representative of the uranium content of waters from this terrane throughout the report area because more than half of the samples assigned to the terrane were collected in an area in which most water samples contain relatively large amounts of uranium. Compared to the shale terrane, the tuffaceous terrane and the sandstone terrane are both represented by a greater number of samples collected over a much larger area and the average uranium content figures derived for them are believed to be representative of the uranium content of waters from, or related to, rock units of the two terranes in the report area.

The average uranium content figures derived for different rock units, or groups of rock units, subdivided by the source type from which the samples were collected (well, spring, stream, municipal water system, reservoir, or lake), and in some cases by geographic parts of the report area, are believed to be of more potential use in any future hydrogeochemical exploration in the area than are the average uranium content figures 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 parts per billion. Several rock units were sampled over large enough areas to indicate that waters from the same rock unit in different parts of the report area may range widely in average uranium content.

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

INTRODUCTION

During 1954, 1955, and 1956, water samples were collected for determination of uranium content in western Kansas, southeastern Colorado, northeastern New Mexico, and the panhandle of Oklahoma. This work was done 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), discuss the uranium content of natural waters and the use 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) and Denson, Zeller, and Stephens (1956, p. 799) found a difference 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 some areas in which water samples contain relatively large amounts of uranium.

Tables 1 and 2 show the average uranium content of ground-water samples from selected rock units and areas in the region. Table 6 summarizes all the analytical data and shows, according to source, the number and average uranium content of samples that were obtained from or are related to stratigraphic units of different age. For purposes of calculating average uranium content, those samples with less than 1.0 part per billion uranium were considered to contain 0.0 parts per billion. For comparative purposes the averages are shown to 0.1 part per billion but are significant only to the first whole number.

Figures 1 and 2 show the areal distribution and uranium content of all water samples collected in the area by the writer during this investigation. The source type of the water sampled is indicated by symbols. Figure 1 shows the general geology of the report areas as modified from State and Federal Geological Survey maps. Rock units that crop out in the area are grouped into five units that are differentiated by patterns. Figure 2 shows the location and source types of water samples that were collected in part of Wallace County, Kans., that could not all be shown at the scale of the map of figure 1.

Wells were the sources for more than half of 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 the least representative 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 least variable sources are wells obtaining water from aquifers 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 Wallace, Logan, Gove, Scott, Finney, Lane, Ness, Hodgeman, Ford, and Gray Counties, Kans., were collected during and following a period of several months in which little or no rain fell in the collection area. During the period of sample collection in Clark, Meade, Seward, Haskell, the northeastern part of Stevens, Grant, Stanton, Hamilton and Kearny Counties, Kans., rain fell generally throughout the area, with quantities ranging from a trace to several inches. The samples from Colorado, Oklahoma, and Morton and the western part of Stevens Counties, Kans., were collected during a period of prevailing dryness in which only a few scattered rains fell.

Tables 7, 8, 9, and 10 show the location, source type, estimated flow in gallons per minute, the rock unit from which the water was obtained, the geologic age of the rock unit, the uranium content in parts per billion, the pH, and other physical data pertinent to the individual samples. Samples are listed in the tables by county and land subdivision. The source type is shown by abbreviations. The flow in gallons per minute is estimated for most of the samples, but in a few cases definite information was available, either verbally from interested parties or in the geologic literature. The samples from Kansas were collected between July 10 and September 21, 1954, and the Colorado and Oklahoma samples were collected between September 21 and November 4, 1954. Three samples from New Mexico were collected in April 1956.

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, with a glass electrode. The uranium content was determined by ethyl acetate extraction method as follows: An acidified aliquot of the sample, usually 100 to 500 ml, was evaporated nearly to dryness and then diluted with distilled water acidified with nitric acid. An aliquot of this solution was salted with recrystallized aluminum nitrate, and the uranium was extracted with ethyl acetate. The extract was then burned off in a platinum dish, and the residue was fused with a sodium fluoride carbonate flux. A sensitive fluorimeter was used to compare the fluorescence of the unknown with standards 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 part per billion (parts per 10^9) for samples containing 10 parts per billion, to about 3 parts per billion for samples containing 100 parts per billion uranium. All analyses were made in the Denver laboratories of the U. S. Geological Survey 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 and 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 comprising each terrane. The most widespread is the Tertiary-Quaternary sequence of tuffaceous, fluviatile sediments, but the Upper Cretaceous shale terrane occupies large areas in Colorado and Kansas, and the upper Permian through Lower Cretaceous sandstone terrane is well developed in southeastern Colorado, southern Kansas, and the Oklahome Panhandle.

It is to be noted that many samples of both ground and surface water are listed in tables 7, 8, 9, and 10 as having been obtained from alluvium of Recent age, whereas the uranium content of the water is believed to be related to the uranium content of older rocks that are either overlain by the alluvium or drained by waters subsequently sampled nearby from alluvial aquifers. In the sense used in the tables alluvium includes colluvium, soils, and thin eolian sediments. The relationship of the samples collected from alluvial aquifers, where determinable, is noted in the "Remarks" column in tables 7, 8, 9, and 10, and summarized in table 6.

Tertiary-Quaternary tuffaceous terrane

The Tertiary-Quaternary tuffaceous terrane comprises rocks ranging in age from late Miocene(?) to Recent. Rock units that are included are the Laverne, Ogallala, and Meade formations. The upper and most widespread portion of the Ogallala is Pliocene in age, but the lower portion and its correlative, the Laverne formation, are considered to be early Pliocene and possibly late Miocene (Moore and others, 1951, p. 20). Frye and Leonard (1952, p. 66) refer some rocks in southwestern Kansas that were formerly included in the Ogallala to the Blanco formation which they believe to be of Pleistocene age. This differentiation was not attempted in the present report. The Ogallala formation in eastern Colorado is probably largely Pliocene, but portions of it may be late Miocene or Pleistocene. Samples from Colorado referred to the Ogallala in table 7 are all believed to come from rocks of Pliocene age or older. 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 Recent age and the wide belt of thick alluvium along the Arkansas River.

Table 6 lists by source type the number and average uranium content of samples obtained from stratigraphic units of the tuffaceous terrane.

Upper Cretaceous shale terrane

This unit includes the formations of Late Cretaceous age overlying the Dakota sandstone that are exposed in the northern part of the Kansas and Colorado portions of the report area. The shale terrane comprises the Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale. These rock units supply water to very few wells and springs, and many of the samples related to 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. Table 6 shows by type of source the number and average uranium content of samples obtained from or related to stratigraphic units of this terrane.

Upper Permian through Lower Cretaceous sandstone terrane

This terrane includes all the rocks of Permian, Triassic, and Jurassic age in the portions of Kansas, Colorado, Oklahoma, and New Mexico covered in this report. It also includes the rocks of Cretaceous age below the top of the Dakota sandstone. Rock units included are the

White Horse sandstone, Day Creek dolomite, and the Taloga, Cloud Chief, and Lykins formations of Permian age; the Dockum group of Triassic age; the Entrada sandstone of Jurassic age; the Early Cretaceous Purgatoire formation consisting of the Cheyenne sandstone and Kiowa shale members; and the Dakota sandstone of Early Cretaceous age. Although several of the rock units of this terrane are largely shale, which normally yields little or no water, the sandstone portions of the terrane are thick and pervious and are among the most important aquifers in the Great Plains region.

The terrane occupies a large surface area in southeastern Colorado but is not well represented in the portion of Kansas covered in this report. However, in many areas where the rocks of this terrane underlie the two previously discussed terranes, water samples were obtained from deep wells drawing water from the formations belonging to this unit. Table 6 summarizes by source type the number and average uranium content of samples obtained from or related to the stratigraphic units comprising this terrane.

URANIUM CONTENT OF WATER FROM INDIVIDUAL ROCK UNITS

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

Table 1.--Average uranium content in parts per billion of well and spring samples of water from selected individual rock units and areas.

Rock units and location of samples	No. of samples	Range in uranium content	Average U content
Rocks of Triassic age, Baca County, Colo., and Texas County, Okla.	2	35 - 41	38.0
Cheyenne sandstone member of the Purgatoire formation, Baca County, Colo.	3	11 - 50	27.0
Rocks of Permian age, Meade and Morton Counties, Kans., Texas County, Okla.	5	11 - 28	16.0
Niobrara formation, Finney County, Kans.	3	11 - 14	12.7
Ogallala formation (including the Laverne formation) average for total area	69	<1 - 88	10.4
Dakota sandstone, Baca County, Colo., Morton, Stanton and Hamilton Counties, Kans.	11	<1 - 18	7.5
Dakota sandstone, Lane, Ness, Hodgeman and Ford Counties, Kans.	7	<1 - 14	5.1
Entrada sandstone, Baca County, Colo.	1		4.0
Ogallala and/or Meade formations, average for total area	9	<1 - 7	3.7
Meade formation, Meade, Seward, and Grant Counties, Kans.	11	2 - 7	3.2
Codell sandstone member of the Carlile shale, Kiowa County, Colo.	2	1 - 2	1.5
Graneros shale, Kearny County, Kans.	1		<1.0

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 or Meade formations, but cannot be definitely attributed to one or the other, are grouped as the Ogallala and/or Meade formations. Well samples that are derived partly from the Laverne formation and partly from the Ogallala formation are included in table 1 with the samples derived solely from the Ogallala formation.

Waters from the Ogallala and Meade formations of Tertiary and Quaternary age were sampled over large parts of the report area and the average uranium content figures 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 period of sample collection. Because of the uncertain source of some waters, the Laverne and Ogallala formations are grouped in Meade County, Kans., and the Ogallala and Meade formations are grouped in parts of southwestern Kansas.

AREAS CHARACTERIZED BY LARGE URANIUM CONTENTS IN WATER

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

Table 2.--Average uranium content in parts per billion of well and spring samples of water from rock units of Tertiary and Quaternary age in various portions of the report area.

Rock units and location of samples	No. of samples	Range in uranium content	Average U content
Ogallala fm. (Pliocene ?), Cheyenne, Crowley, Kiowa, and Lincoln Counties, Colo.	7	3 - 88	26.4
Ogallala fm. (middle ? Pliocene), Baca County, Colo., Morton County, Kans., Cimarron and Texas Counties, Okla.	10	6 - 15	11.4
Ogallala fm. (largely middle Pliocene), Kansas north of Arkansas River, excludes Hamilton and Kearny Counties, Kans.	27	4 - 40	10.9
Ogallala fm. (middle Pliocene), Meade and Clark Counties, and part of Ford County, south of Arkansas River, Kans.	13	1 - 21	7.3
Laverne fm. (upper Miocene ? and lower Pliocene) and Ogallala fm. (middle Pliocene), Meade County, Kans.	2	7 - 7	7.0
Meade fm. (Pleistocene), Meade County, Kans.	2	7 - 7	7.0
Ogallala fm. (middle Pliocene) and/or Meade fm. (Pleistocene), Meade County, and parts of Gray and Ford Counties, south of the Arkansas River, Kans.	5	3 - 7	5.2
Meade fm. (Pleistocene), Seward and Grant Counties, Kans.	9	2 - 4	2.3
Ogallala fm. (middle Pliocene), Stanton County, Kans.	6	1 - 4	2.0
Ogallala fm. (largely Pliocene), Hamilton County, Kans.	4	<1 - 4	1.8
Ogallala fm. (middle Pliocene) and/or Meade fm. (Pleistocene), Seward, Stevens and Stanton Counties, Kans.	4	<1 - 3	1.8

Smoky Hill River valley

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 developed on shales and limestones of Cretaceous age that are overlain by thin deposits of fluviatile and eolian sediments of Pleistocene and Recent age. The Ogallala formation of late Miocene(?) and Pliocene age unconformably overlies the Cretaceous rocks on the upland plains and interstream divides away from the main valley of the Smoky Hill River.

Interpretation of the water analyses from the area is complicated by the fact that samples were collected during two time periods with an intervening period of rainfall. The samples collected in early July and those collected in late August and early September are hereinafter referred to as the July samples and the 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 sampling during both time periods showed essentially no variation in uranium content in a well obtaining water at the contact of Pleistocene sediments and Cretaceous shale (table 7, samples numbers 210708 and 217643, p. 49). Samples obtained from reservoirs dug in the Cretaceous shales showed a large difference in uranium content between the July and the September samplings. One reservoir sampled in July had a uranium content of 380 parts per billion, but resampling in September indicated a content of only five parts per billion (table 7, sample number 210704, p. 59), and many of the reservoirs sampled during the September period contained less than one part per billion (fig. 2). The great difference in uranium content is probably attributable largely to two factors -- evaporation concentration during the dry period preceding the July sampling, and the flow of surface waters into the reservoirs between sampling periods as opposed to subsurface flow prior to the July sampling. Chemical and spectrographic analyses of the residue remaining after evaporation of five gallons of water from the well in sec. 2, T. 13 S., R. 35 W., Logan County are shown in tables 3 and 4.

Samples from 5 wells and 2 springs obtained from the Ogallala range in uranium content from 8 to 20 parts per billion and average 10.1 parts per billion. Thirteen well, stream, and municipal water system samples were obtained from thin alluvial aquifers overlying the Cretaceous shales in the valley. Nine well samples contain an average of 36.1 parts per billion uranium, two stream samples contain an average of 24 parts per billion, and two water system samples contain an average of 18 parts per billion uranium. In contrast, samples from or related to rock units of the Upper Cretaceous shale terrane in Ness, Lane, Finney, Hodgeman, and Ford Counties, Kans. contain far less uranium. Seven well, spring, and municipal water system samples contain an average of 9.4 parts per billion uranium and three stream samples contain an average of 6.3 parts per billion uranium. 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 Smoky Hill River valley and the slightly older rocks of the outcrop area to the southeast. Some of

Table 3.--Chemical analyses of metals in the residue from five gallons (18.925 liters) of water from a 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)

Element	Element in residue (percent)	Element in water (parts per billion)
Calcium	16.5	232,320
Zinc	0.005	70
Uranium	.004	56
Phosphorus	<.003	<42
Arsenic	.002	28
Selenium	.001	14

Table 4.--Semiquantitative spectrographic analyses of the residue from five gallons (18.925 liters) 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)

Element 1/	Percent in residue	Parts per billion in water 2/	Element 1/	Percent in residue	Parts per billion in water 2/
Calcium	xx.	>100,000	Lithium	.ox-	210
Sodium	x.+	96,000	Molybdenum	.oox	45
Magnesium	x.	45,000	Iron	.oox	45
Potassium	.x+	9,600	Aluminum	.oox-	21
Silicon	.x	4,500	Barium	.oox-	21
Strontium	.x-	2,100	Copper	.ooox+	9.6
Boron	.ox+	960	Vanadium	.ooox+	9.6

1/ 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.

2/ Approximate values obtained by use of sub-group midpoints, which are logarithmic means.

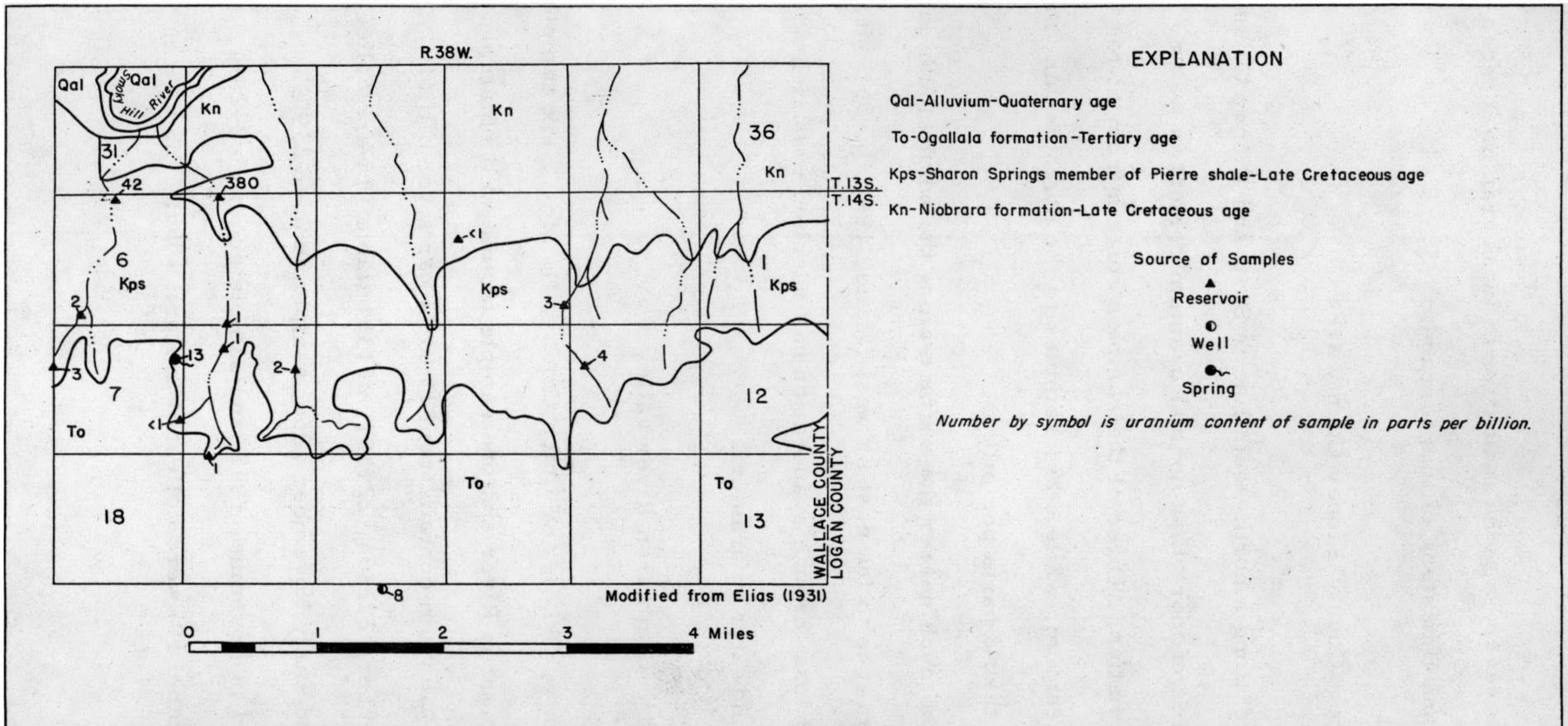

FIGURE 2—MAP SHOWING LOCATION AND URANIUM CONTENT OF WATER SAMPLES COLLECTED IN T.13 AND 14S., R.38W., WALLACE COUNTY, KANSAS.

the water samples, however, may be indicative of local uranium concentrations in the shale and limestone of this terrane.

Scott County-Finney County area

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

The water table is much nearer the surface along the north-south sample collection line than it is to the east or west (Waite, 1947, p. 56). It is possible that water loss through evaporation has resulted in enrichment of the remaining groundwater in uranium.

Cimmaron River valley

In Cimarron County, Okla., and Union County, N. Mex., six samples obtained from the Cimarron River and one sample from a well obtaining water from the river alluvium contain from 13 to 42 parts per billion uranium. Sample numbers 221356, 221357, 221364 (table 9) were collected in late October and early November 1954; sample number 239713 (table 9) was collected in November 1955; and sample numbers 242831, 242832, and 242833 (table 10) were collected in April 1956.

Fix (1956, p. 790) states that in most uraniferous areas the streams usually contain from 1 to 10 parts per billion uranium, but (personal communication) concentrations of as much as 65 parts per billion have been found. The uranium content of the seven samples is abnormally large. The Cimarron River has its source in a large area of extrusive igneous rocks (fig. 1), 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. This area deserves further investigation to determine the source of the uranium in the water samples.

Rule Creek drainage basin

Several stream and spring samples 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 parts per billion uranium. A reservoir on Muddy Creek, upstream from the collection point, may have affected the sample to some extent in that evaporation of water from the reservoir may have resulted in concentration of uranium in the remaining water. Farther south (upstream) a sample from Rule Creek contains 14 parts per billion and a sample from Hackberry Creek, a northwestward flowing tributary, contains 6 parts per billion. A sample from a spring in the Cheyenne sandstone member of the Purgatoire formation contains 50 parts per billion uranium. Several low-grade uranium concentrations 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.

OTHER WATER SAMPLES THAT CONTAIN LARGE QUANTITIES OF URANIUM

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

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

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

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 parts per billion uranium. Other samples of the stream, above and below the spring in section 21, contain less than 1 part per billion, and all samples within eight miles contain less than 5 parts per billion.

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

A sample from a well in sec. 25, T. 4 N., R. 12 E., Texas County, Okla., contains 41 parts per billion uranium. The well is believed to obtain water from Triassic redbeds. A well in sec. 31, T.29S., R. 50 W., Baca County, Colo., also supposedly obtaining water from Triassic redbeds, contains 35 parts per billion 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 parts per billion. With the present data it is impossible to determine whether each of the above-cited samples indicates a local uranium concentration or if 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, R. L., 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 parts per billion 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 parts per billion, in the samples from the Ogallala formation in the area north of the Arkansas River in Colorado may indicate the possibility of local uranium concentrations 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.

RELATIONSHIP OF URANIUM CONTENT TO pH

The pH[/] of the water samples was determined at the time of

[/] 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 of pH 7 is neutral. Therefore, an increase in pH represents a decrease in hydrogen ion concentration, that is, a decrease in acidity; and conversely.

uranium content determination. Fix (written communication) 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 terranes has an alkaline pH range of 7.5 to 9.5.

Determinations of the pH were made on a total of 323 samples for this report. 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.

Though no consistent and unequivocal relationship is present between the pH and uranium content of the samples, when the samples were segregated into groups according to uranium content, and the average pH of each group was calculated, it was found that the groups with larger uranium contents also had a higher average pH; that is, with an increase in uranium content the pH moved away from the neutral point of pH 7 and the water became more alkaline.

RELATIONSHIP OF URANIUM CONTENT TO CHEMICAL CONSTITUENTS

Some chemical constituents of the water, which Fix (written communication) calls "chemical conditioners," also affect the ability of water to dissolve uranium and retain it in solution. Due to lack of data, these other factors cannot be evaluated in this report, but an attempt was made to compare the chemical constituent content of waters for which analyses were available in the literature with the uranium content as determined for this report.

Chemical analyses of water are reported by McLaughlin (1954) from nine sources in Baca County, Colo., that were also sampled for uranium content and pH determinations in the present investigation. The samples for chemical constituent analyses were collected in 1948. Table 5 shows the analyses of the water samples as obtained from McLaughlin (1954, table 6) with the addition of the uranium content and pH as determined for this report. No obvious and consistent relationships are evident, except that the calcium content, with one exception, decreases with increasing uranium content.

Table 5.--Chemical analyses of well water samples from Baca County, Colorado.

Geologic source	Entrada ss	Dakota ss	Cheyenne ss mem.	Dakota ss	Dakota ss	Cheyenne ss mem.	Ogallala fm.	Ogallala fm.	Dakota ss
Sample no.	221303	221365	221269	221298	221281	221301	221267	221282	221335
Well no. 1/	23	151	134	92	266	81	223	320	240
Uranium ppb 2/	4	4	6	6	7	11	12	14	20
Boron (B) ppb	20	40	60	-	20	-	20	-	60
Silica (SiO_2) ppm 3/	15	16	15	20	2.07	17	.17	-	1.27
Iron (Fe) ppb	5080	40	30	-	59	-	650	29	43
Calcium (Ca) ppm	98	80	44	44	42	59	38	29	20
Magnesium (Mg) ppm	30	25	20	12	32	17	27	24	29
Sodium and potassium ppm	45	41	25	26	29	37	23	37	12
Bicarbonate (HCO_3) ppm	192	188	216	174	200	186	158	227	199
Sulfate (SO_4) ppm	275	208	55	56	118	122	177	40	72
Chloride (Cl) ppm	14	9.2	5	7	42	7	33	8	6.8
Nitrate (NO_3) ppm	.2	5.1	1.9	6.6	49	6.7	15	5.0	.0
Fluoride (F) ppm	0.6	1.5	1.4	-	1.7	.9	1.7	-	1.6
Dissolved solids ppm	572	478	275	257	471	358	458	284	282
Total hardness ppm 4/	368	302	192	160	320	217	318	192	190
Noncarbonate hardness ppm	210	148	15	17	156	64	188	6	26
Carbonate hardness ppm	158	154	177	143	164	153	130	186	164
pH	8.2	8.1	8.2	8.0	8.0	8.1	8.1	8.0	8.0

1/ Number in table 6, U. S. Geol. Survey Water Supply Paper 1256.
2/ Parts per billion.
3/ Parts per million.
4/ Calculated as $CaCO_3$.

SUMMARY AND CONCLUSIONS

Table 6 summarizes the analytical data on which this report is based. The number and average uranium content of samples obtained from or related to stratigraphic units of different age are listed according to the type of source. A total of 324 samples were collected but one was a bulk sample for chemical and spectrographic analyses (tables 3 and 4) and the results are not included in table 6.

Almost all of the average uranium content figures shown on table 6 are greater than the background concentration of uranium in natural waters in the United States, which generally is about 0.1 part per billion (Fix, 1956, p. 790). This background figure is roughly analogous to the background intensity of radioactivity and means that any water sample collected in the report area can be expected to contain 0.1 parts per billion uranium or more. Almost all the samples collected for this report and summarized in table 6 contain, as can be expected, as much or more uranium than the regional background figure derived by Fix.

The average of 9.5 parts per billion uranium for a total of 167 well samples is probably the most useful, potentially, of the averages shown on table 6 for the various source types because: (1) wells are the predominant source of water in the report area; (2) water samples from wells are more representative of the uranium content of waters from specific stratigraphic intervals than are waters from other sources because there is less chance of mixing with waters from other aquifers; (3) the effects of evaporation are minimized in well samples; (4) 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 shallow alluvial aquifers overlying the Upper Cretaceous shale terrane in the Smoky Hill River valley and the samples from sandstone and red beds of Triassic and Permian age, the average of 9.5 parts per billion 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 parts per billion 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 of very small volume of flow and are subject to evaporation and dilution during dry and wet periods. The fact that the spring samples ranged from less than 1 to 50 parts per billion will probably be of most usefulness for future comparison.

Streams are, next to well samples, 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 are of small volume of flow and are subject to evaporation, dilution, and mixing of waters from different stratigraphic 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 alluvial aquifers related to the three geologic terranes in the report area may be fortuitous, but the range in uranium content of the stream

Table 6. --Average uranium content in parts per billion of water samples by source type and stratigraphic unit in western Kansas, eastern Colorado, and the Oklahoma Panhandle.

Stratigraphic units	WELLS		SPRINGS		STREAMS		MUNICIPAL WATER SYSTEMS		RESERVOIRS		LAKES		TOTAL	
	No. of samples	Average U content	No. of samples	Average U content	No. of samples	Average U content	No. of samples	Average U content	No. of samples	Average U content	No. of samples	Average U content	No. of samples	Average U content
Recent:														
alluvium related to tuffaceous terrane	21	3.4	1	<1	24	4.2	2	4.0	4	7.8	1	5.0	53	4.1
alluvium 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
alluvium related to sandstone terrane	9	9.7	-	-	35	9.8	-	-	-	-	-	-	44	9.8
alluvium combined	41	12.2	3	<1	68	7.6	5	10.0	18	26.6	2	6.0	137	11.4
Pleistocene:														
fluviatile and aeolian sediments	12	3.4	1	15.0	4	<1	-	-	2	1.0	-	-	19	3.1
Miocene-Pliocene; Pliocene; and Pliocene-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 and Cloud Chief formations	5	16.0	-	-	-	-	1	8.0	-	-	-	-	6	14.7
Undetermined and mixed aquifers	20	6.5	-	-	1	7.0	4	3.8	1	<1	1	3	27	5.7
Totals and averages	167	9.5	18	11.3	73	7.2	37	7.1	23	20.9	5	8.8	323	9.7

samples, from less than 1 to 42 parts per billion uranium, is not excessively large considering the number of samples involved. The average uranium content derived for stream samples in the area, 7.2 parts per billion, 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 parts per billion uranium, compares fairly closely with the average of 9.5 parts per billion uranium 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 remainder are supplied by wells. The smaller uranium content of water samples from municipal water systems may be caused by removal of uranium from the water by rust or other deposits in the hundreds or thousands of feet of pipe the water passed through between the well-head and the sampling points.

The water samples collected from reservoirs exhibit a far greater range in uranium content, from less than 1 to 380 parts per billion uranium, than do samples from any other source type. This extreme range may be due to any or all of several causes in the case of each sample. Most of the reservoirs are shallow and consequently are greatly affected by evaporation because of the large water-air interface for the volume of water contained. They are also subject to great dilution by surface waters during and immediately following a period of rainfall. The average uranium content of 20.9 parts per billion is not representative of the uranium content of samples from reservoirs in the report area because the number of samples is too small compared to the range of uranium content of the samples and the sample localities 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 restricted 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 parts per billion may be representative of the uranium content of the larger, deeper, bodies of water in the report area as the range of uranium content is not large, from 3 to 18 parts per billion. Lakes are probably less variable in uranium content than are reservoirs because the lakes contain a much greater volume of water which exerts a damping effect on differences in uranium content 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 volume of water to be affected by evaporation. Lakes, however, are subject to mixing of waters from different stratigraphic units over a relatively large area and the results of lake sampling may in some cases be meaningless for hydrogeochemical exploration purposes and in other cases only useful as an average to compare with the results of sampling of waters tributary to the lake.

The average of 9.7 parts per billion 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 stratigraphic units that are represented by just a few samples, the averages derived for water samples from the stratigraphic units in the area (tables 1, 2, and 6) are potentially of greater value to any future hydrogeochemical exploration in the parts of Kansas, Colorado, Oklahoma, 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, is shown in tables 7, 8, 9, and 10. The average uranium content of 179 water samples from the Tertiary-Quaternary tuffaceous terrane is 6.7 parts per billion; 48 samples from the Upper Cretaceous shale terrane contain an average of 20.4 parts per billion uranium; and the average uranium content of 83 samples from the upper Permian through Lower Cretaceous sandstone terrane is 10.2 parts per billion.

The tuffaceous terrane was sampled much more extensively, both in number and aerial distribution of samples, than were either of the other terranes. The average uranium content of 6.7 parts per billion 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. An example of this relationship is shown on tables 1 and 2. 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 parts per billion (table 1). On table 2, however, the 69 water samples from the Ogallala are subdivided into seven increments on a geographic basis that was determined by the time period of sample collection and the average uranium content of samples from the seven increments ranges from 1.8 parts per billion to 26.4 parts per billion. 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 mobilization by waters moving through the Ogallala formation.

Water samples related to or collected from rock units comprising the Upper Cretaceous shale terrane have a large range in uranium content, from less than 1 part per billion to 380 parts per billion. Only eight of the 48 samples assigned to the shale terrane were collected from rock units of the terrane; the remaining 40 samples were collected from alluvial aquifers related to rocks of the shale terrane. As previously pointed out the water samples from the Smoky Hill River valley in Wallace, Logan, and Gove Counties, Kans., contain considerably larger quantities of uranium than do samples from the shale terrane in Finney, Ford, Hodgeman, Lane, and Ness Counties, Kans., and they also contain much greater quantities of uranium than do the samples from rock units of the shale terrane in other parts of Kansas and Colorado. Twenty-seven of the total of 48 samples assigned to the shale terrane were collected in the Smoky Hill River valley; and, therefore, the average of 20.4 parts per billion uranium for samples from the shale terrane is probably too large to be representative of the uranium content of water samples collected from this terrane throughout the report area as a whole. The average uranium content of 8 well and spring samples from rock units of the terrane is 8.5 parts per billion, and this figure may be more nearly representative of the uranium content of samples from the shale terrane.

A total of 83 water samples from the upper Permian through Lower Cretaceous sandstone terrane average 10.2 parts per billion uranium. The averages derived for samples from wells, streams, and water systems agree closely with the total average, 10.1 parts per billion uranium for 39 well samples, 9.8 parts per billion for 35 stream samples, and 8.4 parts per billion 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 there are too few samples to be representative. Of most potential usefulness for future comparison is the average of 8.6 parts per billion derived from 29 samples collected from the Dakota sandstone and 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 surface 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.

Although the average uranium content derived for water samples from the Upper Cretaceous shale terrane may not be representative of the uranium content of waters from this terrane, the average figures derived for samples from the tuffaceous terrane and sandstone terrane are believed to be representative of the uranium content of waters from these terranes in the report area. Fix (written communication) found that water samples from carbonaceous shale terranes and from acidic volcanic rock (including tuffs) terranes commonly contain more uranium than samples from other terranes and Denson, Zeller, and Stephens (1956, p. 799) report that groundwater samples from acid tuffs and tuffaceous sedimentary rock in parts of Wyoming and North Dakota contain much more uranium than do samples from other sedimentary terranes in that area. In view of the results of the work of these previous 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 terrane. The Ogallala formation, which is part of the tuffaceous terrane, has a larger average uranium content in the report area than any of the other rock units that were sampled extensively, but water samples collected from some other parts of the tuffaceous terrane contain much less uranium. On the other hand, most of the rock units of the sandstone terrane from which water samples were collected contain an average of from slightly less to considerably more uranium than the Ogallala does. 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 terrane.

General conclusions from the water-sample data gathered for this report are: (1) water samples collected from the geologic terranes and stratigraphic units in the report area contain an average from about 3 to about 38 parts per billion uranium though individual samples may range in uranium content from less than 1 to almost 400 parts per billion; (2) water samples from the upper Permian through Lower Cretaceous sandstone terrane contain on the average as much or more uranium than samples from the tuffaceous terrane in the report area; though this conclusion may be revised as 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 samples collected for hydrogeochemical exploration purposes should be compared not only to the averages derived for the terrane or rock unit in the report area as a whole but should also be compared to samples and sample averages from the same terrane or rock unit in a relatively local area around the sample point; (4) further exploration and evaluation may be worthwhile to determine the source of the uranium in (a) waters from those parts of the report area in which most, or all, water samples contain relatively large amounts of uranium, and (b) waters from several rock units, particularly those of late Permian and Triassic age, that have a large average uranium content in samples collected from them.

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.

Sample no.	County	Location sec., T., R.	Source type 1/	Estimated flow (gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks 2/
213931	Clark	12-30S-25W	WS	100+	Ogallala	Pliocene	4	7.3	Minneola
213932	Clark	36-31S-25W	R	-	Ogallala	Pliocene	<1	7.0	
213935	Clark	8-32S-25W	St	1 - 3	Alluvium	Recent	8	7.3	Tuff
213934	Clark	10-32S-25W	St	1 - 3	Alluvium	Recent	2	7.1	Tuff
213933	Clark	10-32S-25W	Sp	-	Ogallala	Pliocene	1	7.0	
210690	Finney	25-21S-30W	Sp	2 - 5	Niobrara	Cretaceous	11	7.5	From fractured limestone
210689	Finney	26-21S-31W	W	10	Ogallala	Pliocene	7	7.6	
210686	Finney	2-21S-33W	W	15	Ogallala	Pliocene	19	7.7	
210695	Finney	6-22S-27W	L	-	Alluvium and Carlile	Recent and Cretaceous	7	7.6	State Lake Shale
210694	Finney	1-22S-29W	W	1+	Carlile	Cretaceous	6	7.7	
210691	Finney	34-22S-30W	Sp	10	Niobrara	Cretaceous	13	7.5	From fractured limestone
210688	Finney	11-22S-33W	W	5+	?	Pleistocene	6	7.9	

1/ Spring (Sp), well (W), stream (St), city or town water system (WS), reservoir (R), lake (L).

2/ Terrane affiliation of samples from alluvium: tuff (Tertiary-Quaternary tuffaceous terrane); shale (Upper Cretaceous shale terrane); and sandstone (Late Permian through older Cretaceous sandstone terrane).

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type 1/	Estimated flow (gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks 2/
210696	Finney	9-23S-27W	W	5	Ogallala	Pliocene	8	7.8	
210693	Finney	12-23S-29W	W	5	Ogallala	Pliocene	8	8.0	
210692	Finney	15-23S-30W	Sp	1+	Niobrara	Cretaceous	14	7.6	From fractured limestone
210687	Finney	6-23S-32W	W	5	Ogallala	Pliocene	8	7.7	
213910	Ford	29-25S-22W	WS	150	Ogallala	Pliocene	7	7.6	Spearville
213908	Ford	6-25S-23W	W	5+	Alluvium	Recent	7	7.6	Shale
213909	Ford	28-25S-23W	L	-	Ogallala	Pliocene	11	7.3	
213919	Ford	17-26S-21W	W	5	Ogallala?	Pliocene?	4	7.5	
213920	Ford	15-26S-22W	W	3	Alluvium	Recent	4	7.4	Sandstone
213921	Ford	15-26S-22W	W	5+	Dakota	Cretaceous	7	7.3	
213915	Ford	35-26S-25W	WS	2800+	Ogallala	Pliocene	5	7.4	Dodge City
213918	Ford	30-27S-21W	W	250	Dakota	Cretaceous	6	7.4	
213917	Ford	31-27S-21W	W	5 - 10	Alluvium and/or Dakota	Recent and/or Cretaceous	4	7.4	Sandstone
213916	Ford	12-27S-24W	St	5+	Alluvium	Recent	16	7.6	Arkansas River. Tuff

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow (gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
213922	Ford	5-28S-22W	WS	100+	Alluvium?	Recent?	5	7.4	Ford. Tuff
213923	Ford	5-29S-21W	WS	600	Ogallala	Pliocene	4	7.3	Bucklin
213930	Ford	25-29S-24W	W	10+	Ogallala?	Pliocene?	7	7.5	
213929	Ford	2-29S-25W	W	10+	Ogallala	Pliocene	9	7.6	
213927	Ford	32-29S-26W	St	3 - 10	Alluvium	Recent	3	7.3	Crooked Creek. Tuff
213926	Ford	33-29S-26W	W	10	Meade and/or Ogallala	Pleistocene and/or Pliocene	5	7.7	
213928	Ford	35-29S-26W	W	5 - 10	Ogallala and/or Dakota	Pliocene and/or Cretaceous	6	7.5	
210718	Gove	29-14S-29W	W	5+	Alluvium	Recent	16	7.5	Shale
213997	Grant	27-28S-37W	WS	350	Ogallala and/or Meade	Pliocene and/or Pleistocene	1	7.8	Ulysses
214002	Grant	26-29S-35W	W	5 - 10	Meade	Pleistocene	2	7.7	
214001	Grant	33-29S-35W	W	5 - 10	Meade	Pleistocene	2	7.6	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
214005	Grant	2-29S-36W	W	50	Meade	Pleistocene	2	7.7	
213998	Grant	7-29S-36W	St	10	Alluvium and Meade	Recent and Pleistocene	<1	7.4	North Fork Cimarron. Tuff
213999	Grant	21-29S-36W	Sp	1+	Meade	Pleistocene	15	7.2	Spring in bed of North Fork Cimarron River
214000	Grant	35-29S-36W	St	5 - 10	Meade	Pleistocene	<1	7.3	North Fork Cimarron
214006	Grant	6-29S-37W	St	2 - 10	Meade	Pleistocene	<1	7.3	North Fork Cimarron
214007	Grant	22-29S-38W	St	2 - 10	Meade	Pleistocene	<1	7.3	North Fork Cimarron
213984	Grant	9-30S-35W	St	15 - 20	Alluvium	Recent	1	7.9	North Fork Cimarron. Tuff
213983	Grant	16-30S-35W	St	15 - 20	Alluvium	Recent	5	7.7	North Fork Cimarron. Tuff
213982	Grant	24-30S-35W	R	-	Meade	Pleistocene	1	7.7	Pond in a volcanic ash pit
213992	Grant	8-30S-36W	W	2000	Ogallala and/or Dakota	Pliocene and/or Cretaceous	2	7.6	Irrigation well
213993	Grant	17-30S-36W	W	500+	Ogallala and/or Dakota	Pliocene and/or Cretaceous	2	7.5	Irrigation and domestic well

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Age	U (ppb)	pH	Remarks[2]
213991	Grant	24-30S-36W	W	5 - 10	Alluvium and/or Meade	Recent and/or Pleistocene	4	7.3	Tuff
213990	Grant	35-30S-36W	W	10	Meade	Pleistocene	2	7.4	
213994	Grant	12-30S-37W	St	2 - 5	Alluvium and Meade	Recent and Pleistocene	2	7.1	Small tributary of Cimarron River. Tuff
213995	Grant	33-30S-37W	St	20+	Alluvium	Recent	2	7.5	Cimarron River. Tuff
213996	Grant	35-30S-37W	W	10+	Meade	Pleistocene	2	7.6	
214008	Grant	4-30S-38W	St	2 - 5	Meade	Pleistocene	<1	7.0	North Fork Cimarron
213897	Gray	2-25S-28W	W	5+	Ogallala	Pliocene	12	7.6	
213895	Gray	13-25S-30W	W	5+	Ogallala	Pliocene	40	7.4	
213896	Gray	11-26S-28W	WS	250	Ogallala	Pliocene	14	7.6	Cimarron
213914	Gray	36-27S-27W	W	5+	Ogallala and/or Meade	Pliocene and/or Pleistocene	3	7.4	
213913	Gray	7-28S-27W	W	5+	Ogallala and/or Meade	Pliocene and/or Pleistocene	7	7.6	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1/]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2/]
213912	Gray	23-29S-28W	W	5	Ogallala and/or Meade	Pliocene and/or Pleistocene	5	7.5	
214035	Hamilton	25-22S-42W	Sp	1+	Carlile?	Cretaceous?	21	7.5	
214034	Hamilton	25-22S-42W	Sp	1+	Carlile or Alluvium	Cretaceous or Recent	2	7.5	Shale
214033	Hamilton	36-22S-42W	W	2	Dakota	Cretaceous	< 1	8.0	
214032	Hamilton	7-23S-40W	W	5+	Alluvium	Recent	< 1	6.5	Tuff
214030	Hamilton	3-23S-41W	Sp	1+	Alluvium and/or Carlile	Recent and/or Cretaceous	< 1	7.1	Shale
214031	Hamilton	10-23S-41W	Sp	1+	Alluvium	Recent	< 1	7.0	Tuff
214037	Hamilton	1-23S-42W	St	2+	Alluvium	Recent	< 1	7.3	Tuff
214036	Hamilton	2-23S-42W	St	2+	Alluvium	Recent	2	7.2	Tuff
214024	Hamilton	2-24S-39W	W	10+	Alluvium and/or Ogallala	Recent and/or Pliocene	2	7.5	Tuff
214025	Hamilton	25-24S-39W	W	10+	Alluvium and/or Dakota	Recent and/or Cretaceous	< 1	7.7	Tuff

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1/]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2/]
214023	Hamilton	13-24S-40W	W	10	Alluvium?	Recent?	<1	7.8	Tuff
214039	Hamilton	34-24S-41W	W	10	Ogallala?	Pliocene-Pleistocene?	<1	7.8	
214041	Hamilton	33-24S-42W	St	2 - 5	Alluvium	Recent	<1	6.9	Small stream draining Greenhorn-Graneros outcrop. Shale?
214040	Hamilton	36-24S-42W	W	5	Ogallala?	Pliocene-Pleistocene?	<1	7.5	
214038	Hamilton	1-25S-41W	St	2 - 5	Alluvium	Recent	<1	7.0	Small stream draining Greenhorn-Graneros outcrop. Shale?
214042	Hamilton	1-25S-43W	St	2 - 5	Alluvium	Recent	<1	7.2	Do.
214020	Hamilton	18-26S-41W	W	10	Ogallala	Pliocene-Pleistocene	3	7.5	
214044	Hamilton	2-26S-42W	St	2 - 5	Alluvium	Recent	<1	7.2	Tuff
214043	Hamilton	5-26S-42W	W	5 - 10	Alluvium	Recent	2	7.6	Tuff
214022	Hamilton	12-26S-42W	R	-	Ogallala and/or Dakota	Pliocene and/or Cretaceous	<1	7.5	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
214021	Hamilton	13-26S-42W	W	5	Alluvium and/or Ogallala	Recent and/or Pleistocene	8	7.4	Tuff
214019	Hamilton	35-26S-42W	W	10+	Ogallala	Pliocene-Pleistocene	4	7.5	
214004	Haskell	32-29S-32W	WS	275	Ogallala and/or Meade	Pliocene and/or Pleistocene	1	7.5	Sublette
214003	Haskell	13-30S-34W	WS	475	Ogallala	Pliocene	3	7.6	Satanta
213981	Haskell	33-30S-34W	W	5 - 10	Alluvium	Recent	5	7.8	Tuff
213905	Hodgeman	25-21S-24W	W	5	Ogallala	Pliocene	6	7.6	
213906	Hodgeman	8-23S-22W	W	5 - 10	Alluvium or Dakota	Recent or Cretaceous	6	7.4	Sandstone
213900	Hodgeman	6-23S-23W	WS	50+	Alluvium	Recent	6	7.4	Jetmore Shale
213899	Hodgeman	7-23S-24W	St	5+	Alluvium	Recent	5	7.2	Buckner Creek Shale
213898	Hodgeman	7-23S-25W	W	1+	Ogallala?	Pliocene?	14	7.7	
213907	Hodgeman	14-24S-23W	W	5	Dakota	Cretaceous	14	7.4	Formerly artesian well

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
214029	Kearny	11-24S-35W	WS	100+	Alluvium	Recent	3	7.8	Deerfield. Tuff
214028	Kearny	27-24S-36W	WS	800	Ogallala	Pliocene-Pleistocene	3	7.6	Lakin
214026	Kearny	12-25S-38W	W	10	Graneros	Cretaceous	<1	7.7	
214027	Kearny	12-25S-38W	W	5	Alluvium	Recent	<1	7.4	Tuff
210722	Lane	3-16S-27W	W	5	Dakota	Cretaceous	<1	8.3	Well 711 feet deep
210721	Lane	20-16S-27W	W	5	Ogallala	Pliocene	4	7.7	
210720	Lane	32-16S-28W	W	2+	Ogallala	Pliocene	5	8.0	
210723	Lane	21-17S-27W	W	5+	Ogallala	Pliocene	5	7.7	
210717	Lane	3-17S-30W	W	5	Ogallala	Pliocene	8	7.8	
210724	Lane	28-18S-27W	W	100	Alluvium?	Recent?	9	7.9	Shale
210726	Lane	18-18S-28W	WS	500+	Ogallala	Pliocene	10	7.9	Dighton
210682	Lane	14-18S-30W	W	5	Ogallala	Pliocene	9	7.6	
210725	Lane	1-19S-27W	W	10+	Dakota	Cretaceous	<1	8.0	Approximately 600 feet deep

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Age	U (ppb)	pH	Remarks[2]
210683	Lane	30-19S-30W	W	1+	Dakota	Cretaceous	1	8.0	1038 feet deep
217642	Logan	22-12S-35W	W	2+	Ogallala?	Pliocene?	20	8.2	September sample
210708	Logan	2-13S-35W	W	2+	?	Pleistocene?	49	7.8	July sample, 78 feet deep. Shale
217643	Logan	2-13S-35W	W	2+	?	Pleistocene?	48	7.8	September sample, same source as 210708, sample collected for residue analysis. Shale
210707	Logan	20-13S-35W	St	5+	Alluvium	Recent	26	7.5	Smoky Hill River, July sample. Shale
219289	Logan	4-13S-36W	W	2	Alluvium	Recent	40	7.8	September sample. Shale
217644	Logan	16-13S-36W	W	2+	Alluvium	Recent	12	7.9	September sample. Shale
210709	Logan	27-13S-36W	W	2+	Alluvium	Recent	69	7.6	July sample. Shale
210706	Logan	31-13S-36W	W	2+	Alluvium	Recent	50	7.8	July sample. Shale
217645	Logan	5-14S-36W	W	5 - 10	Ogallala	Pliocene	10	7.9	September sample

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow (gpm)	Rock unit	Age	(ppb)	pH	Remarks[2]
210711	Logan	14-15S-33W	St	2 - 5	Alluvium	Recent	22	7.2	Chalk Creek; also called Hackberry Creek. July sample. Shale.
213911	Meade	7-30S-27W	St	5+	Alluvium	Recent	2	6.9	Crooked Creek. Tuff
213925	Meade	6-31S-26W	WS	800	Ogallala	Pliocene	5	7.6	Fowler
213944	Meade	2-31S-28W	W	10	Meade and/or Ogallala	Pleistocene and/or Pliocene	6	7.5	
213937	Meade	2-32S-26W	R	-	Alluvium	Recent	<1	7.3	Tuff
213938	Meade	3-32S-26W	R	-	Ogallala	Pliocene	<1	7.3	
213943	Meade	8-32S-26W	W	5+	Ogallala	Pliocene	6	7.6	
213940	Meade	9-32S-26W	St	2+	Alluvium and Ogallala	Recent and Pliocene	1	7.1	Small tributary of North Branch of Sand Creek. Tuff
213942	Meade	9-32S-26W	W	5+	Ogallala	Pliocene	8	8.3	
213939	Meade	10-32S-26W	St	2 - 5	Alluvium	Recent	5	7.2	Tuff
213936	Meade	12-32S-26W	St	2 - 5	Alluvium	Recent	2	7.3	Tuff

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
213941	Meade	16-32S-26W	W	5+	Ogallala	Pliocene	4	8.4	
213924	Meade	11-32S-28W	WS	900+	Ogallala and Meade	Pliocene and Pleistocene	5	7.6	Meade
213949	Meade	17-32S-28W	Sp	20	Ogallala	Pliocene	21	7.5	Big Spring
213958	Meade	16-33S-26W	St	10+	Alluvium	Recent	3	7.2	Sand Creek.Sandstone
213957	Meade	35-33S-26W	W	5 - 10	Ogallala	Pliocene	6	7.7	
213950	Meade	35-33S-27W	W	10+	Ogallala	Pliocene	7	7.5	
213945	Meade	4-33S-28W	St	10	Alluvium	Recent	4	7.4	Crooked Creek. Tuff
213946	Meade	20-33S-28W	St	10+	Alluvium	Recent	3	7.5	Crooked Creek. Tuff
213959	Meade	34-33S-28W	W	5+	Ogallala	Pliocene	8	8.1	
213948	Meade	15-33S-29W	Sp	10+	Ogallala	Pliocene	7	7.6	
213968	Meade	15-33S-29W	W	200	Ogallala	Pliocene	7	7.8	Artesian well
213947	Meade	24-33S-29W	L	-	Alluvium and Ogallala	Recent and Pliocene	5	7.4	State Lake. Tuff

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
213962	Meade	25-33S-29W	St	2+	Alluvium	Recent	1	7.2	Small tributary of Shorts Creek. Tuff
213956	Meade	13-34S-26W	St	2+	Alluvium	Recent	4	7.4	Tributary of Sand Creek. Sandstone
213951	Meade	19-34S-26W	W	5+	?	Permian	17	8.0	
213955	Meade	24-34S-26W	W	5	?	Permian	13	7.9	
213952	Meade	32-34S-26W	W	5	?	Permian	11	7.6	
213960	Meade	14-34S-28W	St	10+	Alluvium	Recent	4	7.3	Crooked Creek. Sandstone
213961	Meade	32-34S-28W	W	5+	Meade	Pleistocene	7	7.4	
213965	Meade	30-34S-29W	W	10+	Meade	Pleistocene	7	7.5	
213967	Meade	9-34S-30W	W	5	Laverne and Ogallala	Miocene? and Pliocene	7	7.9	
213966	Meade	20-34S-30W	W	5	Laverne and Ogallala	Miocene? and Pliocene	7	7.8	
213954	Meade	2-35S-26W	W	5+	Ogallala	Pliocene	4	7.4	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
213953	Meade	1-35S-27W	W	10+	Alluvium	Recent	3	7.8	Sandstone
213964	Meade	4-35S-29W	R	-	Meade	Pleistocene	1	7.3	
213963	Meade	9-35S-29W	St	20+	Alluvium	Recent	7	7.3	Cimarron River. Tuff
221289	Morton	30-31S-39W	W	2 - 5	Ogallala	Pliocene	12	8.4	
221290	Morton	30-31S-39W	W	2 - 5	Ogallala	Pliocene	12	8.1	
221283	Morton	10-31S-42W	W	2 - 5	Morrison Dockum or Taloga	Jurassic Triassic or Permian?	1	8.3	
221284	Morton	16-31S-42W	W	2 - 5	Ogallala	Pliocene	9	8.1	
221285	Morton	18-31S-43W	W	2 - 5	Dakota	Cretaceous	8	8.0	
221291	Morton	34-32S-40W	W	2 - 5	Ogallala	Pliocene	12	8.2	
221312	Morton	35-32S-40W	W	2+	Alluvium	Recent	7	8.3	Dug well in alluvium by Cimarron River. Tuff
221287	Morton	28-32S-41W	W	2 - 3	?	Permian	28	8.0	Artesian well in Permian redbeds, 610 feet deep
221286	Morton	9-32S-43W	W	5+	Dakota	Cretaceous	18	8.5	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
221311	Morton	2-34S-40W	WS	200	Ogallala	Pliocene	7	8.1	Rolla
221308	Morton	5-34S-42W	W	2 - 5	Ogallala or Dockum	Pliocene or Triassic	20	8.2	
221309	Morton	6-34S-42W	R	-	Alluvium and Ogallala	Recent and Pliocene	29	7.9	Some of water is run-off, some is spring or seep water. May be some evaporation concentration. Tuff
221310	Morton	16,17,20,21 35S-42W	WS	306	Ogallala	Pliocene	12	8.5	Elkhart
213901	Ness	30-18S-23W	WS	50+	Dakota	Cretaceous	11	7.3	Ness City
213902	Ness	31-18S-23W	St	2 - 5	Alluvium	Recent	10	7.7	North Walnut Creek. Shale
213903	Ness	32-19S-23W	W	5	Dakota	Cretaceous	8	7.8	
213904	Ness	32-20S-23W	St	5+	Alluvium	Recent	4	7.0	Pawnee River. Shale
210716	Scott	2-16S-33W	L	200+	Ogallala	Pliocene	18	7.6	Scott Lake; fed mainly by two springs sampled in this township

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type 1/	Estimated flow(gpm)	Aquifer Rock unit	Age	U (ppb)	pH	Remarks 2/
210715	Scott	12-16S-33W	Sp	50	Ogallala	Pliocene	8	7.8	Old Steele Home
210714	Scott	13-16S-33W	Sp	400+	Ogallala	Pliocene	8	7.8	Big Spring
210719	Scott	2-17S-32W	W	10+	Ogallala	Pliocene	8	7.9	
210713	Scott	13-18S-33W	WS	2100+	Ogallala	Pliocene	12	7.9	Scott City
210684	Scott	32-19S-31W	W	5	Ogallala	Pliocene	8	7.8	
210685	Scott	25-19S-33W	W	5	Ogallala	Pliocene	23	7.7	
213980	Seward	6-31S-34W	W	5 - 10	Meade	Pleistocene	2	7.9	
213979	Seward	19-31S-34W	R	-	Alluvium	Recent	1	7.5	Tuff
213975	Seward	21-32S-33W	W	5 - 10	Alluvium	Recent	7	7.5	Tuff
213977	Seward	3-32S-34W	W	2 - 5	Alluvium	Recent	3	7.9	Tuff
213976	Seward	13-32S-34W	W	5+	Meade	Pleistocene	4	7.9	
213985	Seward	30-33S-31W	W	10+	Alluvium	Recent	2	7.3	Tuff
213986	Seward	31-33S-31W	W	5 - 10	Meade and/or Ogallala	Pleistocene and/or Pliocene	<1	6.9	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type [1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
213978	Seward	6-33S-32W	W	5 - 10	Alluvium	Recent	4	7.7	Tuff
213974	Seward	19-33S-32W	W	5	Alluvium ?	Recent?	3	7.9	Tuff
213972	Seward	28-33S-32W	W	5	Alluvium	Recent	3	8.1	Tuff
213973	Seward	30-33S-32W	W	5 - 10	Meade	Pleistocene	2	7.7	
213987	Seward	9-34S-31W	W	10	Alluvium	Recent	<1	7.6	Tuff
213988	Seward	15-34S-31W	W	5 - 10	Alluvium	Recent	4	7.5	Tuff
213970	Seward	22-34S-31W	W	10+	Alluvium	Recent	3	8.1	Tuff
213971	Seward	22-34S-31W	R	-	Alluvium	Recent	1	7.4	Pond in bed of Cimarron River, probably mostly runoff. Tuff
213969	Seward	33-34S-31W	W	5 - 10	Meade	Pleistocene	3	7.6	
214016	Stanton	22-27S-40W	W	10+	Ogallala	Pliocene-Pleistocene	2	7.5	
214017	Stanton	26-27S-40W	W	1000+	Ogallala and/or Dakota	Pliocene and/or Cretaceous	2	7.8	
214015	Stanton	12-27S-41W	W	5 - 10	Ogallala	Pliocene-Pleistocene	4	7.4	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type [1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2]
214009	Stanton	35-28S-39W	W	100	Ogallala	Pliocene	2	7.5	
214014	Stanton	11-28S-41W	W	10+	Ogallala	Pliocene	1	7.8	
214013	Stanton	36-28S-41W	WS	110	Ogallala	Pliocene	2	8.1	Johnson
214010	Stanton	21-29S-39W	W	5 - 10	Meade and/or Ogallala	Pleistocene and/or Pliocene	3	7.5	
214011	Stanton	25-29S-40W	W	10	Meade and/or Ogallala	Pleistocene and/or Pliocene	2	7.7	
214012	Stanton	26-29S-41W	W	10+	Ogallala	Pliocene	2	7.7	
214018	Stanton	2-29S-42W	W	10+	Ogallala	Pliocene	1	7.5	
221277	Stanton	15-29S-43W	St	25	Alluvium and Dakota	Recent and Cretaceous	2	7.8	Bear Creek. Sandstone
221271	Stanton	5-30S-43W	W	5	Dakota	Cretaceous	<1	8.1	
213989	Stevens	26-31S-36W	W	10+	Ogallala and/or Meade	Pliocene and/or Pleistocene	2	7.7	

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow (gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221313	Stevens	29-31S-38W	St	-	Alluvium	Recent	7	7.9	Cimarron River; no flow here, sample from pool. Tuff
221314	Stevens	16-33S-37W	WS	100+	Ogallala and Meade	Pliocene and Pleistocene	8	8.3	Hugoton
210700	Wallace	14-12S-42W	W	1+	Ogallala	Pliocene	11	7.8	July sample
219288	Wallace	6-13S-38W	W	1 - 2	Alluvium	Recent	11	7.6	September sample. Shale
210702	Wallace	21-13S-38W	W	1+	Alluvium	Recent	30	7.8	May obtain some water from Pierre shale; July sample. Shale
210703	Wallace	25-13S-39W	WS	100	Alluvium	Recent	26	8.1	Wallace; July sample. Shale
210712	Wallace	27-13S-40W	WS	50-100	Alluvium	Recent	10	7.8	Sharon Springs; July sample. Shale
210699	Wallace	11-13S-42W	St	2+	Alluvium	Recent	13	7.8	Water mainly from base of Ogallala; July sample. Tuff
217639	Wallace	3-14S-38W	R	-	Alluvium	Recent	3	7.6	September sample. Shale

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
217638	Wallace	3-14S-38W	R	-	Alluvium	Recent	<1	7.6	September sample. Shale.
210704	Wallace	5-14S-38W	R	-	Alluvium	Recent	380	6.9	July sample. Resampled in September. Contained 5 ppb U, pH 7.3. Shale
210710	Wallace	6-14S-38W	R	-	Alluvium	Recent	42	7.0	July sample. Resampled in September. Contained 3 ppb U, pH 7.1. Shale
217634	Wallace	6-14S-38W	R	-	Alluvium	Recent	2	7.6	September sample. Shale
217635	Wallace	7-14S-38W	R	-	Alluvium	Recent	3	7.7	September sample. Shale
217636	Wallace	7-14S-38W	R	-	Alluvium	Recent	<1	7.4	September sample. Shale
217633	Wallace	7-14S-38W	Sp	1 - 5	Ogallala	Pliocene	13	8.1	September sample
217631	Wallace	8-14S-38W	R	-	Alluvium	Recent	1	7.5	September sample. Shale
217632	Wallace	8-14S-38W	R	-	Alluvium	Recent	1	7.5	September sample. Shale
217641	Wallace	8-14S-38W	R	-	Alluvium	Recent	2	7.7	September sample. Shale
217640	Wallace	11-14S-38W	R	-	Alluvium	Recent	4	7.6	September sample. Shale
217637	Wallace	17-14S-38W	R	-	Alluvium	Recent	1	7.7	September sample. Shale

Table 7.--Location and other physical factors pertaining to water samples collected in Kansas.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
210705	Wallace	21-14S-38W	W	1	Ogallala	Pliocene	8	7.6	July sample
210701	Wallace	8-14S-39W	Sp	1	Ogallala	Pliocene	10	7.7	July sample
210698	Wallace	5-14S-41W	W	5+	Ogallala	Pliocene	9	7.9	July sample
210697	Wallace	11-14S-41W	W	2	Alluvium	Recent	9	7.6	July sample. Tuff?

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.

Sample no.	County	Location sec., T., R.	Source type 1/	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks 2/
221300	Baca	32-28S-44W	WS	100	Dakota	Cretaceous	6	8.0	Two Buttes, well 180 feet deep
221299	Baca	32-28S-44W	W	2 - 25	Ogallala or Dakota	Pliocene or Cretaceous	8	8.1	Well 160 feet deep
221303	Baca	1-28S-46W	W	2 - 5	Entrada	Jurassic	4	8.2	
221302	Baca	1-28S-46W	L	?	Alluvium	Recent	3	7.7	Two Buttes; water from runoff, Ogallala, Dakota, Cheyenne, Morrison, and Entrada
221292	Baca	6-28S-46W	St	2 - 5	Aluvium	Recent	2	8.0	Two Buttes Creek. Sandstone
221275	Baca	10-29S-42W	St	1 - 3	Alluvium	Recent	< 1	7.4	Buffalo Creek. Sandstone
221274	Baca	33-29S-43W	St	10	Alluvium	Recent	7	8.0	Horse Creek. Sandstone
221301	Baca	27-29S-44W	W	1500	Cheyenne	Cretaceous	11	8.1	Formerly artesian
221298	Baca	5-29S-46W	W	2 - 25	Dakota?	Cretaceous?	6	8.0	

1/ Spring (Sp), well (W), stream (St), city or town water system (WS), reservoir (R), lake (L).

2/ Terrane affiliation of samples from alluvium: Tuff (Tertiary-Quaternary tuffaceous terrane); shale (Upper Cretaceous shale terrane); and sandstone (late Permian through older Cretaceous sandstone terrane).

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.--Continued

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221358	Baca	10-29S-49W	St	3	Alluvium	Recent	6	7.8	Two Buttes Creek. Shale
221332	Baca	31-29S-50W	W	2 - 3	Dockum group?	Triassic?	35	8.1	Well probably in limestone
221276	Baca	3-30S-42W	St	25	Alluvium	Recent	6	7.8	Bear Creek. Sandstone
221278	Baca	3-30S-42W	W	5+	Dakota	Cretaceous	9	8.0	
221270	Baca	15-30S-42W	W	5 - 10	Dakota	Cretaceous	15	7.9	
221273	Baca	21-30S-43W	St	1 - 2	Alluvium	Recent	2	8.1	Bear Creek. Sandstone
221269	Baca	32-30S-43W	WS	1300	Cheyenne	Cretaceous	6	8.2	Walsh
221272	Baca	30-30S-45W	W	5+	Cheyenne	Cretaceous	20	8.0	
221365	Baca	30-30S-46W	WS	600+	Dakota	Cretaceous	4	8.1	Springfield
221331	Baca	2-30S-50W	St	2+	Alluvium	Recent	5	8.1	Freezeout Creek. Sandstone
221288	Baca	5-31S-41W	St	1 - 2	Alluvium	Recent	16	8.0	Sand Arroyo. Sandstone
221267	Baca	1-31S-45W	W	2 - 5	Ogallala	Pliocene	12	8.1	Well 90-100 feet deep
221268	Baca	1-31S-45W	W	2 - 5	Dakota	Cretaceous	2	8.1	Well 125-135 feet deep, draws from Dakota

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.--Continued.

Sample no.	County	Location sec., T., R.	Source type 1/	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks 2/
221335	Baca	6-31S-48W	WS	100	Dakota	Cretaceous	20	8.0	Pritchett
221334	Baca	28-31S-50W	W	2 - 5	Dakota	Cretaceous	12	8.0	
221281	Baca	5-32S-42W	W	2 - 5	Dakota	Cretaceous	7	8.0	Domestic well at Stonington
221279	Baca	29-32S-46W	W	2 - 5	Dakota or Cheyenne	Cretaceous	2	8.2	
221336	Baca	10-32S-50W	W	5 - 10	Dakota or Ogallala	Cretaceous	10	8.2	
221282	Baca	19-33S-42W	W	2 - 5	Ogallala	Pliocene	14	8.0	Domestic well at Midway
221280	Baca	28-33S-43W	W	3	Ogallala	Pliocene	11	7.9	
221340	Baca	27-33S-50W	St	10+	Alluvium	Recent	9	8.2	East Carrizo Creek;water may be partially runoff. Sandstone
221354	Baca	31-33S-50W	St	100+	Alluvium	Recent	8	7.9	From tributary of West Carrizo Creek. Sandstone
221307	Baca	10-34S-46W	WS	100+	Cheyenne and Dakota	Cretaceous	4	8.1	Campo; Cheyenne is principal water strata

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221352	Baca	10-34S-50W	St	2 - 5	Alluvium	Recent	11	8.1	East Carrizo Creek. Sandstone
221353	Baca	15-34S-50W	St	25+	Alluvium	Recent	6	7.9	West Carrizo Creek. Sandstone
221355	Baca	12-35S-50W	St	25 - 50	Alluvium	Recent	6	8.1	Carrizo Creek. Sandstone
221361	Bent	23-23S-52W	St	750	Alluvium	Recent	32	8.1	Purgatoire River; Surface Water Branch, U.S.G.S., records show 1.7 cfs. on November 1, 1954. Sandstone
221362	Bent	6-26S-51W	St	15+	Alluvium	Recent	28	8.0	Rule Creek. Sandstone
221359	Bent	19-26S-51W	St	2 - 3	Alluvium	Recent	14	7.9	Rule Creek. Sandstone
221363	Bent	15-27S-51W	St	2	Alluvium	Recent	6	7.7	Hackberry Creek. Sandstone
219290	Cheyenne	20-14S-44W	WS	500	Ogallala	Pliocene ?	6	7.9	Cheyenne Wells
219291	Cheyenne	22-14S-46W	W	2 - 5	Ogallala	Pliocene ?	3	7.9	From domestic well at First View
219292	Cheyenne	6-16S-45W	W	2 - 5	Ogallala	Pliocene ?	16	7.7	From basal 8 feet of Ogallala

Table 8. --Location and other physical factors pertaining to water samples collected in Colorado. --Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221266	Crowley	32-21S-59W	Sp	.1	Ogallala	Pliocene?	8	7.9	Seep at base of Ogallala
219297	Kiowa	8-18S-44W	W	2 - 5	Codell	Cretaceous	1	8.4	Well 570 feet deep, probably draws from Codell, water clear but has sour, sulferous (H_2S) odor
219293	Kiowa	25-18S-44W	W	2 - 5	Ogallala?	Pliocene?	88	7.8	From domestic well in Sheridan Lake, 65 feet deep down to shale, water very hard, probably in Ogallala
219296	Kiowa	13-18S-46W	W	2	Codell	Cretaceous	2	8.2	Well approximately 500 feet deep, probably drawing from Codell
219294	Kiowa	22-18S-48W	WS	500	Ogallala	Pliocene?	3	8.3	Eads
219302	Kiowa	9-18S-50W	W	5	Ogallala	Pliocene?	28	8.2	
219298	Kiowa	29-18S-51W	WS	50?	Ogallala?	Pliocene?	11	7.5	Haswell
219295	Kiowa	1-19S-47W	W	1	Codell or Ogallala	Cretaceous or Pliocene	40	7.8	Water now clear, hard; formerly was black, soft, full of asphaltic material. Water may now be from Ogallala

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221360	Las Animas	34-28S-51W	Sp	1	Cheyenne	Cretaceous	50	8.1	
221333	Las Animas	2-30S-51W	W	2 - 3	Alluvium or Dakota	Recent or Cretaceous	10	7.9	Sandstone
221337	Las Animas	26-32S-52W	St	2 - 5	Alluvium	Recent	<1	7.6	Sandstone
221338	Las Animas	9-33S-52W	Sp	2+	Dakota?	Cretaceous	1	8.0	Spring in crossbedded sandstone, probably Dakota
221339	Las Animas	14-33S-52W	St	?	Alluvium	Recent	<1	7.7	Tecolote Creek; no flow visible, probably partly runoff. Sandstone
221366	Las Animas	13-33S-57W	St	3	Alluvium	Recent	2	7.9	Chacuaco Creek. Sandstone
221367	Las Animas	18-33S-58W	St	2	Alluvium	Recent	5	8.2	Alkali Creek. Sandstone
221368	Las Animas	33-33S-59W	St	10	Alluvium	Recent	7	8.2	Trinchera Creek. Sandstone

Table 8.--Location and other physical factors pertaining to water samples collected in Colorado.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
219299	Lincoln	18-9S-54W	WS	25+	Ogallala	Pliocene ?	3	7.7	Genoa; from spring at base of Ogallala.
219300	Lincoln	5-11S-56W	W	2 - 5	Ogallala	Pliocene ?	4	7.7	
219301	Lincoln	22-15S-55W	W	2 - 5	Ogallala	Pliocene ?	38	8.0	Previous analysis(quality of water) showed large quantity of nitrate-at store south side of road, Karval, Colorado
221306	Prowers	7-25S-46W	St	10+	Alluvium	Recent	7	8.0	Clay Creek. Sandstone
221304	Prowers	13-26S-47W	St	10+	Alluvium	Recent	6	7.9	Clay Creek. Sandstone
221305	Prowers	21-26S-47W	W	2 - 5	Alluvium and/or Dakota	Recent and/or Cretaceous	10	8.3	Sandstone
221297	Prowers	4-27S-44W	St	1 - 3	Alluvium	Recent	1	7.4	North Butte Creek. Sandstone
221296	Prowers	4-27S-45W	W	1 - 3	Alluvium and/or Dakota	Recent and/or Cretaceous	18	8.1	Stock well, NE 4, depth unknown. Sandstone

Table 8. --Location and other physical factors pertaining to water samples collected in Colorado. --Concluded.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221293	Prowers	20-27S-45W	W	2 - 5	Alluvium, Ogallala or Dakota	Recent, Pliocene or Cretaceous	5	8.0	
221294	Prowers	27-27S-45W	St	5 - 10	Alluvium	Recent	4	8.0	Two Buttes Creek. Sandstone
221295	Prowers	7-27S-46W	W	2 - 5	Dakota?	Cretaceous?	<1	7.5	Water from tank

Table 9.--Location and other physical factors pertaining to water samples collected in Oklahoma.

Sample no.	County	Location sec., T., R.	Source type[1/]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2/]
221329	Cimarron	25-2N-6E	W	2 - 5	Alluvium	Recent	5	8.0	Tuff
221330	Cimarron	31-2N-8E	W	2 - 5	Ogallala	Pliocene	6	8.2	
221328	Cimarron	15-3N-5E	WS	153	Ogallala	Pliocene	6	8.5	Boise City
221327	Cimarron	12-4N-7E	WS	70 - 90	Ogallala	Pliocene	7	8.2	Keyes
221356	Cimarron	4-5N-1E	St	100+	Alluvium	Recent	25	8.0	Cimarron River. Sandstone
239713	Cimarron	4-5N-1E	St	100+	Alluvium	Recent	19	8.0	Cimarron River, from same point as 221356, collected November 1955. Sandstone
221357	Cimarron	11-5N-2E	St	100+	Alluvium	Recent	13	8.3	Cimarron River. Sandstone
221364	Cimarron	5-5N-5E	W	2 - 5	Alluvium	Recent	26	8.2	Water from Cimarron River alluvium. Sandstone

1/ Spring (Sp), well (W), stream (St), city or town water system (WS), reservoir(R), lake (L).

2/ Terrane affiliation of samples from alluvium: Tuff (Tertiary-Quaternary tuffaceous terrane); shale (Upper Cretaceous shale terrane); and sandstone (late Permian through older Cretaceous sandstone terrane).

Table 9.--Location and other physical factors pertaining to water samples collected in Oklahoma.--Continued.

Sample no.	County	Location sec., T., R.	Source type[1]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[2]
221318	Texas	11-1N-18E	W	2 - 5	Alluvium and Cloud Chief	Recent and Permian	6	8.0	Probably does not penetrate redbeds. Sandstone
221319	Texas	11-1N-18E	W	2 - 5	Cloud Chief	Permian	11	8.0	Water brackish, draws from redbeds
221320	Texas	26-2N-17E	WS	100?	Cloud Chief?	Permian?	8	8.1	Hardesty
221326	Texas	2-3N-10E	W	2 - 5	Ogallala	Pliocene	15	8.3	
221323	Texas	22-3N-13E	St	25+	Alluvium	Recent	7	7.9	North Canadian River. Sandstone and tuff
221316	Texas	13-3N-15E	St	5 - 10	Alluvium	Recent	7	8.3	North Canadian River. Tuff
221322	Texas	31-3N-15E	WS	536	Ogallala	Pliocene	8	8.2	Guymon
221321	Texas	35-3N-16E	W	2 - 5	Ogallala	Pliocene	11	8.1	
221317	Texas	26-3N-17E	St	25+	Alluvium	Recent	7	8.3	North Canadian River. Tuff

Table 9.--Location and other physical factors pertaining to water samples collected in Oklahoma.--Concluded.

Sample no.	County	Location sec., T., R.	Source type [1/]	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks [2/]
221325	Texas	19-4N-11E	W	40	Ogallala and/or redbeds	Pliocene and/or Triassic	1	8.0	Draws from Triassic redbeds and maybe also from Ogallala
221324	Texas	25-4N-12E	W	3	redbeds	Triassic	41	7.9	Believed to draw from Triassic redbeds
221315	Texas	34-5N-17E	WS	300+	Ogallala	Pliocene	5	8.5	Hooker

Table 10.--Location and other physical factors pertaining to water samples collected in New Mexico.

Sample no.	County	Location sec., T., R.	Source type	Estimated flow(gpm)	Aquifer Rock unit	Aquifer Age	U (ppb)	pH	Remarks[1/]
242831	Union	28-31N-29E	Stream	20	Alluvium	Recent	42	7.9	Cimarron River. Sandstone
242832	Union	12-31N-31E	Stream	20	Alluvium	Recent	23	8.0	Cimarron River. Sandstone
242833	Union	36-32N-34E	Stream	15 - 20	Alluvium	Recent	19	7.9	Cimarron River. Sandstone

1/ Terrane affiliation of samples from alluvium: Tuff (Tertiary-Quaternary tuffaceous terrane); shale (Upper Cretaceous shale terrane); and sandstone (late Permian through older Cretaceous sandstone terrane).

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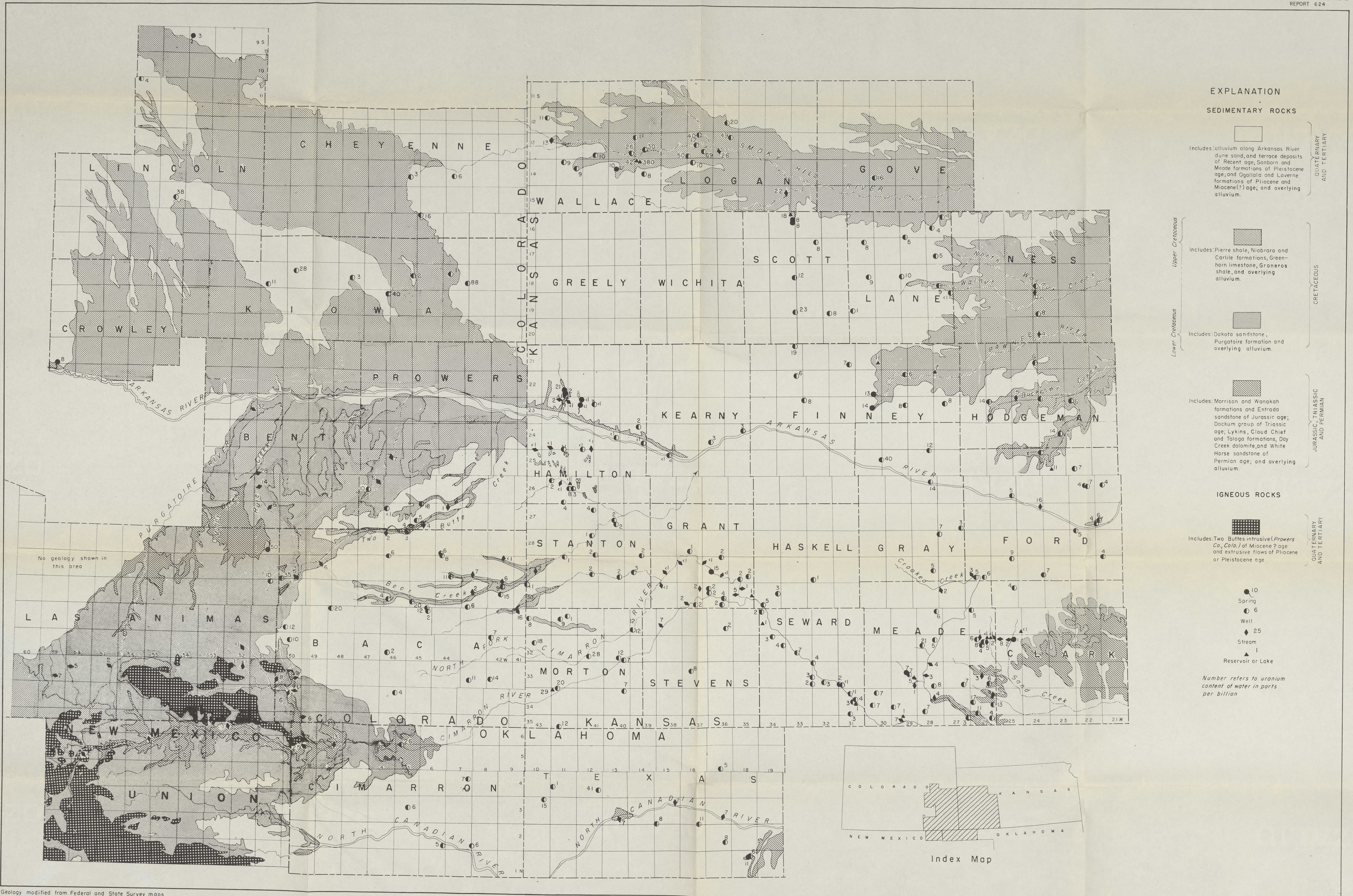

FIGURE 1.- GENERALIZED GEOLOGIC MAP SHOWING URANIUM CONTENT OF GROUND AND SURFACE WATERS IN PARTS OF KANSAS, COLORADO, AND OKLAHOMA.

10 0 10 20 30 40 Miles