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BUREAU OF MINES AND MINERAL RESOURCES

A DEPARTMENT OF THE SCHOOL OF MINES

Socorro, New Mexico

E. C. ANDERSON
Director

GROUND-WATER REPORT 1

Geology and Ground-Water Resources
of the Eastern Part of
Colfax County, New Mexico

By

ROY L. GRIGGS

UNITED STATES GEOLOGICAL SURVEY



Prepared in cooperation with the
County Commission of Colfax County,
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THE NEW MEXICO BUREAU OF MINES AND
MINERAL RESOURCES

The New Mexico Bureau of Mines and Mineral Resources, designated as "a department of the New Mexico School of Mines and under the direction of its Board of Regents," was established by the New Mexico Legislature of 1927. Its chief functions are to compile and distribute information regarding mineral industries in the State, through field studies and collections, laboratory and library research, and the publication of the results of such investigations. A full list of the publications of the New Mexico Bureau of Mines and Mineral Resources is given on the last pages of this Bulletin.

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EXPLANATORY NOTE

By

E. C. ANDERSON

Realizing the need for further ground-water surveys in the State, the 18th State Legislature allocated special annual funds to the State Bureau of Mines and Mineral Resources to be spent for this purpose on a cooperative basis with the U. S. Geological Survey and the office of the State Engineer, provided such cooperation could be arranged.

This report, made at the request of the county commissioners of Colfax County and with their financial assistance, is the first of a series of the ground-water cooperative projects. The survey was made by Roy L. Griggs, geologist of the U. S. Geological Survey, under the supervision of Mr. C. V. Theis, District Geologist, Ground Water Division of the Survey, and is printed by the Bureau in bulletin form as Ground-Water Report 1.

Field work in San Miguel County has been completed and a report will be printed at an early date. Studies are now underway in Eddy and Torrance Counties.

Geology and Ground-Water Resources of the Eastern Part of Colfax County, New Mexico

By

ROY L. GRIGGS

ABSTRACT

This report describes the geology of and the occurrence and availability of ground water in the eastern part of Colfax County, in northeastern New Mexico. The study on which the report is based was made by the United States Geological Survey in cooperation with the county commissioners of Colfax County.

Colfax County lies mainly between the Southern Rocky Mountains on the west and the High Plains on the east, and the area specifically investigated is a plains area in which the low relief is broken in many places by mesas and volcanic cones. The rocks of the plains area range in age from Triassic through Quaternary, but the greater part of the area is immediately underlain by Upper Cretaceous formations ranging from the Dakota sandstone at the bottom through the Pierre shale at the top. The bulk of this sequence is shale, but the thin Greenhorn limestone and Fort Hays limestone member of the Niobrara formation occur at about 160 and 420 feet, respectively, above the Dakota sandstone. Sedimentary rock units younger than the Pierre shale are locally present. They include the Trinidad sandstone and Vermejo formation of late Cretaceous age and the Raton and Ogallala formations of Tertiary age. There are also Tertiary and Quaternary igneous rocks.

Perennial stream water is available in only a small area of the county, and it is necessary to store surface water for irrigation and for the public supplies of three towns. Four towns and the ranches and farms use ground water. The chief aquifers of the area are the Dakota sandstone and the Ogallala formation. The Dakota sandstone is present at shallow to moderate depths at places in the eastern and south-central parts of the county, but in the south-central part of the county its water is of poor quality, apparently because of additions of magmatic constituents. The Ogallala formation is present in the southeastern corner of the county, where only the lower 10 to 20 feet of the formation is saturated. The water in this formation is good. The Greenhorn limestone and Fort Hays limestone member are capable of fur-

nishing water of fair quality for small domestic and stock supplies at short distances down dip from exposures of the limestones. Small springs emerge at several places from lava-capped mesas. In the central part of the county, in the area where the Niobrara formation and Pierre shale are thick, ground-water supplies are very difficult to locate. In this latter area potable water is present at places in alluvium along streams.

INTRODUCTION

In the summer of 1945 the county commissioners of Colfax County, New Mexico, entered into an agreement with the United States Geological Survey for the purpose of financing a study of the water resources of the county. Under this cooperative agreement a general investigation, including surface-water, groundwater, and quality-of-water studies, was to be made by the Geological Survey, Colfax County furnishing half the necessary funds. At that time the county commissioners were Messrs. Earl V. Swope, C. B. Hart, and C. H. Garner. The Geological Survey was represented by Messrs. Berkeley Johnson, Charles V. Theis, and C. S. Howard, who are in charge, respectively, of the Surface Water, Ground Water, and Quality of Water Divisions of the Survey in New Mexico.

One of the problems that existed in the area concerned the possibility of augmenting the public supplies of some of the municipalities with ground water. For instance, the City of Raton, the county seat of Colfax County, was considering the use of spring water from some springs known to exist in the vicinity of their surface reservoir. The town of Springer was in need of additional water, and the possibility existed of obtaining ground water from the Dakota sandstone. These were problems of immediate importance, but a general appraisal was needed of both surface water and ground water in order that each could be fully and best utilized. A few flowing wells had recently been drilled, and the question had arisen as to whether all large supplies, such as for irrigation, would have to come from stored surface water or whether there was a possibility of some irrigation with ground water. Finally, because the location of wells for small domestic and stock supplies is difficult in many parts of the area, a fairly comprehensive report was needed on the occurrence and character of water-bearing beds in the county.

During the summer and fall of 1945 Mr. Theis commenced a study of the springs in the vicinity of Raton which were then being considered as a possible source of the municipal supply for that city. In December 1945 the writer was assigned to the project to continue and complete the general study under the supervision of Mr. Theis. The field work was continued through the early

part of December 1946. During the time of the field study the plains portion of the county lying east of the Trinidad sandstone escarpment, including the Raton Mesa area, was investigated and mapped geologically in conjunction with the Geologic Branch of the Survey, and the present report was written during the winter and spring of 1946-47.

METHODS OF INVESTIGATION

In the field work for this report the geology, including the water-bearing properties of the various stratigraphic units of the county, was studied and a large number of wells were visited in order to determine which stratigraphic units were capable of yielding water. In many wells visited the static water level was measured with a steel tape from a fixed measuring point. A representative number of water samples were taken to determine the quality of the water produced from the various stratigraphic units. The chemical analyses of these samples were made by the Geological Survey's Quality of Water Division.

As elevation data are lacking in the area, except for a few level lines and the 50-foot contouring of the Raton, Brilliant, and Koehler quadrangles, barometric elevations were run to nearly all the wells. Existing bench marks were used as control and, when possible, the altimeter was compared with one of these every hour or two. In this way the pressure tendency could be plotted and necessary adjustments could be made in the altimeter readings. It is believed that the elevations given in the well tables are generally accurate to ± 25 feet.

In the late summer and fall of 1946 a geologic map was prepared for the part of the county lying south and east of the Trinidad sandstone escarpment at the front of Raton Mesa. (See pl. 1.) The mapping was done in cooperation with the Geologic Branch of the Survey, under the direction of Charles B. Read, by Gordon H. Wood, Stuart A. Northrop, and the writer on aerial photographs having a scale of approximately 3 inches per mile. The eastern part of the area was mapped by Mr. Northrop, Mr. Wood, and the writer, and the western part by Mr. Wood. For the preliminary copy of the map the geology was transferred by Mr. Wood by visual inspection to a base prepared from the New Mexico State Highway Department's map of Colfax County, which has a scale of 2 miles to the inch. The chapter on geology in this report was prepared by the writer with emendations by Mr. Northrop and Mr. Wood.

ACKNOWLEDGMENTS

Appreciation is expressed to the many residents and well drillers of the county who supplied data necessary in identifying

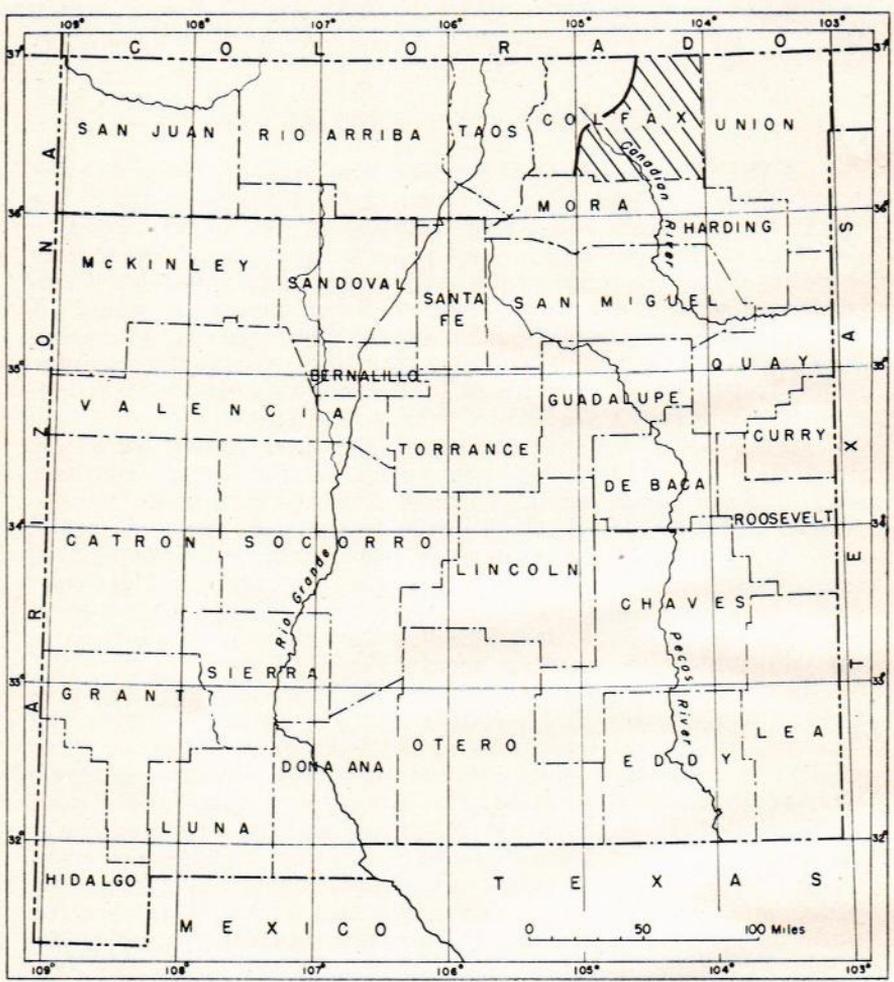


Figure 1.—Map showing area in Colfax County, New Mexico, covered by this report.

the water-bearing zones from which the present wells produce. Especial thanks are due Hiram G. Smith, a local driller, for his aid in determining the approximate thickness of the saturated zone in the Ogallala formation.

The investigation was made under the general supervision of O. E. Meinzer and A. N. Sayre, successively Geologists in Charge of the Ground Water Division of the Survey. Mr. Theis, who directly supervised the project, was particularly helpful at all times during the investigation. He also spent a great deal of time in planning, and aiding in the preparation of, the following report. Mr. Read arranged for the participation of the Fuels Section of the Geological Survey in mapping the area and supervised the production of the map. Mr. Wood transferred the geology from the aerial photographs to the base map and prepared the structural-contour map on the top of the Dakota sandstone from barometric control run by him and the writer. Miss Mariam Jo Cowan prepared the base map from the New Mexico State Highway map of Colfax County. Particular thanks are due Mr. Read and others of the Geologic Branch for their cordial interest in the work, which resulted in a much more accurate geologic map than could have been produced without their aid. The Texas Co. lent the author several sets of cuttings from oil tests.

GEOGRAPHY

Colfax County is in northeastern New Mexico. (See fig. 1.) It is adjacent to Colorado on its northern boundary and is separated from Oklahoma and Texas on the east by Union County. On the west it is bounded by Taos County, and on the south, by Harding and Mora Counties. It covers an area of more than 3,700 square miles, or about 2,400,000 acres. Its average east-west dimension is about 73 miles, its average north-south length about 51 miles.

TOPOGRAPHY AND DRAINAGE

Topographically the county is predominantly a series of plains and remnants of plains at several levels. The eastern half of the county is largely a plain of low relief surmounted by volcanic cones and mesas of varying heights. This plain rises from south to north, and along the north boundary of the county it is studded with a group of very prominent high mesas. West and north of the lower plains country and intermediate in altitude between the plains and the highest mesas, is a highland deeply cut by canyons, called locally the Raton Mesa Coal Field, and which will be referred to herein as the Raton Plateau. The eastern edge of this dissected highland extends from near Raton

in the north-central part of the county southwestward to the vicinity of Ute Park in the southwestern part of the county. The eastern edge of this highland is abrupt and is marked by a cliff face in which the light-colored Trinidad sandstone is conspicuous. West of this eastern border the highland slowly rises and finally abuts against the Southern Rocky-Mountains in the western part of the county. These mountains include the Sangre de Cristo and Cimarron Ranges in this area. The slopes of the Sangre de Cristo Range extend only a few miles into the county, but the small Cimarron Range, which stands east of the main Sangre de Cristos, covers a significant portion of the southwestern part of the county.

The lowest elevation in the county is in the valley of the Canadian River where this stream crosses the southern boundary of the county. This elevation is about 5,500 feet above sea level. Much of the lower plains country lies between 5,800 and 7,000 feet, although several of the surmounting mesas and volcanos considerably exceed 7,000 feet. Laughlin Peak extends over 8,800 feet, and much of the high mesa country in the northern part of the county exceeds 8,500 feet. Elevations in the western, mountainous part of the county are commonly above 10,000 feet, and a few peaks are near or above 12,000 feet.

A low, inconspicuous divide extends northward across the eastern part of the county. West of this divide the county is drained by the (South) Canadian River, which has essentially all its headwaters within the county. A few unimportant intermittent tributaries to this system originate on the west flank of the low divide, but the main stem of the Canadian and the major tributaries, such as the Vermejo and Cimarron Rivers, all normally perennial streams, originate in or near the mountains along the western border of the county. Chicorico Creek, an intermittent tributary of moderate importance, heads in the high mesa country along the north edge of the county. East of the low divide approximately two tiers of townships are drained by the "Dry" Cimarron River and other small intermittent creeks that are tributary to the (South) Canadian River in eastern New Mexico and in Texas.

CLIMATE

The climate of Colfax County is semiarid. The lower plains receive an average annual precipitation ranging from slightly over 14 inches to about 16 inches. Westward toward the mountains there is a gradual increase in precipitation. Vermejo Park, in the higher part of the Raton Plateau, has an average annual precipitation of 16.88 inches,¹ and Elizabethtown, in the moun-

¹Hardy, Erie L., *Climate of the States; New Mexico*: U. S. Dept. Agr. Yearbook (separate no. 1849. p. 1011. 1941.

tains, has an average of 17.37 inches. The higher parts of the mountains receive over 20 inches. The high mesa country at the north edge of the county also receives a greater precipitation than the lower plains. The record of the water station near Lake Alice in the upper valley of Chicorico Creek shows an average annual precipitation of 20.18 inches over a period of 30 years. This station is considerably below the top of the adjacent high mesas which probably receive precipitation in excess of 21 inches annually.

The heaviest precipitation comes during the warm months from local thunderstorms. These local showers occur from April to September, inclusive, and reach their maximum intensity during July and August. As a record, 11.35 inches² of rain fell at Raton in July of 1914, when essentially half the annual precipitation that year occurred in the one month. In winter the snowfall is generally light over the lowlands, but it is fairly heavy on the high mesas and quite heavy in the mountains:

Except in the mountains, the winters are relatively mild. Severe cold spells with near-zero temperatures are of short duration. Raton has an average January temperature of 30.3° and Springer, 30.0°. At Elizabethtown, in the mountains, the January average is 19.4°. In summer only a few days are quite hot, and the nights are always cool. Raton's maximum recorded temperature is 104°, but its July average is 69.1°. Elizabethtown's average July temperature is 57.6°.

Precipitation record, in inches, of Colfax County³

	Length of record	Yrs.												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Aurora	30	0.53	0.83	1.22	1.42	1.90	2.42	3.92	3.52	2.13	1.39	0.71	0.59	20.58
Black Lake	30	.45	.60	.85	.91	1.38	1.88	3.39	3.20	1.63	1.12	.50	.43	16.34
Cimarron	35	.28	.62	.97	1.44	1.85	1.74	2.66	2.40	1.58	1.32	.49	.39	15.74
Dawson	30	.31	.56	.64	1.15	1.97	1.99	2.87	2.60	1.40	1.45	.40	.37	15.71
Elizabethtown	34	.80	1.08	1.55	1.47	1.37	1.21	3.03	3.01	1.29	1.13	.72	.71	17.37
Johnson Park	13	.18	.41	.67	1.52	2.53	2.45	3.33	2.77	1.39	1.32	.33	.53	17.43
Lake Alice (near)....	30	.53	.70	1.23	1.86	2.67	2.24	2.97	3.16	1.90	1.54	.68	.70	20.18
Maxwell	26	.17	.33	.68	1.20	1.75	1.82	2.74	2.78	1.46	.94	.40	.31	14.58
Miami	31	.25	.56	.86	1.05	2.10	2.12	2.65	2.52	1.49	1.44	.55	.35	15.94
Raton (near)	38	.34	.54	.70	1.29	1.96	1.90	2.89	2.36	1.96	1.12	.60	.46	16.12
Springer	38	.26	.42	.54	1.01	1.82	1.80	2.77	2.46	1.61	.82	.50	.32	14.33
Taylor Springs	23	.25	.49	.80	1.04	2.08	1.74	2.79	2.76	1.43	1.33	.47	.46	15.64
Vermejo Park	21	.47	.60	.95	1.64	1.29	1.52	3.73	3.07	1.39	1.14	.52	.56	16.88

² Martin, R. J., Climatic summary of the United States: U. S. Dept. Agr., Weather Bur., Section 28—Northeastern New Mexico, p. 16. 1933.

³ Hardy, Eric L., Climate of the States; New Mexico: U. S. Dept. Agr. Yearbook (separate no. 13491, p. 1011. 1941.

In the lowlands the last killing frost in the spring usually comes during the first week of May, and the first killing frost in the fall during the first 10 days of October. This gives an average growing season of about 150 days. However, in 1908 the last killing frost was as late as June 6 at Springer, and the growing season was only 105 days.

AGRICULTURE, NATURAL RESOURCES, AND INDUSTRY

According to the 1940 census there are 659 ranches and farms in Colfax County, and ranching and farming rank highest in the county's economy. Of the approximate 2,400,000 acres of land in the county, over 1,800,000 acres, or roughly 75 percent of the county, is in ranches and farms. The greater part of the land is in ranches, some of which approach or exceed 100,000 acres in area. In 1946 there were about 65,000 head of beef cattle, 3,500 head of dairy cattle, and 35,000 head of sheep in the county. Farming is of lesser importance than ranching, but between 40,000 and 50,000 acres of land in the county is farmed with the aid of irrigation, and a similar area is developed by dry-farming methods. The irrigated land is in a south trending belt through the central part of the county. It is adjacent to the Canadian River and its main tributaries, which furnish the necessary water. Most of the dry farming is done in the southeastern part of the county.

Coal mining is carried on in four localities extending from the Brilliant No. 2 camp (the old town of Swastika) , in the north-central part of the county, southwestward through Van Houten and Koehler to Dawson, in the central part of the county. The aggregate amount of coal produced annually is about 1000,- 000 tcns, as of 1946. Movable coal beds occur in both the Vermejo and Raton formations, but at present coal is being mined only from the Vermejo. Beds in the Raton formation have been utilized in the past and doubtless will be in the future. The Phelps-Dodge Co. operates at Dawson, and the St. Louis & Rocky Mountain Co. operates the other three camps. The coal reserves, most of which are controlled by the St. Louis & Rocky Mountain Co., appear to be large. Up to the present time only the most accessible areas have been worked.

Colfax County is crossed from north to south by the main line of the Atchison, Topeka, & Santa Fe Railway from Chicago to Los Angeles, on which Raton is a division point. Branch spurs from this trunk line serve the coal camps operated by the St. Louis & Rocky Mountain Co. The Southern Pacific Railway has a branch freight line for transporting coal from Dawson to its main line at Tucumcari. Several hard-surfaced Federal and State highways make the county accessible from all directions by automobile.

POPULATION

According to the 1940 census the county has a population of 18,718, over half of which is concentrated in the towns and unincorporated communities. The population density of 4.9 inhabitants per square mile is almost the same as that for the State as a whole, which is 4.4 inhabitants per square mile. Raton, the county seat, had a population of 7,607 in 1940. This figure increased, possibly as much as 1,000, between 1940, and 1946 making it the largest of the municipalities by far. Other towns listed by the Census Bureau are: Springer, 1,314; Cimarron, 744; and Maxwell, 483. The unincorporated town of Farley and the four mining camps are not listed.

GEOLOGY

By

R. L. GRIGGS, S. A. NORTHROP, AND G. H. WOOD

The rocks of the earth's crust take in water from the atmosphere, transmit it at various rates, and finally discharge it to streams, to the atmosphere, to spring areas, or to the sea. Meinzer⁴ says, "From the time the precipitated water reaches the solid earth as rain or snow until it is returned to the atmosphere or the sea, its movements and composition are determined primarily by the geology of the terrain on or in which it occurs." In brief, the character of the geologic strata and the geologic structure determine the availability of ground water in any locality. For this reason any study of ground water must begin with a study of the pertinent geology.

PREVIOUS INVESTIGATIONS

A study of the ground-water resources of Colfax County has not been made previously, though Lees discussed ground water briefly in the Raton-Brilliant-Koehler folio, where he described the presence of the springs around the high mesas near Raton and remarked about the sulfate water from the Pierre shale. In this work of Lee's, as well as in his earlier work with Knowlton⁷ the object of concern was the coal and associated formations of the coal-producing area of the county. Prior to these investigations many geologists, though mainly those attached to the early armies of exploration and geologic and geographic surveys of the West, gave descriptions and interpretations of the geology of the region. Lee and Knowlton' give an excellent bibliography, dat-

⁴ Meinzer, O. E., Hydrology in relation to economic geology: Econ. Geology, vol. 61, no. 1, p. 3, Jan-Feb. 1946.

⁵ Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 17, 1922.

⁶ Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, 1917.

⁷ Idem., pp. 17-37.

ing from 1821, of this early work which is now of interest mainly from a historical point of view. Since the publication of Lee's Raton folio, a few papers have appeared dealing directly or indirectly with the basic geology of the county. References to most of these papers are made in footnotes in this report.

STRATIGRAPHY

The age, character, and relationships of the rock units present in an area are referred to as the stratigraphy of the area. Age, though not of fundamental importance to ground water, is used technically as a common and convenient means of classification, and the stratigraphic units of Colfax County will be described from oldest to youngest in the same way as one might start at the bottom and work up in describing the formation of a layer cake. It must be kept in mind, however, that, although most of the rocks were formed in horizontal positions, later mountain-making movements have disturbed these original positions so that the oldest and originally lowest rocks now stand at high elevations locally, and some of the younger rocks are now at comparatively low elevations in the Raton structural basin.

PRE-TRIASSIC ROCKS

The oldest rocks exposed in the plains of the county are of Triassic age (pl. 1) , but in the mountains in the western part of the county older rocks crop out. The oldest of these rocks are of pre-Cambrian age, and they are exposed in the core of the Cimarron Range and at several places along the western boundary of the county. Eastward from the mountains the surface of the pre-Cambrian rocks drops off rapidly and is overlain by younger rocks. The pre-Cambrian surface probably is below sea level as it crosses the lower parts of the axis of the Raton basin. East of the axis it rises, though still remaining at considerable depth, to a buried ridge underlying the crest of the Sierra Grande (Las Animas) arch (pl. 2). It then drops off in an easterly direction again. These pre-Cambrian rocks consist of granite, gneiss, schist, and quartzite. They are of no hydrologic significance in the plains area of Colfax County as they are present at too great a depth.

Resting uncomfortably upon the pre-Cambrian at several places in the mountains is the Magdalena group of Pennsylvanian age. The area of outcrop of these beds is small, but they constitute a very thick stratigraphic unit. Smith and Ray,⁸ in their study of the Cimarron Range, estimated that there the Magdalena group has a thickness of 3,500 to 4,000 feet. The group

⁸ Smith, J. J., and Ray, L. L.. Geology of the Cimarron Range, New Mexico: Geol. Soc. America Bull., vol. 54, p. 898, 1993.

may be thicker than this in the western part of Colfax County.⁹ The rocks of the Magdalena consist of limestone, shale, arkose, and sandstone. A part of the upper "red beds" of this group (included in the Magdalena by Darton¹⁰ and by Smith and Ray¹¹) are equivalent to the Sangre de Cristo formation¹² of Pennsylvanian and Permian age, the Chinle formation of Upper Triassic age, and the Entrada sandstone and Morrison formation, of Jurassic age.¹³ The Magdalena and Sangre de Cristo almost certainly thin east of the mountains where they are not exposed and they may be absent over the Sierra Grande arch. An oil-test well drilled in 1925 in the SW¹/₄SIAT Y4 sec. 15, T. 23 N., R. 24 E., indicates that the Permian probably rests on the pre-Cambrian at a depth of about 2,500 feet in that locality. The bottom-hole sample from this test could have come from arkose, but it appears to have been cut from fresh granite.

Paleozoic representatives normally intervening between the pre-Cambrian and the Pennsylvanian are missing in the mountains, but some such representatives may possibly be present above the pre-Cambrian in the subsurface of the eastern part of the county.

TRIASSIC SYSTEM

DOCKUM GROUP

Strata belonging to the Dockum group of Upper Triassic age are the oldest rocks exposed in the plains area of the county. These beds crop out over a very limited area in sec. 12, T. 26 N., R. 26 E., in the center of Temple Butte, a small, almost circular structure on the east flank of the Sierra Grande arch. (See pl. 1.) The rocks surrounding the dome and the steep dip of its flanks indicate that these beds are carried to considerable depth within a short horizontal distance from the outcrop of the beds within the dome.

These strata consist predominantly of sandstone and silty shale with some conspicuous beds of shale containing pebbles of limestone, siltstone, and shale. The color of the strata is in large part brownish or purplish red, but in smaller part gray and gray green. Some fresh-water clams (*Unio* sp.) were found in place in these strata and a few pieces of fossil wood were found as float.

The total thickness of the Dockum group is probably over 1,000 feet, but only the upper few hundred feet, or rocks belonging only to the Chinle formation, is exposed.

⁹ Read, C. B., oral communication.

¹⁰ Barton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, p. 19, 1928.

¹¹ Smith, I. F., and Ray, L. L., op. cit., p. 899.

¹² Northrop, S. A., et al., Geologic maps of a part of the Las Vegas basin and of the foothills of the Sangre de Cristo Mountains, San Miguel and Mora Counties. New Mexico: U. S. Geol. Survey Oil and Gas Investigations Preliminary Map 54, 1946.

¹³ Read, C. B., informal communication.

JURASSIC SYSTEM

ENTRADA SANDSTONE

The Entrada sandstone is represented by a few sporadic outcrops in both the Temple and Joyce domes (sec. 12, T. 26 N., R. 26 E., and secs. 25 and 26, T. 27 N., R. 25 E., respectively). The exposures of this unit are poor in these structures, though it no doubt is continuous in both areas. Here, as generally elsewhere, it is massive and bedding is not visible. Its color varies from white to light buff. The well-rounded sand grains of uniform size composing this formation are rather poorly cemented.

At Old Mills, just south of the county in the Canadian Canyon, excellent exposures of the Entrada occur. There is a single cliff divisible into two portions. The lower part of the cliff is composed of 75 feet of brownish-pink sandstone in a few massive beds, and shows the usual rounded to elliptical pits developed by weathering. The upper 45 feet of the cliff is light-buff sandstone, whose bedding shows up as numerous thin ledges. This total thickness of 120 feet compares favorably with an indicated thickness of 105 feet in the oil test in sec. 15, T. 23 N., R. 24 E., on the Jaritas ranch, where the Entrada was reported as soft white and pink sandstone between depths of 600 and 705 feet. Because of the poor exposures at Joyce and Temple domes the thickness there could not be measured.

In all three of these outcrop areas the relation to the underlying Dockum group is one of apparent conformity. However, Lee¹⁴ found an angular discordance between the two units in Union County, where he called what is probably Entrada the Exeter sandstone and assigned to it a maximum thickness of 75 feet.

MORRISON FORMATION

As in the case of the two preceding units, the Morrison formation has very small exposures in Colfax County. Its full thickness crops out only in the Joyce and Temple domes (see above), where the exposures are poor. The upper portion of the formation is present along three creeks in the extreme eastern part of the county, and in the Canadian Canyon west of Jaritas ranch.

The Morrison formation consists of beds of shale and subordinate interbedded sandstone. The well-known predominating olive to pea-green and maroon colors of the generally fine-grained clay shales serves as a distinguishing characteristic of the formation. There is also some pale-gray and lavender clay shale. Some of the interbedded sandstones are greenish though most of them are light gray, weathering to buff. Some pinkish sand was also noted. Some of the sandstones are fine-grained

¹⁴ Lee, W. T., Morrison shales of Southern Colorado and northern New Mexico: Jour. Geology, vol. 10, p. 40, 1902.

and quartzitic; others are coarse and poorly cemented. Usually the quartzitic beds are only a few inches thick and are interbedded in a zone of predominant shale. The coarse, commonly poorly cemented sandstone generally occurs as beds over 5 feet in thickness. Fragments of pink, red, and pale bluish-gray chalcidony were seen in the cuttings from one oil test. They came from near the middle of the Morrison. Similar fragments were also seen as float in the field but never in place in the sequence. Cuttings from a thin limestone bed about 60 feet above the base of the Morrison were found in the samples from an oil test in sec. 35, T. 27 N., R. 24 E.

The Todilto limestone member, which occurs at the base of the formation in some places in New Mexico, L⁵ may be present locally in Joyce dome (secs. 25 and 26, T. 27 N., R. 25 E.). Here one outcrop of thinly bedded gray porous limestone was found on the east side of the structure. The porous parts of the limestone contain small gypsum crystals. No evidence of the member is present in Temple dome or at Old Mills in the Canadian Canyon.

The thickness of the Morrison may vary considerably, although the relation to the underlying Entrada sandstone is apparently conformable at the exposures studied. The following section was measured at Old Mills in the Canadian Canyon, about 10 miles south of Colfax County:

Dakota sandstone.

Morrison formation:

	Feet.
Shale, green, with some thin beds of greenish quartzitic sandstone poorly exposed	85
Shale, green and variegated, with three or four beds of light-gray sandstone 5 to 10 feet thick.....	110
Sandstone, light gray_	45
Sandstone, light gray to pinkish. -----	50
Shale, variegated maroon, with subordinate sandstone, and with 3 feet of white sandstone near base -----	80
Total -----	370

Entrada sandstone.

A thickness of 370 feet of Morrison was also determined from the samples from the oil test in sec. 35, T. 27 N., R. 24 E. The sample log of this well also indicates a fairly similar sequence to that given for the Old Mills section. Sections were not measured at Joyce and Temple domes because of the poor ex-

—15 Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, p. 9, 1936.

posures. However, the thickness of the unit at these places seems less than the figures given above.

CRETACEOUS SYSTEM

DAKOTA SANDSTONE

The Dakota sandstone is well exposed through its full thickness in the Canadian Canyon south of Taylor Springs, and it is present in more gentle slopes over a wider area in the eastern part of the county. The largest outcrop area is north of Farley and east of Chico post office, where the sandstone is exposed over an area of about 60 square miles. There are less extensive exposures southwest of Laughlin Peak, and there are some exposures in the western part of the county, beyond the boundary of plate 1.

The fresh rock as seen in drill cuttings is white to light gray, but the weathered sandstone is almost everywhere buff to brown or reddish brown, and the upper part of the formation tends to weather to deeper hues than does the lower part. The weathered surface, particularly in the upper part of the formation, is very irregular and pitted owing to variations in the cementation, and quartz veinlets commonly stand out on the weathered surfaces. Most of the beds of the Dakota are several feet thick. Typical weathered exposures show thick beds with striking cross-bedding extending diagonally across the beds.

The Dakota sandstone is a fine- to medium-grained sandstone containing numerous small pebbles of quartz, and the formation is best described as composed of heavy-bedded, well cemented, quartzose sandstone. The degree of cementation varies; some beds are impervious, dense quartzite, and nearly all the formation has at least a moderate amount of cementing material, and only a few beds are uncemented and incoherent. In an oil-test well drilled recently 7 miles east of Cimarron, during one 8-hour shift the drill penetrated only 6 inches through a strongly quartzitic portion of the formation. According to the crews of this drilling rig, very soft zones, which would suggest a higher permeability, were few and thin at this locality. As to the widespread continuity of lithologically similar beds or zones, which may be highly permeable or highly impermeable, there is no concrete evidence. The exposures are not conducive to making a thorough lithologic zonal study, but it is possible that some similarly cemented zones may have a fairly widespread distribution.

The thickness of the Dakota is fairly constant. Below the top of the sandstone escarpment at Old Mills, south of the county, a thickness of 155 feet was measured. An additional 30 to 60 feet is poorly exposed in the low slope back of the escarpment, mak-

ing a total thickness of about 200 feet at this locality. At the headquarters of the Lazy V Bar ranch, 3 miles northwest of Springer, a hole completely penetrated the sandstone. The driller's log of this hole indicates a thickness of 220 feet. To the northeast, in sec. 5, T. 25 N., R. 24 E., the samples from an oil-test well drilled there show a thickness of 180 feet. Still farther northeast, in sec. 35, T. 27 N., R. 24 E., the samples of another oil test indicate 160 feet of Dakota. The driller's log of a test known as the old Eureka well, 10 miles southeast of Raton, indicates a thickness of 180 feet, and, although a section could not be measured accurately near the eastern border of the county, the formation is at least 175 feet thick there.

The Dakota sandstone, as the name is used in this report, includes all the sandstone, with its minor amount of included shale, between the underlying green shales of the Morrison formation and the overlying Graneros shale. No readily mappable boundary exists within this sandstone unit. However, there is the probability that although no Lower Cretaceous fossils were found, an indefinite portion of the lower part of these beds, identical in character, or essentially so, with the upper part, is of Lower Cretaceous age and correlative with the Purgatoire formation of southeastern Colorado. T. W. Stanton¹⁶ first pointed to the presence of marine Lower Cretaceous in southeastern Colorado and the extreme eastern part of New Mexico. He described, beneath the Dakota on the Purgatoire River in Colorado, on the Dry Cimarron River in Union County and near Tucumcari, New Mexico, beds which carried a Lower Cretaceous marine fauna. These beds were noted first on the Purgatoire River about 20 miles south of La Junta, and also on the Purgatoire in the vicinity of Chaquaqua Creek. At these places, according to Stanton, the Dakota comprises "not far from 100 feet" of the section. Below this he described about 50 feet of dark shale with thinly bedded sandstone, immediately below which was about 15 to 60 feet of sandstone lithologically similar to the Dakota. The shale zone yielded the Lower Cretaceous fossils. In the same paper he described similar sequences near Tucumcari, New Mexico, and on the Dry Cimarron in western Oklahoma and in Union County, New Mexico. Later Stose¹⁷ applied the name Purgatoire formation to these beds beneath the Dakota in the Apishapa quadrangle of Colorado. Stose implies that there the Dakota sandstone and the sandstone' of the lower part of the Purgatoire (beneath the zone of shale originally described by Stanton) are essentially alike, but says that the sandstone of the Purgatoire is lighter-colored and more porous. The observation on the greater porosity led him to believe that the Purgatoire

¹⁶ Stanton, T. W., The Morrison formation and its relations with the Comanche Series and the Dakota formation: Jour. Geology, vol. 13, pp. 661-665, 1905.

¹⁷ Stose, G. W., U. S. Geol. Survey Geol. Atlas, Apishapa folio (no. 186), 1912.

produced most of the water in that area.

The Dakota sandstone section in Colfax County is abnormally thick. The workers in southeastern Colorado cited above and Dane, Pierce, and Reeside¹⁸ have referred a maximum thickness of 100 feet to the Dakota there. A section of 200 feet in Colfax County is sufficient to cause some doubt, but a conspicuous, intervening fossil-bearing shale zone is apparently lacking. There is some characteristic soft, dark bluish-gray shale in the Dakota sandstone unit. Thin lenticular beds of this nature have been noted even in the upper 25 feet of the unit. A definite and continuous intermediate shale zone could not be demonstrated. However, this may have been due to the type of exposures. Sub-surface data may show a continuous shale zone comparable to that at the top of the Purgatoire in the localities previously discussed. According to the samples examined from two -oil tests, although there are two well-defined shale breaks in one and three in the other, there is a comparable zone in each whose base is about 70 feet above the base of the Dakota. This may represent the shale of the Purgatoire formation. If this should be the case, the sand below this would, of course, also be Purgatoire. Partial logs of these well samples are given below.

Log of Dakota sandstone portion of oil-test well in sec. 35, T. 27 N., R. 24E.

Graneros shale.

Dakota sandstone:

	Depth (feet)
Sandstone, light gray, fine- to medium-grained	_ 460 to 490
Shale, dark gray	490 to 500
Sandstone, as above, possibly containing some thin shale partings	500 to 540
Shale, as above	_____ 540 to 550
Sandstone, as above	_ 550 to 620

Morrison formation.

Log of Dakota sandstone portion of oil-test well in sec. 5, T. 25 N., R. 24E.

Graneros shale.

Dakota sandstone:

Sandstone, light gray, fine- to medium-grained	420 to 455
Shale, dark gray	455 to 465
Sandstone, as above	465 to 475
Shale, as above	475 to 480
Sandstone, as above, possibly containing some thin shale partings	480 to 520
Shale, as above	520 to 530
Sandstone, as above.....	_____ 530 to 600

Morrison formation.

¹⁸Dane, C. H., Pierce, W. G. and Reeside, J. B., Jr., The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado: U. S. Geol. Survey Prof. Paper 186-K, 1937.

GRANEROS SHALE

The Graneros shale, named by Gilbert¹⁹ from a creek in the Walsenburg, Colorado, quadrangle, lies conformably upon the Dakota. It crops out in the southern part of the county and in several places around and within the sill-complex area (see p. 28 and pl. 1) north of Chico post office. Good exposures are normally lacking, and no exposures are known in the eastern tier of townships. The soft, easily eroded rock does not form good outcrops. The only good outcrops are of the upper part of the shale in the vicinity of Taylor Springs, where this part of the formation has been preserved in low cliffs by the overlying Greenhorn limestone. The lower part of the shale is known from drill records.

The formation consists predominantly of dark-gray to black fissile shale. A thin limestone bed has been reported by drillers in the lower part of the shale. Another thin dark brownish-gray fine-grained limestone bed 5 inches thick is present about 50 feet below the top of the shale along the railroad track south of Taylor Springs. Two other limestone beds, one 2 inches thick and the other 7 inches thick, are separated by 2 feet of shale in the upper part of the unit at the same exposures. These thin limestones are about 30 feet below the top of the formation. At these exposures the formation has many thin silty to fine sandy laminae containing numerous foraminifera. These laminae are lenticular and range up to one-half inch in thickness. Dane, Pierce, and Reeside²⁰ have reported thin beds of bentonite in the lower part of the Graneros in eastern Colorado. Similar beds as much as 2 inches thick are abundant and well exposed in the upper part of the shale immediately north of Taylor Springs. These beds are white where fresh, but their weathered surface is a rusty yellow or brown and is studied with gypsum crystals.

The thinnest known section of the Graneros is reported from the oil test in sec. 35, T. 27 N., R. 24 E. Here it is 135 feet thick. It appears to thicken to the south. Along the southern edge of the county water-well logs indicate it to be approximately 170 feet thick. The average thickness is approximately 160 feet.

GREENHORN LIMESTONE

The Greenhorn limestone, which conformably overlies the Graneros shale, was named by Gilbert²¹ from Greenhorn station and Greenhorn Creek near Pueblo, Colorado. Exposures in Colfax County are not well developed, but they are numerous. The best outcrops are in the southern part of the county.

The formation consists of thin limestone beds separated by

¹⁹ Gilbert, G. K., The underground water of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey 17th Ann. Rept., pt. 2, p. 564, 1896.

²⁰ Dane, C. H., Pierce, W. G., and Reeside, J. B., Jr., op. cit., p. 209.

²¹ Gilbert, G. K., op. cit., p. 564.

thin beds of shale. The limestone beds range in color from gray to black, but almost all of them weather to a light color. Essentially all of them are quite argillaceous and all are finely crystalline or sublithographic. In contrast to the limestone beds of the the Fort Hays limestone member of the Niobrara formation, the Greenhorn limestone beds, with one exception, are all less than 1 foot thick. The basal bed of the formation is slightly more than 1 foot in thickness. Almost all the other beds range between 3 and 6 inches in thickness. On weathering, the outer surface of the limestone beds bleaches to light gray, and foraminifera can almost always be seen, with the aid of a hand lens, as tiny speckles on this weathered surface. It is also common to see, weathering out of the limestone beds, small, irregularly shaped nodules of limonite altered from pyrite or marcasite. These small nodules are as much as 1 inch in diameter. The separating shale beds are dark gray to black, and of about the same thickness as the limestone beds. The shale beds are calcareous. Some show faint color lamination, indicating variations in calcite content.

Following is a detailed section of the formation measured in a small tributary to the Canadian River about a quarter of a mile northwest of Taylor Springs (see pl. 4,A) :

Greenhorn limestone:

	ft.	in.
Limestone, dark gray, fine-grained, argillaceous (abundant <i>Inoceramus</i> sp.)		3 to 4
Shale, dark gray, calcareous	5	0
Limestone, dark gray, fine-grained, argillaceous (abundant <i>Inoceramus</i> sp.)_		7
Shale, dark gray, calcareous -----		8
Shale, dark gray, fine-grained, highly calcareous.		5
Shale, dark gray, fine-grained, calcareous		3
-----		7
Shale, dark gray, fine-grained, highly calcareous		11
Shale, dark gray, fine-grained, calcareous _____		4/2
Shale, dark gray, fine-grained, highly calcareous _____		6
Shale, dark gray, fine-grained, calcareous		3
Shale, dark gray, fine-grained, calcareous _____		5%
Limestone, dark gray, fine-grained, argillaceous.....		214
Shale, dark gray, fine-grained, calcareous.....		534
Limestone, dark gray, fine-grained, argillaceous. _____		7
Shale, dark gray, fine-grained, calcareous _____		4
Limestone, dark gray, fine-grained, argillaceous _____		5 1/2
Shale, dark gray, fine-grained, calcareous-----		Y4
Limestone, dark gray, fine-grained, argillaceous _____		7 1/2
Shale, dark gray, fine-grained, calcareous -----		3
Limestone, dark gray, fine-grained, argillaceous _____		6
Shale, dark gray, fine-grained, calcareous _____		5
Bentonite (?), weathers rusty		2
Limestone, gray, fine-grained (abundant <i>Inoceramus</i> sp.)_		4
Shale, black, very thinly bedded		9
Shale to limestone (variable), black to dark gray.....		7



A. The Greenhorn limestone a quarter of a mile northwest of Taylor Springs.



B. The fossiliferous zone in the upper part of the Carlile shale.

CRETACEOUS SYSTEM

27

	ft.	in.
Limestone, dark dove gray, fine-grained _____		5 1/2
Shale, dark gray, thinly bedded, calcareous (abundant <i>Globigerina</i>)		7
Limestone, dark gray, fine-grained, argillaceous, irregular at both top and bottom, contains abundant nodules of limonite -----	3 1/2 to 5	
Shale, dark gray, thinly bedded, calcareous	3 to 4	
Limestone, dark gray, fine-grained, upper part varied	4 1/2	
Shale, dark gray, fine-grained, calcareous, laminated -----	3	
Limestone, black to dark gray, fine-grained, argillaceous. _		5 1/4
Shale, dark gray, fine-grained, calcareous, laminated	3%	
Limestone, black to dark gray, fine-grained, argillaceous ____		7
Limestone to shale (variable), dark gray, fine-grained, thinly bedded -----		7
Limestone, dove gray, fine-grained		5
Shale to limestone (variable), dark <i>gray</i> _____		11
Limestone, dark gray, fine-grained, argillaceous _____		5
Limestone to shale (variable), dark gray		2
Limestone, black, fine-grained, argillaceous -----		6
Shale, dark gray, thinly bedded, highly calcareous. ----		7
Limestone, dove gray, fine-grained		10 1/2
Limestone, black, fine-grained, argillaceous, shaly at top and bottom -----		4 1/2
Limestone, dark gray, fine-grained, argillaceous _____		6 1/2
Shale, dark gray, thinly bedded, highly calcareous		2 1/2
Limestone, dark gray, fine-grained, argillaceous ____		5
Shale, dark gray, thinly bedded, calcareous		7
Limestone, dark to medium gray, laminated, small limonite nodules		6
Shale, dark gray, calcareous, thinly bedded, small limonite nodules		5
Limestone, dark gray, fine-grained, argillaceous, limonite nodules		7
Shale, dark gray, calcareous, thinly bedded -----		7
Shale, dark <i>gray</i> , calcareous, thinly bedded, limonite nodules		6
Shale, black, calcareous, thinly bedded -----		3 1/2
Limestone, gray, fine-grained, argillaceous, scattered limonite nodules		8
Shale, dark gray, silty, with 1 in. limestone in middle containing pyrite crystals		51
Limestone, gray, fine-grained, argillaceous -----		3
Shale, dark gray, calcareous		1
Limestone, dark gray, fine-grained, argillaceous, concretionary, lenticular, and very irregular; absent in places -----		2
Shale, dark gray to black, fine-grained, calcareous _____		7
Concealed -----	1	
Limestone, dark gray, fine-grained, argillaceous_	1	2
Total, about -----		35 feet

Graneros shale.

The thickness of the formation is close to 35 feet everywhere in the southern part of the county. Two well logs indicate that it may thin to about 25 feet farther north.

The Carlile shale overlies the Greenhorn limestone conform-

CARLILE SHALE

ably. Its upper portion is fairly well exposed from the southern part of the county northeastward to T. 29 N., R. 27 E. In this area the upper part of the formation is commonly held in steep slopes by the overlying Fort Hays limestone member of the Niobrara formation. The lower 100 feet of the formation is not well exposed anywhere in the county, as gentle soil-covered slopes have developed on it.

Little is known of the lower half of the Carlile except that it is dark-gray shale. Samples from one well indicate it to be somewhat calcareous, and north of the Arkansas River in Colorado it contains a definite calcareous shale member (Fairport chalky shale member) 75 to 125 feet thick? Two features characteristic of the upper part of the shale are a zone of large calcareous septarian concretions and a highly fossiliferous zone of thin beds of limestone and shale. Both zones typically form small erosional benches below the overlying Fort Hays limestone member. (See p. 30.)

The concretion zone is from 20 to 30 feet thick and occurs between 50 and 80 feet below the top of the Carlile. It consists of septarian concretions ranging from 1 foot to 5 feet in diameter, though sizes from 2½ to 4 feet in diameter are most common, in a matrix of dark-gray fissile shale. The body of these concretions is gray fine-grained argillaceous limestone weathering to lighter gray or, more commonly, yellow to yellowish brown. The cracks are filled with light- to dark-gray calcite. These concretions have the approximate shape of oblate spheroids with axes varying in length, and they are locally thought to represent fossilized turtles. They occur at two or three separate horizons in this zone of shale. In one place a thin sandstone bed passes through the concretions.

The fossiliferous zone is 5 to 10 feet thick and occurs between 10 and 20 feet below the top of the Carlile. It consists of thin irregular, lenticular beds of dark brownish-gray fine- to medium-grained limestone interbedded in dark-gray shale. Most of the individual limestone beds in this zone are less than 1 inch thick. They are argillaceous or silty, weather brown, and have a strongly bituminous odor when broken. A characteristic fauna is present in this thin sequence. It consists mainly of *Ostrea* sp., *Scaphites warren*, *Prionocyclus wyomingensis*, and shark teeth, as identified by J. B. Reeside, Jr. The most abundant form is a small oyster, about the size of a quarter, with small crenulations at the outer edge of the shell.

Following is a typical section of the upper part of the Carlile, measured on the west side of the Canadian River Valley, about 1½ miles northwest of Taylor Springs (see pl. 4,B) :

—22 Dane. C. II_ Pierce, W. G., and Reeside, J. B., Jr., op. cit., p. 215.

	29
	in.
CRETACEOUS SYSTEM	
Hays limestone member of Niobrara formation. shale:	
Shale, light gray near contact, dark gray below, thin silty layers M3-1/4 inch thick	9
Limestone, dark gray, finely crystalline, silty, fossiliferous	1
Shale, dark gray, some silty laminae	2
Limestone and shale interbedded; limestone dark gray, finely crystalline, silty, highly fossiliferous, weathers brown; shale, dark gray; most beds less than 1 inch thick	6
Shale, dark gray to black, very fissile, poorly exposed.	20
Limestone, gray, concretionary	5
Shale, dark gray, very fissile.	5
Limestone, brownish gray, finely crystalline, highly fossiliferous	2
Shale, dark gray, fissile	9
Sandstone, silty, calcareous, weathers greenish gray	4
Shale, dark gray, fissile	
Shale, dark gray, fissile, containing large septarian concretions; top concretion horizon shows 5 inches of brown sandstone	10
Shale, black, fissile	
<hr/>	
Total -----	_120+feet
Base of exposure.	

Over much of western Kansas and eastern Colorado the Codell sandstone member of the Carlile shale is present at the top of the formation. It is the source of non flowing artesian water in a large area north of the Arkansas River in Colorado. In their work in that area Dane, Pierce, and Reeside²³ demonstrated the absence of the Codell "in the La Junta region and perhaps somewhat farther west." Farther east it extends down to or nearly to the septarian-concretion zone. They believed that in the La Junta region the Codell had been replaced in part by a fossiliferous limestone faces at the top of the Carlile carrying the same fauna as the Codell farther east. Their fossiliferous limestone faces is probably identical with the fossiliferous zone in the upper part of the Carlile in Colfax County. Their limestone faces is the highest part of the Carlile, but in Colfax County it is overlain by a few feet of shale which also is assigned to the Carlile.

In Colfax County, sandstone is lacking except for the 4-inch bed 45 feet below, and the 5-inch bed 55 feet below, the top of the formation (see detailed measured section), but the upper part of the formation is generally silty. It seems probable that the Codell sandstone member faces of eastern Colorado and western Kansas is represented in Colfax County by everything above the septarian concretion zone, that is, everything above

23 Dane, C. H., Pierce, W. G., and Reeside, J. B., Jr., op. cit., p. 217.

and including the lowest thin sandstone bed.

A section of the Carlile was measured northeast of Taylor Springs. The thickness there was determined as about 210 feet. Well samples from sec. 35, T. 27 N., R. 24 E., indicate a thickness of 220 feet, and drillers' logs in the southern part of the county indicate a thickness of 215 feet. In the northern part of the county it appears to be slightly thinner.

NIOBRARA FORMATION

The Niobrara formation lies conformably on the Carlile shale and is about 950 feet thick. In the present work in Colfax County this thick sequence of beds has been divided into two members, as follows: (1) A basal 15 to 20 feet of limestone with interbedded shale, and (2) an overlying member of predominately shaly composition more than 900 feet thick. These two members are probably equivalent to the two members of the Niobrara as subdivided by Dane, Pierce, and Reeside²⁴ in their recent work north of the Arkansas River in Colorado: The basal limestone with interbedded shale is identified as their Fort Hays limestone member, and the overlying thick shale sequence is identified as their Smoky Hill marl member. As to previous subdivisions²⁵ of the Niobrara in Colfax County, the Fort Hays limestone member is believed to be equivalent to part of the Timpas limestone of previous usage, and the Smoky Hill marl member is approximately equivalent to the Apishapa shale. The Timpas limestone or Timpas formation, as originally defined by Gilbert²⁶ in Colorado, consisted of a basal limestone member and overlying limy shale beds with occasional thin limestone beds. Such a unit is unsatisfactory in Colfax County, as the upper part of the unit is indefinite, but it seems probable that the Fort Hays limestone member is equivalent to Gilbert's basal limestone of his Timpas formation, and that his limy shale beds with occasional thin limestone beds are herein included in the Smoky Hill marl member.

Fort Hays limestone member.—The Fort Hays limestone member immediately overlies the Carlile shale. It is from 15 to 20 feet thick, and consists of seven or eight limestone beds that are separated from each other by beds of calcareous shale. Nearly all the limestone beds are more than a foot thick (in contrast to the thin limestone beds of the Greenhorn limestone), and the fresh rock is light gray or rarely dark gray, finely crystalline, sub lithographic limestone. These beds weather to a creamy

—²⁴ Dane, C. H., Pierce, % V. G., and Reeside, J. B., Jr., op. cit., pp. 220-224.

²⁵ Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 6, 1922.

²⁶ Dorton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, pp. 40-41, 1928.

²⁶ Gilbert, G. K., The underground water on the Arkansas Valley in eastern Colorado: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 566-567, 1896.



A. Fort Hays limestone member of Niobrara formation along the creek south of the rodeo grounds at Springer.



B. Palo Blanco Mountain, an eroded volcano composed of latitic tuff.

color, and there is a tendency for a caliche-like film to form on the weathered surface. They contain infrequent small nodules of limonitic composition similar to those in the Greenhorn limestone. The limestone of the Fort Hays tends to break up into flattish, conchoidally fractured chips whose long dimensions are parallel to the bedding. The Greenhorn limestone, lower in the stratigraphic sequence, tends to break up into flat plates whose longest and shortest dimensions are parallel to the bedding, resulting from a strong tendency to fracture perpendicularly to the bedding. The shale interbedded in the Fort Hays is dark gray and calcareous. The individual shale beds range from those scarcely discernible to 2 feet in thickness.

Below is a detailed section of the Fort Hays limestone member measured along the bank of the small creek immediately south of the rodeo grounds at Springer (see pl. 5,A).

Niobrara formation; Smoky Hill marl member.

	ft.	in.
Fort Hays limestone member:		
Limestone, light gray, fine-grained		31/2
Shale, dark gray, calcareous.		
1		
Limestone, as above	1	1
Shale, as above.		10
Limestone, as above		5
Shale, as above	1	10
Limestone, as above.		4
Shale, as above		8
Limestone, as above		7
Shale, as above.		5
Limestone, as above, and massive	2	4
Shale, as above		6
Limestone, light gray, fine-grained	1	4
<hr/>		
Total		71/2
15		
Carlile shale.		

The Fort Hays is fairly resistant to erosion and is generally well exposed. In many cases, because of its greater resistance to weathering and erosion than either the underlying or overlying shale, it forms an escarpment or cliff. Cliffs capped by the Fort Hays are particularly prominent northeast of Taylor Springs, and exposures are almost continuous along the main outcrop band across southern and eastern Colfax County. They enter the county just east of Colmor and continue with slight interruptions to the northwest part of the sill-complex area (see p. 40), northeast of which the exposures are poor. There is also a small area of exposure south of Cimarron, near the east flank of the Cimarron Mountains.

Smoky Hill marl member.—The shaly material overlying the Fort Hays limestone member is not a true marl throughout its

vertical range in Colfax County, and this member is herein referred to informally as shale of the Niobrara formation, but the name Smoky Hill marl member is used formally in order not to introduce a new member name at the present time.

The soft shales of this member are poorly exposed throughout the county, and for this reason its character is not known in detail. Perhaps with better exposures it could be divided into three units, but with only the existing occasional exposures on gentle soil-covered slopes this is not possible. However, the lower part of the member is highly calcareous, shale containing some thin beds of very shaly limestone. Along the railroad track immediately south of Springer are four beds of shaly limestone, each about 1 foot thick, in the lower 25 feet of shale. These shaly limestone beds are gray but weather to a light-gray color. The shales in the lower part of the unit vary considerably in their calcareous content and, on weathering, assume various shades of gray to light gray. When fresh they are gray or dark gray. The calcareous content of the lower part of the unit appears to decrease upward from the base, but it is noticeable for 150 or 200 feet upward. It is probable that this zone of high lime content is equivalent to the upper part of the Timpas formation of Gilbert?'

About 250 feet above the base of the member a noticeably sandy zone appears in at least some localities. It is gray calcareous, highly arenaceous shale, apparently about 100 feet thick. This sandy zone weathers to a yellowish color. Above it is about 600 feet of shale that is exposed only occasionally, and individual exposures are of small stratigraphic extent, but this zone appears to be of rather uniform lithology. It is gray calcareous, slightly sandy shale commonly weathering into a yellowish rubble of small slabs about 1 inch in thickness. In one locality what is believed to represent the uppermost part of the Niobrara was noted to be nonsandy dark-gray calcareous shale with tiny white specks which presumably are high concentrations of carbonate.

The conformable boundary between the Smoky Hill marl member and the overlying Pierre shale is not readily recognizable, and this boundary is generally covered by pediment gravel, loess-like deposits, or soil. For these reasons the two stratigraphic units are included together as one map unit on the accompanying geologic map. The approximate position of the boundary between the two stratigraphic units can be pointed out, however. Near the south edge of the county, at the southeast corner of Gonzalitos Mesa, it is between the base and upper slopes of the mesa. It continues northeastward from there, passes west of French, and is close to the town site at Maxwell. Farther northeast it is near the old Eureka oil-test well in sec. 10, T. 29

27 Gilbert. G. K.. op. cit., p. 566.

N., R. 24 E. Still farther northeast it is a short distance south of Meloche Mesa, and from there it continues eastward sinuously, then finally, at the north edge of the county, it is probably in T. 32 N., R. 26 E.

The approximate thickness of the Smoky Hill marl member is known from the oil test mentioned above. This oil test starts close to the top of the member, and here the depth to the top of the Dakota sandstone is 1,365 feet. As the interval between the top of the Fort Hays limestone member and the top of the Dakota sandstone is 435 feet, a thickness of over 900 feet is assigned to the Smoky Hill marl member.

PIERRE SHALE

The Pierre shale, conformably overlying the Smoky Hill marl member of the Niobrara formation, is poorly exposed in Colfax County. Over most of its extent it is covered by pediment gravel, loess-like deposits, or soil, but from the few exposures and well records it is known to consist predominantly of noncalcareous black fissile shale. This shale contains, at several horizons, argillaceous limestone concretions that usually weather to a yellowish gray. One zone of these concretions is conspicuous along U.S. Highway 64 immediately southwest of the eastern junction of the Maxwell-Dawson road. These concretions are noticeable because of their weathering to a rusty-orange color. There is also a sandy zone about 50 feet thick at the top of the Pierre, just below the Trinidad sandstone. The black fissile, slightly silky-lustered shale constitutes over 90 percent of the formation. This compact shale weathers with difficulty to yellowish-brown material, in which indications of the original thin bedding remain for a long period. The little available ground water found in the Pierre occurs in such weathered debris.

A thickness of about 1,650 feet is assigned to the Pierre shale. This thickness has been determined as follows: Four and a half miles southeast of Meloche Mesa what is believed to be the highest strata of Niobrara age are at an elevation of 6,650 feet, and nearby exposures of the Trinidad sandstone are at an elevation of 7,900 feet. In the distance between the two points the Pierre shale dips about 400 feet. With this correction, the Pierre is indicated to be 1,650 feet thick. A similar thickness is corroborated by a recently drilled oil-test well (7 miles east of Cimarron), which began about 750 feet below the Trinidad sandstone and encountered the Dakota sandstone at a depth of 2,225 feet. As the post-Dakota—pre-Pierre stratigraphic interval is known to be over 1,300 feet thick, a thickness of over 1,600 feet for the Pierre shale is confirmed by this oil test.

TRINIDAD SANDSTONE

The Trinidad sandstone conformably overlies and interfingers

with the Pierre shale. It crops out in the steep slopes of Bartlett, Barilla, and Johnson Mesas, and in the escarpment of Raton Mesa from Raton to Ute Park, about 12 miles west of Cimarron, in which it is conspicuous as a light-colored zone. A few miles east of Raton the formation pinches out beneath the lava cap of Johnson Mesa. It originally extended to the east of this locality but was removed by pre lava erosion.

The formation is approximately 100 feet thick at most places in Colfax County. It is a massive to thin-bedded, light gray to light buff, somewhat feldspathic sandstone. At least some of the thin-bedded portions are micaceous. The formation is shown on the accompanying geologic map in the area north and east of Raton, but between Raton and Cimarron the base of the formation is the western boundary of the map.

VERMEJO FORMATION

The Vermejo formation conformably overlies and interfingers with the Trinidad sandstone. It consists of sandstone, shale, and coal beds, and it is the formation from which all the coal is now mined in Colfax County.

The formation has been extensively described by Lee and Knowlton,²⁸ and the reader is referred to their comprehensive work for any further desired treatment. The formation is shown on the accompanying geologic map through the short distance between Railroad and Linwood Canyons, immediately north of Raton. East on Linwood Canyon the Vermejo was removed by late Cretaceous erosion.

TERTIARY SYSTEM

PALEOCENE SERIES

Raton formation.—The Raton formation rests unconformably on the Vermejo formation over the latter's extent, and where the Vermejo is absent, east of the town of Raton, the Raton formation rests unconformably on the Trinidad sandstone. With minor exceptions the formation lies at the surface throughout the Raton Plateau. It is also present beneath the lava caps of Bartlett, Fishers Peak, and Barilla Mesas, but under the cap of Johnson Mesa it was largely removed by prelava erosion. Northwest of Raton the formation is about 2,000 feet thick, but, owing to the prelava erosion and the westerly dip of the beds, only about 1,000 feet of the formation is present immediately north of Raton, and it is absent about 5 miles east of the west end of Johnson Mesa.

The rocks composing the Raton formation are coal, carbonaceous shale, sandy shale, arkosic sandstone, and, particularly at the base, conglomerate. The bulk of the formation is sandy shale

²⁸ Lee, W. T., and Knowlton, F. H., op. cit.

and sandstone of yellowish-tan color. Most of the sandstone is poorly cemented. The composing grains range in size from fine to moderately coarse.

PLIOCENE SERIES

Ogallala formation.—*The Ogallala formation of Pliocene and possibly late Miocene age covers nearly five townships in the southeastern corner of the county, where an outlier of the formation has been preserved. (See pl. 1.) The bulk of the formation in Colfax County is sand, silt, and clay but the formation also includes, principally at the base, gravel and boulders as much as 2 feet in diameter. The deposit is a heterogeneous lenticular mass with rapid lateral changes. The sand, dominantly quartz, contains also a slight to moderate amount of pinkish feldspar, which together with yellow clay give the formation a pink to yellow color. The boulders that are apparently abundant at the base of the deposit are largely of porphyritic monzonite, quartz monzonite, and other granitic rocks.*

The Ogallala formation lies with slight angular discordance on an erosion surface of low relief which slopes to the southeast at a rate of about 50 feet per mile. The formation is beveled by the High Plains surface, which is continuously developed beginning at a point some 40 miles farther east. The formation thickens to the southeast from about 130 feet south of Chico to about 250 feet at the southeastern corner of the county.

In the northern part of the county Lee²⁹ first noted apparently continuous sand and gravel ranging from 10 to 70 feet in thickness lying beneath the basalt on Johnson and Barilla Mesas. He also described small patches of similar material overlying the basalt at two localities on Johnson Mesa. The age of this sand and gravel presents a problem. Lee believed that all the gravelly deposits should be assigned to the Quaternary. He disagreed with a previous interpretation of Darton³⁰ that the gravel beneath the lava of Mesa de Maya in southeastern Colorado was equivalent to the Ogallala (the lava of Mesa de Maya is of the same age as the lava of Johnson and Barilla Mesas). Lee believed the eroded surface beneath the high mesa gravels to be equivalent to the early Quaternary High Plains surface. However, the present work indicates that Darton's early interpretation was correct. The sand and gravel of the high mesas is identical in appearance with the unquestionable Ogallala of southeastern Colfax County and projects into it. The projection has been determined as follows: The erosion surface underlying the gravels of the high mesas slopes southeast at a rate of 50

²⁹ Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 8, 1922.

³⁰ Darton, N. I., Preliminary report on the geology and underground water of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 178-179, 1905.

feet per mile, as shown by relative elevations on the high mesas and on the mesa at Cunico, an erosional outlier of the high mesa. This slope is identical with that of the erosion surface underlying the Ogallala, and at this slope the two erosion surfaces project into each other (fig. 2).

QUATERNARY SYSTEM

LANDSLIDES

Considerable portions of the area mapped are covered by landslide and talus debris. Slopes beneath most of the mesas covered by lava flows are partially or wholly obscured by landslides.

The frequency and occurrence of the landslides depends upon the erodibility and plasticity of the underlying rocks. They occur most commonly where Cretaceous shale is overlain by lava flows; less commonly where limestone or siltstone underlies an area; and rarely in areas underlain by igneous rocks or the Dakota sandstone.

On the flanks of Barilla and Bartlett Mesas landslides were not mapped. Springs issuing from crevices at the base of these lavas and from the Raton formation necessitated mapping these stratigraphic units instead of the landslides.

QUATERNARY ALLUVIUM

Quaternary alluvium occurs as narrow bands along present-day streams, and as flat-lying, tabular deposits. The tabular deposits consist mainly of gravel veneers on pediments, but south of the King ranch there is some sheet like alluvium that appears to have been deposited in a poorly drained area.

The stream-channel alluvium is best developed along the Canadian River and its main tributaries. It is less well developed along the smaller streams, although a surprising amount of it is found along some of the small creeks. This material consists of silt, sand, and gravel that has been deposited by the streams, and it seldom extends for an appreciable distance away from the stream channels.

Quaternary pediment remnants are most conspicuous near the Canadian River drainage. They occur as mesas, tableland, and flat-topped spurs extending out from higher topography. The pediments are remnants of surfaces formed in past erosion cycles, and because subsequent erosion has taken place they stand above the lower plains. The highest and oldest Quaternary pediment is the surface beneath the lava of Bartlett Mesa. It is about 600 feet above the adjacent streams. The lowest remnants are about 50 feet above the adjacent streams. The streams that cut these flat surfaces generally deposited a veneer of gravel on top

of the surfaces and in many places lava later covered the gravel. This pediment gravel has a maximum thickness of about 20 feet, but in most places it is thinner, and in places on Bartlett Mesa it is completely absent. The pediment deposits range in size from clay to small boulders, although much of the material is sand and gravel.

In the eastern part of the county, south of the King ranch and north of Palo Blanco Mountain, sheet like alluvium is associated with small lakes and larger, undrained depressions. The exact extent of this alluvium cannot be determined because of poor exposures and a soil cover. It has been reported to be as much as 100 feet thick in one well, but its average thickness is doubtless much less. Over much of its extent it probably is not more than a few feet thick. The material ranges from yellowish silty clay to fine gravel, and the color and the gravel suggest that it was derived from the Ogallala formation. It is believed that this material was washed into a poorly drained area by streams, and as part of the area is now ponded, it is probable that some of it is of lacustrine origin.

LOESS-LIKE DEPOSITS

Wind-blown silt and clay occur in places on the lower plains west of the Canadian River. This loess-like material is grayish to yellowish, and locally it shows on a small scale some vertical jointing like that of the typical Mississippi Valley loess. It is not so well sorted as true loess, as there is considerable admixed clay. In a well dug on the property of Earl Swope near Cimarron a large proportion of clay was present in 20 feet of the wind-blown material, which rests on pediment gravel at this locality. The material was not tested to ascertain if the carbonate content was similar to that of true loess, but some fibrous calcite or aragonite was observed in samples taken from test holes near Maxwell. The 20-foot thickness in the well referred to above is not typical. These deposits are usually less than 15 feet thick, and in places near Maxwell they are separated from the underlying Cretaceous shale by a thin layer of clayey to silty gravel, which may have been spread over shallow depressions by "cloudburst" wash prior to the deposition by wind.

IGNEOUS ROCKS

With respect to mode of origin, the igneous rocks may be divided into two general types—intrusive and extrusive. The intrusive rocks are those which have been emplaced within the preexisting bedded sedimentary rocks. They are the dikes, sills, and volcanic feeders or plugs. The extrusive igneous rocks are the lava flows of the area. The igneous rocks of the area mapped

in Colfax County are an interesting suite because of their chemical variations. As the extrusive rocks have been more highly subdivided in the mapping, it will *be* easier to describe them first, in spite of the fact that some of the intrusive rocks are older.

EXTRUSIVE IGNEOUS ROCKS

The extrusive rocks are of interest also because they have formed protective coatings on some of the erosion surfaces that have developed on the soft rocks during late geologic time. Because of these coatings of "armor" many erosion surfaces, which allow the physiographic history of the area to be traced, have been preserved in the form of mesas. In turn, the physiographic development of an area is often important in getting a rough idea of the history of ground-water recharge and discharge.

The volcanic rocks have been roughly divided into three age groups, and one of these groups has been further subdivided on a basis of difference in composition.

Group I.—The oldest flows in the area are normal olivine basalts that belong to two separate periods of eruption. The older basalts are the flows on top of Johnson and Barilla Mesas, the highest mesas, and there are two small outliers of these flows, on Dry Mesa and on the mesa at Cunico. The younger of these basalts are the flows on slightly lower mesas such as Bartlett, Rayado, and Gonzalitos Mesas. Flows of this sequence are present also south of Farley. The exact age of the flows of Larga Mesa and Tinaja Mountain are in doubt. The rocks of both these periods of eruption are alike chemically and contain about 50 percent feldspar, 30 percent augite, 10 or 15 percent olivine, and the remainder magnetite. Mertie³¹ first pointed out, in the Raton-Brilliant-Koehler folio, that about the only difference between these rocks was in the olivine, which is conspicuous as phenocrysts. In the flows of the older period of eruption this mineral is greatly altered, whereas in the younger flows the olivine is much less altered. Mertie also pointed out that augite is slightly more abundant in the flows of the younger stage, occurring there to some extent as phenocrysts. Both of these early types range from gray to dark gray, the younger type tending to be slightly darker in color.

Where the flows of these two periods of eruption occur at different elevations in close proximity the difference in age is obvious, and in most cases the rocks can be differentiated on the basis of the alteration of the olivine phenocrysts, but in some cases a distinction is difficult or impossible to make. Because of this difficulty of separation in some places, both of these basalt sequences were mapped as a single unit.

³¹ Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214). p. 9. 1922.



A. The edge of one of the recent Capulin-type basalt flows.



B. Point of Rocks, or Peck's Mesa sill, southeast of Chico.

The age of the older basalt is tentatively regarded as late Pliocene, as the flows rest on gravel believed to be of Pliocene age. (See p. 35.) They are believed to be approximately contemporaneous with the similar basalts interbedded in the Santa Fe formation along the Rio Grande. The age of the younger sequence of basalt is regarded as early Quaternary.

Group II.—The volcanic rocks of this intermediate age group are variable in composition, and the map unit includes many rock types, some of which are abnormal in composition. Extremely alkalic rocks such as nepheline and hauynite basalts are present, and subalkalic basalts with a low percentage of plagioclase also occur. Other types are pyroxene andesites and felsic rocks near quartz latite in composition. The felsic rocks occur mainly in the eastern part of the county and were mapped separately.

The rocks of this group are present at many elevations because they were extruded over a considerable period of time and upon several erosion surfaces developed during that time. Some are on top of Johnson Mesa. Others cap high pediment remnants such as Hunter, Meloche, and Buckhorn Mesas. They extend down to lower surfaces such as the pediment beneath and northeast of Eagle Tail Mountain, and down to the lower plains in the extreme eastern part of the county, where erosion has been at a minimum. All the rocks of this group show noticeable erosion, however, and those which are lowest in relation to present drainage have been cut through by streams.

The several periods of eruption of these rocks covered much of the Quaternary period. The eruptions occurred from many small volcanos of the central-vent type. The wide variety of rocks extruded in a small area indicates that the magmatic differentiation must have occurred under unusual conditions, possibly within small pockets. As the volcanos are along the flanks of the Sierra Grande arch, it is possible that the differentiation was controlled by deep-seated adjustments of this arch.

Group III.—The youngest lava flows are normal olivine basalts which are identical with the Recent flows extruded by Capulin volcano immediately east of Colfax County. This volcano is very young, although old enough to have small trees on it, and the mass of soft cinders that compose it has not yet been scoured by erosion. The flows associated with Capulin volcano broke out around the base, and they are believed to be slightly younger than the cinder cone, as they seem identical with the crater filling. In Colfax County similar flows cover only small areas near the crest of the Sierra Grande arch. They are so young that vegetation is poorly developed on them, and small flow ridges on their upper surface are visible on aerial photographs. One of these flows follows a valley, and its lower surface rests on a terrace that is about 3 feet above the present grade of the stream.

EARLY INTRUSIVE IGNEOUS ROCKS (SILL-COMPLEX)

The oldest intrusive rocks of eastern Colfax County are fine-to medium-grained monzonitic porphyries of various colors. Most of them are light to medium gray, a few are pinkish, and one distinctive type has a green matrix containing large white feldspar phenocrysts. Most of them have conspicuous light-colored phenocrysts of feldspar and dark phenocrysts of pyroxene or amphibole. Biotite is rare. One of the most distinctive features of these rocks is the common occurrence of small cross-forming intersecting crystals, probably penetration twins, of pyroxene or amphibole.

These rocks occur as a group of sills showing some cross-cutting relations and in many places terminating abruptly. There are a few dikes of the same age. The bulk of the exposed sill-complex was intruded in the Graneros shale, although some of the sills extend up to the Fort Hays limestone member. The intrusive activity formed a northwest-trending dome which covers about 3 townships in the eastern part of the county. The lower part of this dome is shown on the structural-contour map of the top of the Dakota sandstone. It is across the top of, and at right angles to, the Sierra Grande arch. This indicates that the primary feeders for the sills were probably at right angles to the arch.

Gravel and boulders derived from the distinctive porphyries are included in the Ogallala formation, which was therefore deposited after the uncovering of the sills. They are therefore post-Cretaceous and pre-Ogallala in age. They are probably of the same age as the intrusives of western Colfax County and southeastern Colorado. The latter rocks cut Paleocene sediments and were probably intruded during the mountain building of early Tertiary time.

LATE INTRUSIVE ROCKS

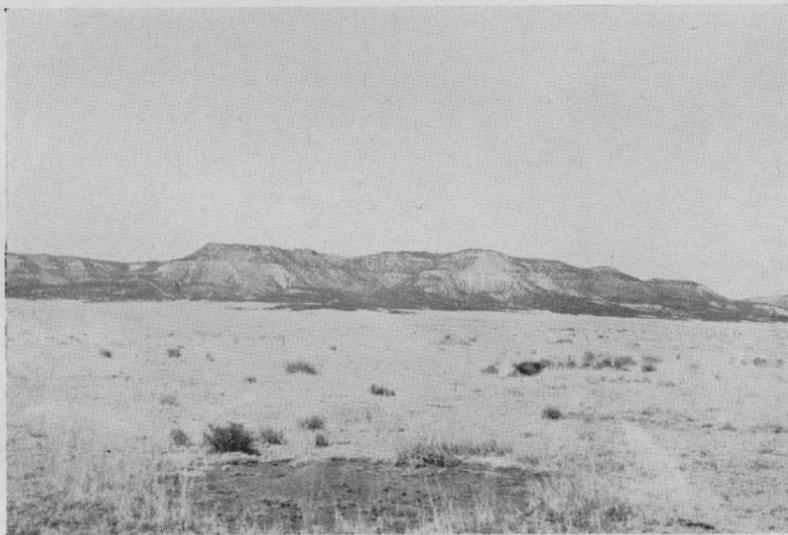
There are many basaltic dikes and plugs of late Tertiary and Quaternary age believed to be equivalent to the basaltic volcanics of the first two age groups of lava flows of the area. No attempt was made to separate these rocks as was done in the case of the corresponding lavas.

GEOLOGIC STRUCTURE

The principal structural features of Colfax County are, from west to east, the mountains, the Raton structural basin, and the Sierra Grande arch. Uplift of the area now occupied by the Sangre de Cristo and Cimarron Mountains at the western edge of the county occurred during late Cretaceous and early Tertiary



A. The southwest corner of Johnson Mesa (from a point
3 miles south of Raton).



B. The Trinidad escarpment (east edge of Raton Plateau).

time. Contemporaneous with the uplift of the mountains a basin was formed to the east, in which the Vermejo and Raton formations, as well as younger formations to the north, were deposited. The limits of this area of accumulation cannot be definitely established. In late Tertiary time the present Sangre de Cristo and Cimarron Ranges, and concomitantly the Raton structural basin, were formed. The Raton structural basin in Colfax County is a north-trending and north-plunging trough whose axis of greatest depression lies about 20 miles west of Raton. The trough is asymmetrical with its steeper limb on the western side. East of the axis the beds gently rise to the crest of the northeast-trending Sierra Grande arch. (See pl. 2.) The crest of this broad arch enters the county from the south in the neighborhood of the Jaritas ranch. From here it trends northeastward across the county, passes beneath Palo Blanco Mountain, and then leaves the county in T. 28 N., R. 27 E. East of this axis the beds dip to the southeast.

The above-described features are the major structures, and they are shown roughly by the generalized cross-sectional sketch (fig. 2). Smaller structural elements are superimposed on the dominate features. A large anticline is present at Vermejo Park in the northwestern part of the county, and the intrusion of the sill-complex has resulted in a broad, northwest-trending dome on the Sierra Grande arch. (See pls. 1 and 2.) Some small domes have developed on this latter feature. One dome is northeast of Chico post office, in the northeastern part of T. 26 N., R. 26 E.; another is north of the Joyce ranch, in the southeastern part of T. 27 N., R. 25 E.; and another is northeast of Laughlin Peak, in the north half of T. 28 N., R. 26 E. There are also numerous structural noses around the edge of the sill-complex.

Plate 2, prepared by G. H. Wood, shows the structure on top of the Dakota sandstone in the central and eastern parts of the county. The contour lines on this map pass through points of equal altitude on the upper surface of the formation. Therefore the map may be used to determine the approximate depth to the top of the Dakota sandstone in those areas where the formation does not crop out. In order to determine the approximate depth at any point, subtract the altitude of the Dakota sandstone, as indicated by the structural-contour map, from the altitude of the land surface at the same point. For instance, the altitude of the business district in Springer is approximately 5,810 feet. From the map the top of the Dakota is seen to lie between the 5,300- and 5,400-foot contour lines at this locality or at about 5,360 feet. Subtracting 5,360 from 5,810, the difference of 450 feet is the calculated depth to the top of the formation. For another example, the business district in Raton is at an elevation of about 6,665 feet. The same point on the structural-contour map is just below the

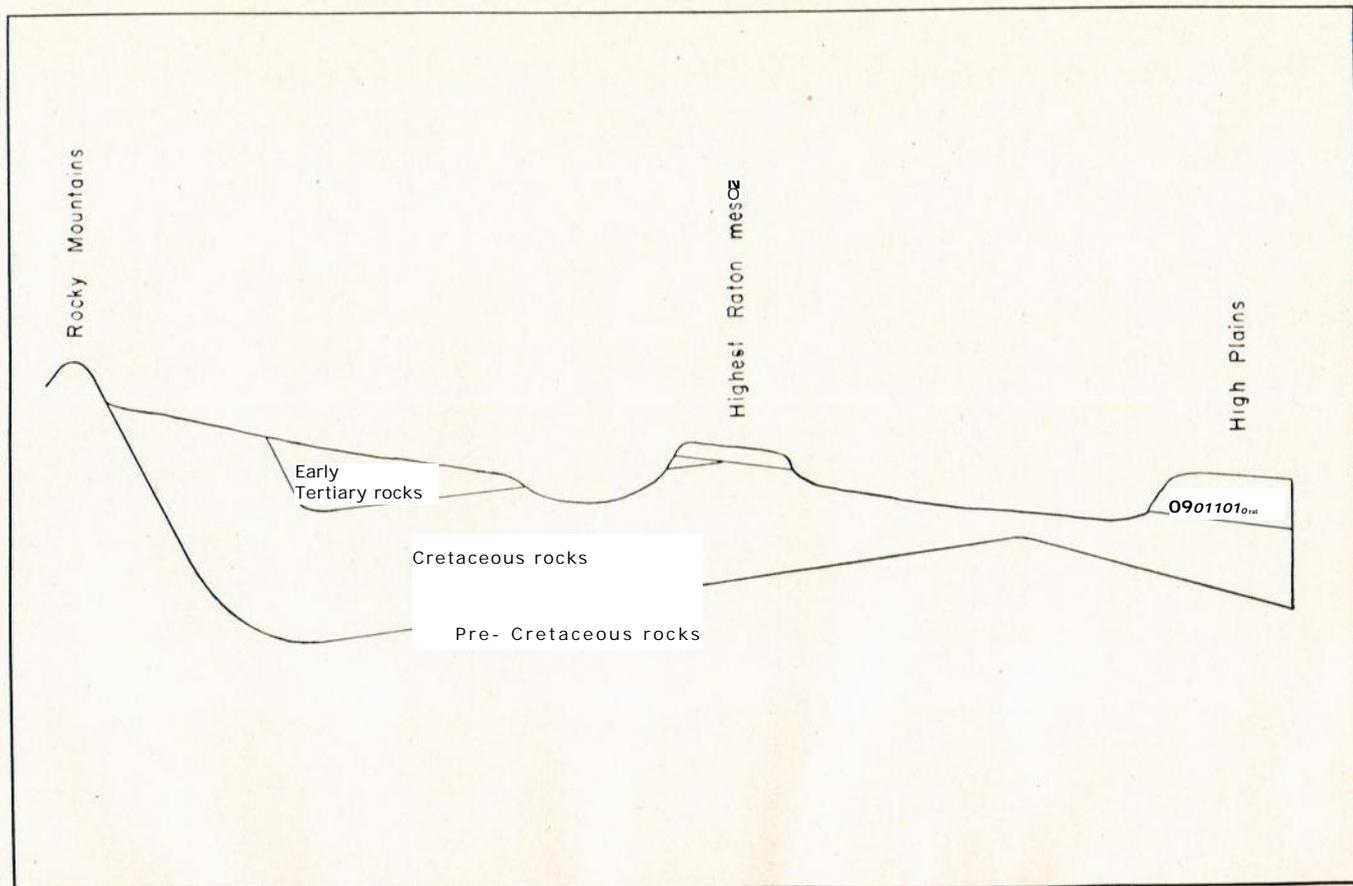


Figure 2.—Diagrammatic cross section showing the general geologic structure of the Raton Basin.

3,900-foot contour line, or at about 3,875 feet. The difference of 2,790 feet is the calculated depth to the Dakota at Raton.

PHYSIOGRAPHY

Colfax County is situated predominately in what has been called the Raton section of the Great Plains.³² This section lies between the Southern Rocky Mountains on the west and the High Plains on the east. Fenneman subdivides the section on a basis of altitudes, and from highest to lowest these general subdivisions are: (1) The Raton Mesa group, (2) the Park Plateau, (3) the Las Vegas Plateau. Figure 3 shows the extent, in Colfax County, of these three subdivisions. The subdivision called by Fenneman the Park Plateau is referred to locally as the Raton Mesa or the Raton Mesa Coal Field. However, the name Raton Mesa has been used in the geologic literature in a restricted sense for the mesa in Colorado capped by Fishers Peak and for clarity referred to in this report as Fishers Peak Mesa, its generally used local name. In this report Fenneman's Park Plateau has been referred to as the Raton Plateau to avoid confusion. Figure 3 also shows the extent of the Southern Rocky Mountains in the western part of the county and an outlier of the High Plains in the southeastern part of the county.

Fenneman's Raton Mesa group includes the high mesas along the north edge of the county and Ocate Mesa, which lies in the southern part of the county. This group, with some small outliers, comprises the basalt-capped remnants of two southeasterly-sloping erosion surfaces. Fishers Peak and Barilla and Johnson Mesas are along the north edge of the county. Just north of the county the basalt cap of Fishers Peak Mesa rises to an elevation of over 9,500 feet. The lava on these three mesas caps remnants of the highest erosion surface in the area, which includes small outliers at Dry Mesa and at the mesa at Cunico, and is believed to be correlative with the erosion surface at the base of the Ogallala formation. (See p. 35.) Bartlett Mesa, at the north edge of the county, and part of the surface of Ocate Mesa, in the southern part of the county, are the main remnants of a slightly lower, basalt-capped erosion surface. Bartlett Mesa is about 500 feet lower than the adjacent, higher mesas, and about 600 feet above the adjacent streams. There are also several small outliers of this erosion surface including Rayado and Gonzalitos Mesas in the southern part of the county.

The Park or Raton Plateau is a highly dissected, forested surface which has been cut on the Raton formation. Its southern and eastern boundary extends from Raton to Ute Park, about

³²Fenneman, N. M., *Physiography of the western United States*, McGraw-Hill Book Co., p. 37, 1931.

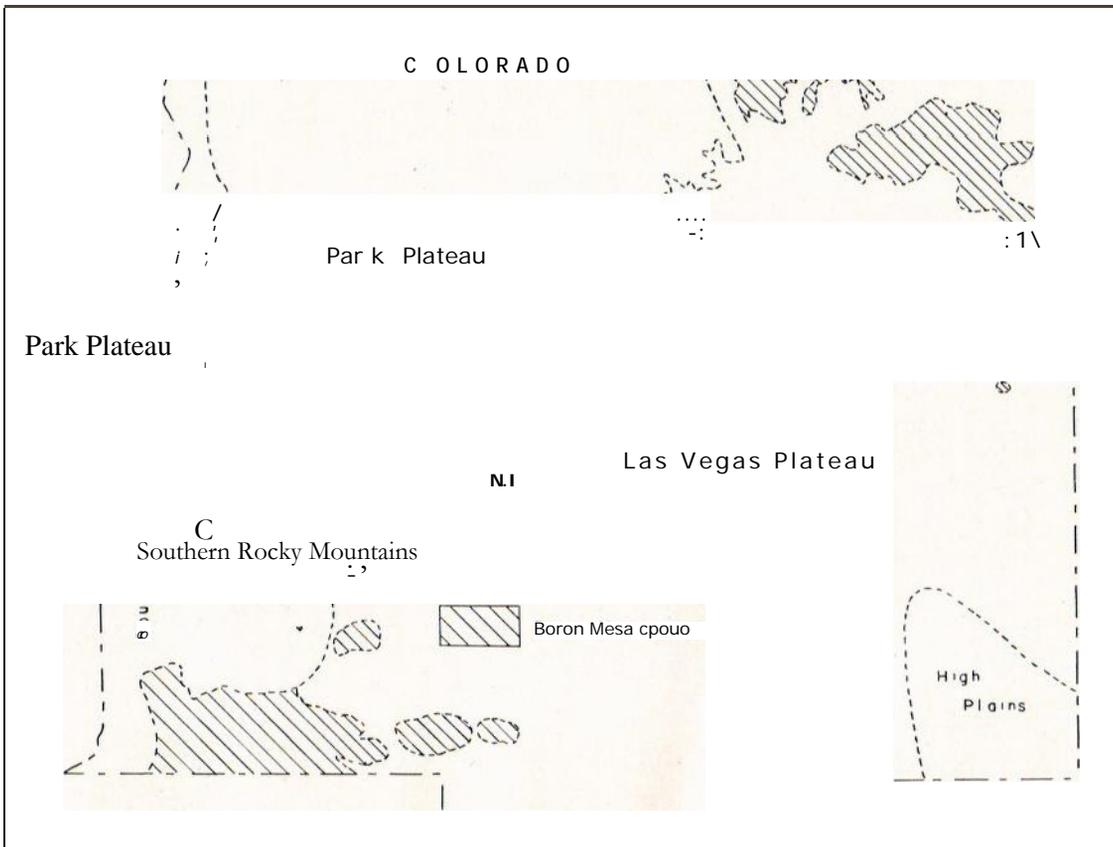


Figure 3.—Sketch showing the physiographic subdivision of Colfax County according to Fenneman.

12 miles west of Cimarron and is marked by cliffs in which the light-colored Trinidad sandstone is prominent. From here the plateau slowly rises and extends to the Sangre de Cristo Mountains on the west and into Colorado on the north. The southern part of the plateau surface is equivalent to the erosion surface of Bartlett Mesa. The northern part of the plateau surface may be a slightly lower erosion surface.

The Las Vegas Plateau covers the greater part of the area shown on the geologic map (p1. 1). It is largely a plains area which has been cut on soft Cretaceous shale. The plains rise to the north and lie mainly between 5,500 and 7,000 feet above sea level. They are surmounted by numerous pediment remnants, and the northeastern part of the plains is studded with volcanic cones. The pediment remnants stand as mesas and tablelands which are lower than the two erosion surfaces of Fenneman's Raton Mesa group. Many of the pediment remnants are capped by lava. Some of the most extensive remnants are those of a basalt-capped pediment beneath and northeast of Eagle Tail Mountain. The most prominent volcanos of the northeastern part of the plains are Eagle Tail, Palo Blanco, and Laughlin volcanos. The Laughlin volcano rises to an elevation of about 8,800 feet. The Las Vegas Plateau also includes an area of low hills north of Chico cut on the harder rocks of the sill-complex.

The High Plains in the southeastern part of the county is underlain by the Ogallala formation. This formation originally extended to the Rocky Mountains. The present land forms of the Raton section are the result of late Tertiary-Quaternary erosion and most of them have been cut from rocks originally beneath the western extent of the Ogallala formation.

GROUND WATER

PRINCIPLES

The rocks of the outer part of the earth contain pores or interstices, and below a certain depth these interstices are saturated with water. (See fig. 4.) The upper limit of this zone of saturation is called the water table. It is present at various depths, but it is usually a subdued replica of the land surface. In some places, because of the alternation of permeable and impermeable rocks, there are thin zones of water above the main water table. Such water is called perched ground water. (See fig. 5.)

Although most of the interstices in the rocks are of very small size, they largely control the availability of ground water. In sandstone the interstices consist of the pore spaces between the sand grains, and sandstone that is composed solely of grains

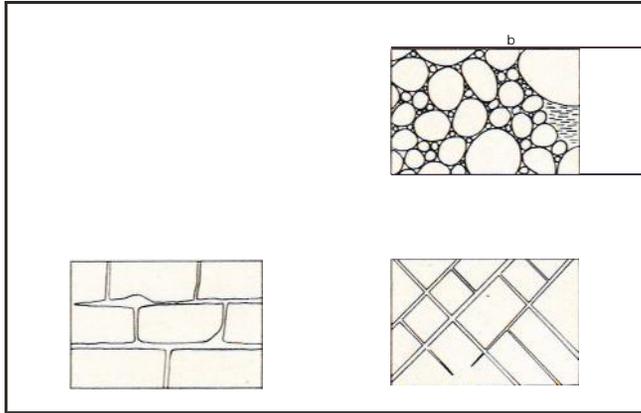


Figure 4.—Diagram showing four types of rock interstices (modified from O. E. Meinzer, U. S. Geol. Survey Water-Supply Paper 489, p. 3).

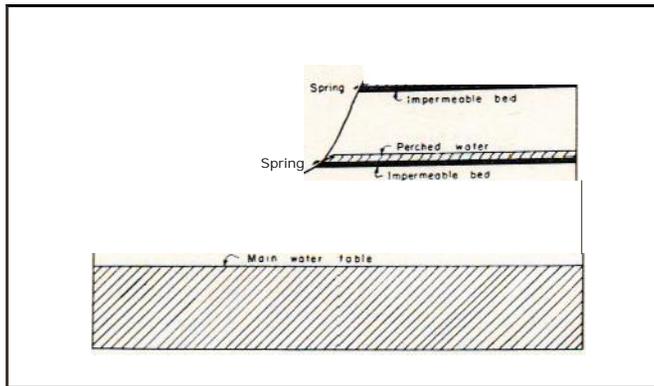


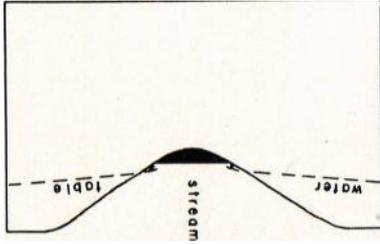
Figure 5.—Diagram showing main water table and two zones of perched water (modified from O. E. Meinzer, U. S. Geol. Survey Water-Supply Paper 494, p. 41).

of uniform size will have more pore space than one in which clay or silt fills in around the grains. Cementation around the grains of sandstone also lowers the amount of pore space. In a limestone the interstices commonly consist of fractures or of solution channels which have developed along fractures or bedding planes. Figure 4 shows several types of rock openings.

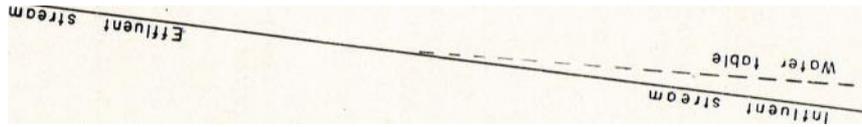
The porosity of rock is the ratio of the total volume of pore space to the total volume of rock. Porosity, or the percentage of pore space present in a rock, does not in itself indicate the availability of ground water. It is necessary for the pore spaces to be interconnected in order that ground water may move through them and into a well, and they must be large enough to transmit water under the hydraulic gradients that exist in nature or can be practicably induced. Shale beds may be saturated with water, but the pores are so tiny and poorly connected that water moves through them slowly or not at all; thus shales usually are nearly impermeable. Permeability is the capacity of rock to transmit water. The degree of this capacity is called the coefficient of permeability. It may be expressed as the number of gallons of water that can pass in 1 day through a square-foot cross-sectional area of the rock at right angles to the direction of flow under a unit hydraulic gradient.

All ground water of economic importance is moving from a place of recharge to a place of discharge. If all the rock above the water table in an area is permeable, water-table conditions are said to exist and recharge may be accomplished by water from precipitation or from streams moving directly downward to the water table. (See fig. 6.) If impermeable beds overlie the zone of saturation the recharge is received where the permeable beds crop out. After reaching saturated beds the water then moves through the ground-water zone. Velocities ordinarily range from a few feet to a few hundreds of feet per year. They are greatest for water that follows the most permeable beds. Finally the water is discharged to effluent streams, to springs or seeps, directly to the air or through vegetation transpiring water, or to the sea.

The zone of saturation itself is transected by beds or formations of varying permeability. Some of the formations are impermeable; others are permeable enough to act as conduits. A formation that will yield water in sufficient quantity to be of consequence is called a water-bearing formation or an aquifer. If a saturated aquifer is immediately overlain by an impermeable formation, the ground water is known as confined or artesian water in the aquifer, and may give rise to flowing wells. (See fig. 7.) The hydrostatic pressure at a given point in a body of water is caused by the weight of water at higher elevations in the same zone of saturation. This pressure drops off in the direc-



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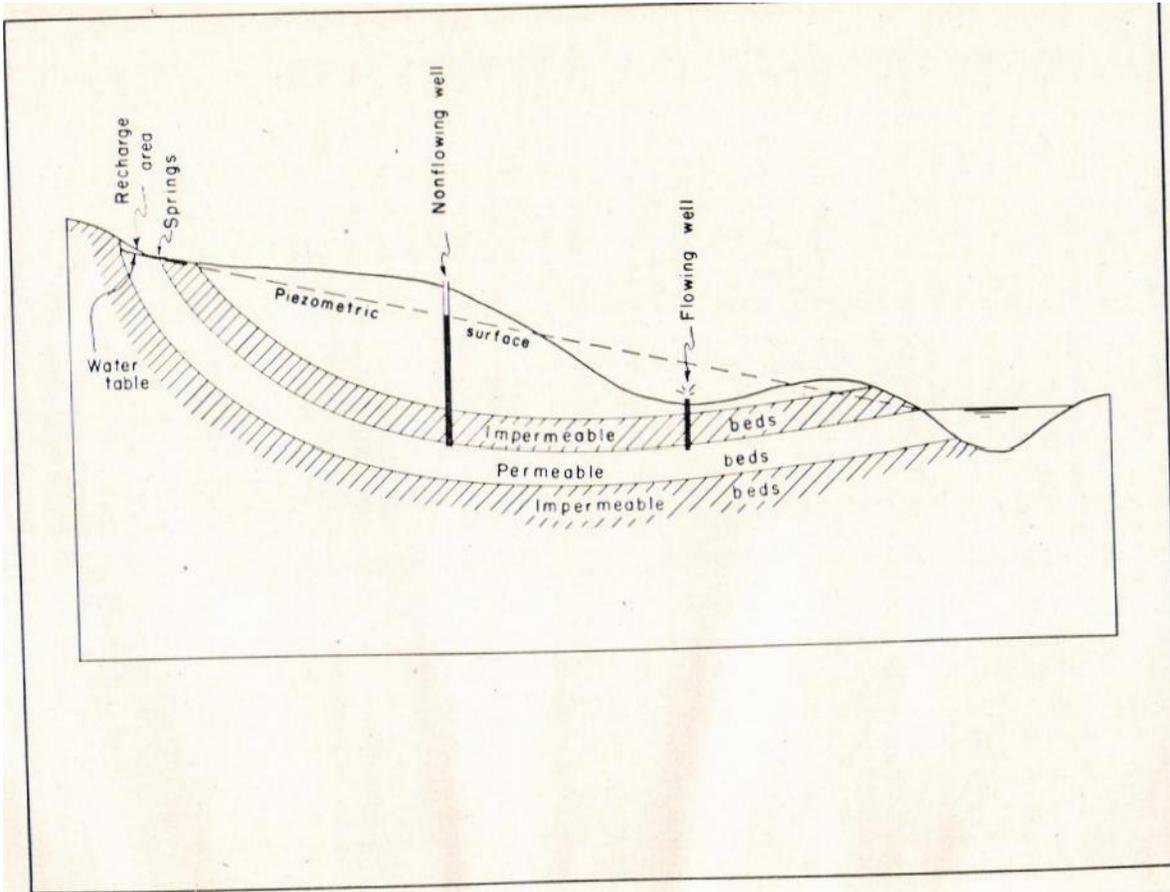
tion of movement of the water as energy is used in overcoming the frictional resistance to flow. If the aquifer passes beneath an impermeable formation and if the loss in pressure in the aquifer is less rapid than the downward slope of the beds, the water in the aquifer will be confined under pressure beyond the point at which the impermeable formation descends to the water table. If the aquifer is drilled into, the water will rise above the upper surface of the aquifer. The distance the water will rise depends upon the hydrostatic pressure at that point. The imaginary surface coinciding everywhere with the level to which water will rise in wells penetrating a confined aquifer is known as the piezometric surface. If the piezometric surface is above the land surface, the well will flow.

When a well is pumped its water level is lowered. The lowering continues at an ever-decreasing rate, and finally the water level becomes almost stationary. If the pump is shut off the water level rises rapidly at first, then more and more slowly until it finally recovers. During pumping, the total lowering of the water level is proportional to the pumping rate, and the productivity of the well is shown by its specific capacity, generally expressed as the number of gallons per minute that it will yield per foot of drawdown.

The quality of ground water depends upon the type of rocks with which the water has been in contact. Water from limestone will usually contain calcium bicarbonate, as calcium carbonate is the primary constituent of limestone and is dissolved and changed to the bicarbonate through the action of carbon dioxide dissolved in the water. Such water is usually good though hard. Water that is obtained from shale is generally high in sulfate. The water from a sandstone is usually low in dissolved matter, although some of the water from the Dakota sandstone in Colfax County is high in dissolved matter. In this case it is believed that additions of magmatic water have been made to the water of the sandstone. (See p. 54.)

GENERAL CONDITIONS IN COLFAX COUNTY

The domestic water supplies of most of the ranches and farms come from ground water. In a few places cisterns are used to store rain water, and in a few places in the area underlain by the Pierre shale, where ground water is difficult to obtain, the domestic supplies are hauled in. The public supplies for Raton, Springer, and Cimarron come from surface water. The towns of Maxwell, Farley, Dawson, and Koehler use ground water. The public supply for the mining community of Van Houten is shipped in by railroad from Raton. As perennial stream water is available in only a rather small area, most of the stock



supplies come from ground water. With a better distribution of stock wells more cattle probably could be raised in the county. In any case, a satisfactory well distribution makes for economy in that it keeps the livestock from walking excessive distances for water and from overgrazing the range adjacent to scattered water supplies. There are few good aquifers in Colfax County, however, and in the large area underlain by shale of the Niobrara formation and the Pierre shale the available water supplies are particularly scarce. It is hoped that this report, with the accompanying maps, will give a logical basis for locating ground water. They will indicate, in general, feasible localities and depths at which to seek water from wells.

The ground-water recharge for Colfax County is essentially local. Almost all of it originates as precipitation within the county. In the following part of the report the availability and quality of the water are described according to the geologic formation or aquifer in which the water occurs.

WATER-BEARING CHARACTERISTICS OF ROCKS IN THE PLAINS AREA

PRE-DAKOTA ROCKS

The pre-Dakota rocks that crop out in the plains area of Colfax County include the Dockum group, the Entrada sandstone, and the Morrison formation. Although little is known of the water in these units, it is probable that they are of no importance as aquifers, and they are within reach of the drill over a very limited area only.

The Dockum group is exposed over an area of about 1 square mile in the center of the dome 3 miles northeast of Chico post office. Within a short distance from this exposure the beds extend to depths that would be prohibitive for drilling.

The Entrada sandstone is exposed in the above-mentioned dome and also in the small dome $3\frac{1}{2}$ miles north of the Joyce ranch headquarters. This formation is relatively permeable and possibly could be of some importance as an aquifer if it were conveniently distributed. However, the outcrops of the formation cover such a small area that the recharge must be very small, and like the Dockum group the formation is deeply buried outside its immediate outcrop area.

The poorly cemented sandstone beds of the Morrison formation could possibly yield some water. Where the formation crops out along the valleys southeast of Palo Blanco Mountain, it would be worth while to test these beds, in the absence of any other water. It is only in this area that the formation could contain water at economically feasible depths.

DAKOTA SANDSTONE

The Dakota sandstone underlies most of Colfax County, although it is buried beneath younger rocks over the greater part of its extent. The formation crops out as narrow bands along the east flanks of the Cimarron and Sangre de Cristo Mountains in the western part of the county. There are also exposures around an anticline at Vermejo Park in the northwestern part of the county. The formation is buried through the central part of the county. The depth to it is greatest along the axis of the north-plunging Raton structural basin. East of this basin the formation rises to the crest of the Sierra Grande arch, and it crops out at several places along the flanks of this arch in the eastern part of the county. These exposures are shown on plate 1. They cover an area of about 70 square miles in and around the domed sill-complex area. They are less extensive along the Canadian River south of Taylor Springs.

The aquifer receives recharge at the outcrops in both the eastern and western parts of the county, and some recharge occurs outside the county. The greater part of the recharge is taken in at the rather flat-lying outcrops north of Farley and south of Laughlin Peak, and perhaps almost as much is taken in at the outcrops near Ocate in northwestern Mora County. The narrow outcrop areas of the steeply dipping beds in western Colfax County probably are not very important recharge areas.

Some of the discharge takes place at the outcrops in the Canadian Canyon south of Taylor Springs. There are several seeps in this area, and the water levels in existing wells in the Dakota indicate gradients to this area from three general directions. These directions are from the northeast, the northwest, and the southwest, or, respectively, from the following outcrops: (1) Those south of Laughlin Peak and north of Farley, (2) those in the western part of the county, and (3) those in the vicinity of Ocate. Water-level measurements also indicate water movement to the southeast and south from the outcrops north of Farley. This water is moving down dip on the southeast flank of the Sierra Grande arch. It is discharged beyond the limits of the county.

Several wells in the southeastern part of the county now produce from the Dakota. They are southeast of a sinuous line that extends from a few miles west of Springer northeastward through T. 28 N., R. 27 E. (See the accompanying well tables.) The aquifer is at relatively shallow depths over much of the area southeast of this line, and additional wells can be drilled into the Dakota within this area. Wells can probably be obtained in the Dakota at feasible depths somewhat beyond the northern part of the present producing area, but the limit of the present producing

area can hardly be extended in the southern part of the county, where one of the present wells northwest of Springer (sec. 5, T. 25 N., R. 22 E.) is over 1,000 feet deep.

The Dakota sandstone aquifer is probably saturated, and the water is confined under artesian pressure by the overlying Graneros shale over most of the extent of the aquifer in Colfax County. A few wells flow in the vicinity of Springer, and many other wells in the Dakota have a water level that is above the top of the aquifer. The water is not confined, of course, in the areas where the aquifer crops out, and in some places for a considerable distance down the dip from these areas. Two wells, whose water levels were measured, indicate that water-table conditions exist in the aquifer in the extreme southeastern part of the county. One of these wells is at Farley, the other in the SW $\frac{1}{4}$ sec. 2, T. 24 N., R. 26 E. Reported water levels indicate that these conditions extend to the southeastern corner of the county. In this particular area the aquifer is overlain by the Graneros shale, but the upper part of the aquifer is unsaturated.

The Dakota extends over an area of about 3,000,000 acres in Colfax County. As it is about 200 feet thick and has an effective porosity of probably about 10 percent, it would contain, if completely saturated, about 60,000,000 acre-feet of water. As it is not saturated throughout its extent, it contains less water than this, but it may contain something of the order of 50,000,000 acre-feet of water. If the transmissibility of the aquifer were high, its water could be withdrawn at a high rate. However, the transmissibility is low because of the tightly cemented character of the sandstone, so that only a small proportion of the stored water is economically available. A recently drilled well near Springer (NWT sec. 2, T. 24 N., R. 22 E.) was bailed at a rate of 40 gallons per minute by the driller. The water level was lowered about 40 feet during this test, which would indicate a specific capacity for the well of 1 gallon a minute per foot of drawdown. This is about equal to the specific capacity found elsewhere in wells in the Dakota sandstone. In the case of another recently drilled well (SW $\frac{1}{4}$ sec. 7, T. 25 N., R. 26 E.) south of Chico post office, the aquifer produced a negligible amount of water until the drill had penetrated more than 150 feet of the beds. After 180 feet of penetration of the aquifer the well filled to above the top of the aquifer. This indicates what may occur occasionally where the beds are unusually well cemented. It seems probable from a study of the outcrops that the lower part of the aquifer is somewhat more permeable than the upper part.

The quality of the water in the Dakota differs greatly between the eastern and western parts of the present producing area. Most of the wells in the eastern two tiers of townships have fairly good water, although two analyses from this part of the

county (sec. 10, T. 25 N., R. 26 E., and sec. 34, T. 26 N., R. 27 E., see tables) show a fluoride content slightly over 1 part per million. Westward, in the vicinity of Springer, the water from the Dakota sandstone is of poor quality. Here the analyses show the water to be high in sodium chloride, sodium bicarbonate, and fluoride. Fluoride much in excess of about 1.5 parts per million causes mottling of teeth while they are in process of development in children. This water is unsuitable for human consumption.

Wells are not sufficiently abundant to determine just where the quality of the water changes between the eastern and south-central parts of the county. It is of poor quality at least as far east as the well in sec. 5, T. 25 N., R. 24 E. One well 85 feet deep on the Jaritas ranch has water of fair quality, although it is hard, and another well only 7.5 feet deep at the same place has good water, but the recharge for it is entirely local. Another well 1.5 miles west of Abbott yields water of good quality except for a high iron content. It is probable that the change in quality from east to west occurs close to the crest of the Sierra Grande arch.

The cause of the poor quality of the water in the Dakota of the south-central part of the county cannot be determined beyond doubt, but this poor quality is probably related to the Quaternary igneous activity. Carbon dioxide is one of the most common volcanic gases, and it is usually present in relatively large amounts, either free or in chemical combination, in the waters of most hot springs. Sodium bicarbonate, sodium chloride, borate, and fluoride are also common constituents of some waters which almost certainly owe their character to admixtures from igneous emanations. In the alkaline waters of Yellowstone Park "Bicarbonates and chlorides (of the alkali metals) in quantities amounting to several hundred parts per million each, are the important acid radicals, while boric acid and fluorine in much smaller quantities appear to be invariably present."³³ This is also an adequate statement of the character of the water in the Dakota in the south-central part of Colfax County. This water has fluoride and borate in about the same quantities as the alkaline waters of Yellowstone Park. The bicarbonate, chloride, and sodium exceed in amount these constituents in the alkaline waters of Yellowstone. It seems probable that they have been added to the meteoric water of the Dakota sandstone from igneous emanations. It is known that such characteristic additions are possible, and there seems no other source for the strong concentrations of the bicarbonate and chloride of sodium. The sodium chloride could hypothetically come from originally contained connate water. However, the rate of movement of water through the Dakota is probably of the order of 25 feet per year,

³³ Allen, E. T., and Day, A. L., Hot Springs of the Yellowstone National Park: Carnegie Inst. Washington Pub., p. 71, 1933.

assuming an effective porosity of 10 percent, a permeability of 5 gallons per minute per square foot, and a hydraulic gradient of about 50 feet per mile as indicated in the southeastern part of the county. As intake areas of the formation have been exposed on the flank of the Sangre de Cristo Mountains since early Tertiary time, and discharge areas have been exposed immediately east of the county since pre-Ogallala time, it is evident that at such a rate of flow all the connate water should have been flushed out of the formation.

It is probable that the igneous constituents were added to the water of the Dakota by emanations rising along the boundaries of the Quaternary dikes and plugs. Many such intrusives are known to have been emplaced in the area during Quaternary time. Feeders for the latest lava flows are of late Quaternary age.

Most of the Quaternary intrusives are along or west of the crest of the Sierra Grande arch. It is probable that they have also acted to retard the movement of water through the Dakota in this part of the county. To the east of this arch in the eastern part of the county, there are apparently no dikes, and there are only a few plugs, none of which are of Quaternary age. Also, in this latter area recharge and discharge have been taking place within relatively short distances at least during the latter half of Quaternary time. These factors probably explain the better quality of the water from the Dakota in the extreme eastern part of the county.

GRANEROS SHALE

The Graneros shale immediately overlies the Dakota sandstone. Its exposure belt is between that of the Dakota sandstone and that of the Greenhorn limestone, the next higher formation, but within its exposure belt the Graneros is usually covered by soil. In some areas it is covered by later deposits. In all cases bare outcrops are uncommon.

The fine-grained fissile shale composing the Graneros is nearly impermeable, although a few wells produce small quantities of water from the Graneros in the southern part of the county. These wells probably obtain most of their water from thin silty laminae which have been noted within the fissile shale in this part of the county. One of these wells (NW¹/₄ sec. 15, T. 24 N., R. 24 E.) on the Jaritas ranch penetrates the greater part of the total thickness of the Graneros. This well was pumped, and the indicated specific capacity was about 0.01. In other words, the well could produce about 1 gallon per minute per 100 feet of drawdown. No more can be expected of the formation elsewhere. Instead of stopping a well within the Graneros, it is better to drill through to the immediately underlying Dakota sandstone.

The quality of the water in the Graneros is poor, and the water is suitable for stock only. The water of the few wells in this formation in Colfax County has the odor of hydrogen sulfide. It is probable that all the water is high in sulfate also. An analysis of water from the previously mentioned well in the Graneros on the Jaritas ranch showed a high concentration of sodium bicarbonate.

GREENHORN LIMESTONE

The Greenhorn limestone is well exposed at the top of the low cliffs south of Taylor Springs. It is less well exposed to the east, but essentially continuous outcrops are present as far north as the Gillespie ranch and as far east as the vicinity of Abbott. North of Taylor Springs and the Gillespie ranch the Greenhorn is generally buried beneath younger rocks, although it crops out in a few places within and around the border of the sill-complex centering north of Chico. In the extreme eastern part of the county there is one outcrop, in the valley immediately southwest of Cunico. East of Cunico the exposure belt of the formation is covered by a veneer of alluvium.

A few wells in both the southern and eastern parts of the county obtain their water from the Greenhorn. In the southern part of the county wells produce from this formation from the Gillespie ranch headquarters southeastward to sec. 17, T. 23 N., R. 26 E. and in the eastern part of the county, in the immediate vicinity of Cunico and eastward to sec. 22, T. 28, N., R. 27 E. All the present wells are shallow; the deepest extends to about 125 feet. Two of the wells are located at outcrops of the formation, and the rest are located either a short distance down dip from outcrops, or a short distance down dip from areas where the formation is overlain by permeable material. Hence the recharge, which supplies the present wells is local.

The water from most of the wells in the Greenhorn is of fair quality, though it is hard. The water from one well (sec. 31, T. 25 N., R. 25 E.) on the Gillespie ranch has some hydrogen sulfide which is probably derived from the shale interbedded in the limestone. The water from this well is also high in calcium bicarbonate and sulfate. It is possible that the water from the Greenhorn may be of similar quality where the formation is encountered at some distance from areas of recharge.

Little is known of the permeability of the Greenhorn limestone. None of the present wells are reported as being particularly "weak," but it is doubtful that any of them have specific capacities greater than 0.5. The permeability of limestone is commonly erratic because it depends on connected fractures and solution channels. The Greenhorn is highly fractured at its outcrops, but it shows no evidence of solution channels. The fractures that are

conspicuous at outcrops probably decrease in abundance down the dip of the beds. They are certainly more tightly closed down the dip, as in this direction the formation is subjected to a progressively greater load of overlying rocks. For this reason, future wells that encounter the Greenhorn at depths greater than 200 or 300 feet may be "weak" or even dry.

The approximate depth to the top of the Greenhorn may be calculated by first determining the depth to the Dakota (as described under Geologic Structure on p. 41). From this depth subtract 200 feet, the interval between the tops of the two formations. The difference will be the approximate depth to the Greenhorn.

CARLILE SHALE

The Carlile shale overlies the Greenhorn limestone. Its exposure belt, though generally soil-covered, is between those of the Greenhorn limestone and Fort Hays limestone member of the Niobrara. This belt is rather wide from the vicinity of Springer northeastward to the Maxwell-Chico post office road, but farther north, as the formation swings around the northwest side of the sill-complex, the exposure belt is narrow because of the formation's steep dips in this area. Northeast of Laughlin Peak the formation is largely covered by alluvium.

The Carlile is impermeable except for the silty and limy portion (see stratigraphic description, p. 28) immediately below the Fort Hays limestone member. This part of the formation, from the concretion beds up to the base of the Fort Hays, is sufficiently permeable that under favorable conditions it can supply wells of small capacity. The favorable conditions require that this upper zone receive recharge and occur at sufficiently shallow depth that the overlying load of rocks does not tightly compress the zone. It is doubtful that the zone could yield much water where it is below a depth of 200 feet.

Two wells (secs. 12 and 14, T. 28 N., R. 26 E.) northwest of Cunico obtain their water from the upper, permeable part of the Carlile, and one small spring on the north slope of the mesa southeast of Cunico emerges from this zone. An analysis was made of the water from the well in the NE1/4 sec. 14, T. 28 N., R. 26 E. Although this water had an odor of hydrogen sulfide, it was otherwise of fair quality.

NIORRARA FORMATION

FORT HAYS LIMESTONE MEMBER

The Fort Hays limestone member of the Niobrara is composed of alternating beds of limestone and shale. This sequence, 15 to 20 feet thick, maintains fairly conspicuous outcrops across

the eastern part of Colfax County. The Fort Hays enters the county from the south in the vicinity of Colmor. From there it follows an irregular course northeastward to T. 29 N., R. 27 E. North of the latter place are two exposure areas in the extreme northeastern part of the county, and there is one small exposure area near the east flank of the Cimarron Mountains, northwest of Rayado Mesa. The outcrops are good as far north as Laughlin Peak, but farther northeast, toward the King ranch, they are poor and scattered. Along its main exposure belt the Fort Hays dips beneath the shale of the Niobrara formation, the Smoky Hill marl member, the next younger unit, but a narrow, isolated wedge of the Fort Hays is overlain by the late Tertiary Ogallala formation between the Joyce ranch and Abbott. The base of the Fort Hays is 410 to 420 feet stratigraphically above the top of the Dakota. Exposures of the formation can therefore be used as an indicator of the depth to the Dakota.

The Fort Hays is not a highly permeable rock, but the permeability, though probably variable, is sufficient to supply wells of small capacity. In a gas test (sec. 1, T. 26 N., R. 24 E.) recently drilled on the Sauble ranch the formation was struck at a depth of about 50 feet and it was necessary to case off the inflowing water before drilling could be resumed. This probably represents unusual conditions, for here the formation is near the surface and close to an area of recharge. The permeability of the shale interbedded in the Fort Hays is low. The permeable part of the formation is the limestone beds, which are generally more than a foot thick. The permeability of these beds depends upon interconnected fractures and bedding-plane openings. There is no evidence of solution channels. Fractures are abundant in the limestone at outcrops, but they probably decrease in abundance down the dip of the beds, and those that remain are more tightly closed beneath the overlying shale of the Niobrara formation. Consequently the permeability can be expected to decrease down the dip from exposures, but it is probable that water production can generally be extended to about 2 miles west of the main belt of the formation's exposures, or to where the formation is 200 to 300 feet below the surface. In locating new wells it will be necessary to place them down dip from outcrops where the formation is receiving recharge.

At present there are several wells in Colfax County that obtain their water from the Fort Hays. Two of these wells are 2 miles east of Robinson siding, and there are several in an area between 2 and 5 miles northwest of Cunico. Some other wells probably produce from the Fort Hays.

Three analyses were made of water from the Fort Hays. All the analyses indicated the water to be good, although rather high in carbonate hardness.

SMOKY HILL MARL MEMBER

The shale of the Niobrara formation, the Smoky Hill marl member, overlies the Fort Hays limestone member and underlies the Pierre shale. The shale, in a small area south of Cimarron, dips to the northwest, toward the axis of the Raton structural basin. Hence the exposure belt of the shale extends diagonally, from northeast to southwest, across Colfax County, and this belt, several miles wide, reaches from the Fort Hays limestone member to the Pierre shale. At the Fort Hays side of the shale belt it is only 435 feet to the Dakota sandstone, but at the Pierre side of the belt it is over 1,300 feet to the Dakota.

The Niobrara shale is about 950 feet thick and is composed of the calcareous to sandy shales described in some detail in the section of stratigraphy. (See pp. 31-33.) These shales are not very permeable. Several dry holes are known to have been drilled into them, and under ordinary conditions they would be described as fairly impermeable and of no importance. However, in an area such as Colfax County where aquifers are scarce they offer some chance of obtaining small-capacity stock wells. The beds support some wells at the present time (1946). The areas in which these wells occur are north of Tinaja Mountain, southwest of French, and northwest of Colmor. All the wells are weak, and it is doubtful that any of them are capable of producing more than 2 gallons per minute continuously. Wells of greater capacity may be obtained in the alluvium along some stream valleys within the belt underlain by the Smoky Hill. It is generally advisable to test any nearby valleys for water-bearing alluvium before drilling or digging a hole in this shale.

The quality of the water in the Smoky Hill is poor, and nearly all the analyzed samples indicate a very high proportion of sulfate. The water is commonly so high in magnesium and sodium sulfate that it acts as a laxative on human beings, and such water is therefore suitable only for stock.

PIERRE SHALE

The Pierre shale, overlying the Niobrara formation and underlying the Trinidad sandstone, dips northwest and is exposed in the area between those formations. The exposure belt is about 12 miles wide, and at the northwest side of the belt the depth to the Dakota sandstone is about 3,000 feet.

The Pierre is about 1,650 feet thick and is composed of black fissile shale in which calcareous concretions occur at several horizons. Because of the impermeable character of the shale virtually no water can be yielded to wells, in spite of the fact that the shale beds are saturated with water to within a relatively short distance of the land surface. However, in places there

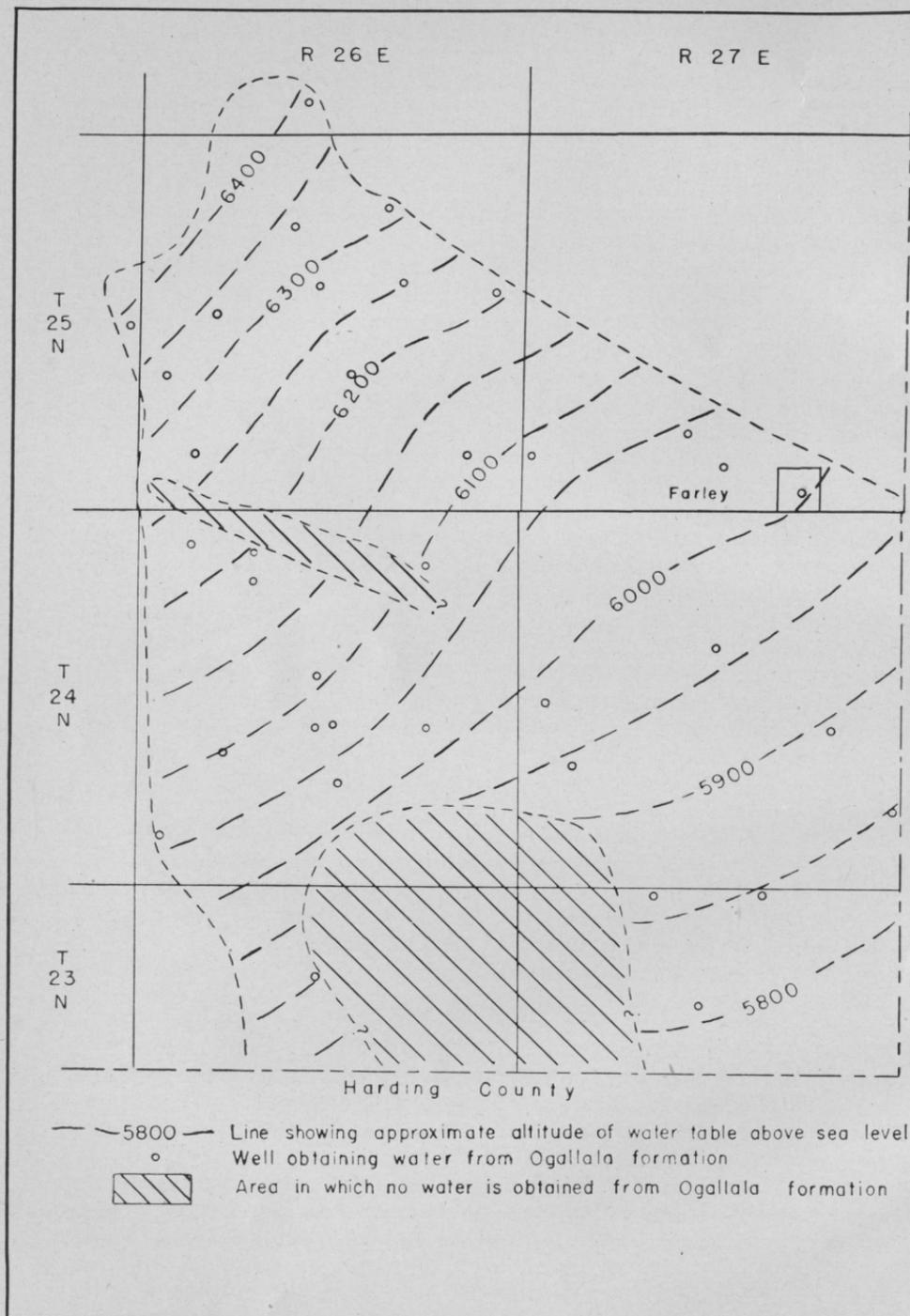


Figure 8.—Area in which wells obtain water from the Ogallala formation.

is several feet of weathered shale immediately below the land surface. This weathered material transmits water somewhat more readily than the underlying fresh shale, and a few wells obtain their water from this weathered zone where its base lies below the local water table. Even these wells are "weak." A few drilled wells extend down into the fresh shale, but they probably receive little water from it.

Future attempts to locate wells in the Pierre shale are likely to be unsuccessful. Therefore, the best prospects in the belt of the Pierre shale lie in water-bearing alluvium, which occurs at some places along streams and arroyos. All the present wells of notable capacity within the belt underlain by the Pierre shale obtain their water from alluvium. If it should become necessary to locate a well in the shale, the attempt should be made in an area that is low in relation to the surrounding topography. In such areas there is a better chance of finding a zone of weathered material whose base is below the local water table. It would also be better to dig, rather than to drill, such a well, to provide a reservoir of large volume.

All the water in the Pierre shale is of poor quality, and none is suitable for human consumption. Some of the water has the odor of hydrogen sulfide, and all of it has sufficient sulfate to be tasted.

OGALLALA FORMATION

This formation underlies an area of a little more than 4 townships in the southeastern corner of the county. (See pl. 1 and fig. 8.) At its most southwesterly point the western boundary of the formation enters the county from the south in sec. 13, T. 23 N., R. 25 E. From there the boundary trends northward sinuously, crosses Highway 58 about a mile east of Abbott, then, still maintaining a general northerly course, extends to within a short distance of Chico post office. South of Chico post office the northeastern boundary swings to the east, flanks the south part of the Point of Rocks or Peck's Mesa sill, then extends southeastward, passing about 1¹/₂ miles north of Farley, and finally leaves the county near the northeast corner of sec. 36, T. 25 N., R. 27 E. Inside this boundary the formation is continuous except for a small area around the lake in sec. 36, T. 26 N., R. 25 E. In a few places it is punctured by volcanic necks, and south of Highway 58 it is locally covered by basalt flows.

The thickness of the Ogallala varies from a feather edge to more than 200 feet in the southeastern most part of the county. All around its outer boundary and to some extent along young valleys inside its outer boundary it has been thinned by erosion. At a well in the SW¹/₄ sec. 7, T. 25 N., R. 26 E., where it is essen-

tially uneroded near its northwestern limit, it is 130 feet thick. South and east of here there is a gradual thickening, except where it has been thinned by local erosion or where it locally overlies high areas on the old plain on which it was deposited. In the vicinity of the southeastern part of T. 24 N., R. 26 E., it is slightly over 200 feet thick, and farther southeast it may reach 250 feet in thickness. Near the badly eroded border the formation has been thinned to 75 feet—for example, at a well 21/2 miles south and about half a mile east of Chico post office—and at Farley to 40 feet. In a recently drilled well 6 miles west of Farley, which is near the crest of a northwest-southeast-trending hill on the old plain on which the formation was deposited, it is 126 feet thick. This is at least 25 feet thinner than it would be at this locality if it were not for the buried ridge.

The low hummocks on the nearly featureless plain underlying the Ogallala affect the water production in some localities. There is no way of predicting the precise position or limits of all these low hills, though two are roughly known. One is south of Highway 58, where it covers a little over three sections at the southeast corner of T. 24 N., R. 26 E., and extends into the three bordering townships. It probably passes southward into Harding County. In this area at least six wells have found the base of the Ogallala at elevations high enough for the aquifer to be dry. In these holes it was necessary to go on to the Dakota sandstone for water. Six miles west of Farley, the recently drilled well, referred to above, found the base of the formation too high for production. In this case, also, it was necessary to drill to the Dakota. How far southeast of this locality the buried ridge extends is unknown, but a dry hole that was not carried to the Dakota is reported in the eastern part of sec. 36, T. 25 N., R. 25 E. This, together with three other nearby Ogallala wells that penetrate zones of saturation thinner than usual, indicates a probable northwesterly extension of the same buried ridge. A few wells north of this buried ridge indicate a zone of saturation slightly thicker than usual. This latter fact, together with a slight depression of the water table north of this buried ridge, suggests the presence of an old southeast-trending buried valley.

As previously stated in the section on geology, the lower surface of the Ogallala formation rests on several different formations. Near its northeastern limit it rests on the Dakota sandstone. At Farley there is about 30 feet of Graneros shale between the Ogallala and the Dakota. Southwest of Farley, at the western limit of the Ogallala near the south border of the county, the interval between these two important water-bearing units thickens to the extent that here the Ogallala rests on the Greenhorn limestone, some 195 feet above the Dakota. Southwest of Chico and north of Abbott, near its northwestern limits, the Ogallala

rests on the Fort Hays limestone member. Here the Ogallala and Dakota are separated by more than 400 feet.

The water body in the Ogallala occupies the lower part of the formation. The static water levels of the wells producing from the Dakota in the area are lower than those in, the Ogallala and therefore indicate that the Ogallala water is perched or semi-perched. The thickness of the saturated zone ranges from a feather-edge to possibly as much as 30 feet because of the slight surface irregularities at its lower surface. Where there are slight hills on this surface, the zone of saturation in the formation is thin and, in places, absent. Where there are slight depressions the zone of water is thickest. These irregularities probably have no relation to low hills and shallow valleys in the topography of the present ground surface. It would be possible to drill in a present valley and get a dry hole, or to drill on a hilltop and find 30 feet of saturation.

The average thickness of the saturated aquifer seems close to 15 feet. Because the area that produces water covers about 70,000 acres, and assuming a porosity of 15 percent, there is about 160,000 acre-feet of water in the aquifer. This water is moving slowly southeast, as is shown by the contours of the water table (fig. 8), which has a gradient of about 50 feet per mile. The formation is recharged by water from precipitation on the surface that seeps down until it joins the saturated zone. The amount of recharge per year is relatively small. Some of the water from precipitation runs off, some evaporates, and some is used by the surface plant life. From estimates³⁴ made under very similar conditions in the southern High Plains, it is probable that the annual recharge to the aquifer in Colfax County is of the order of 0.1 to 0.2 inch. As the total area of the formation is roughly 100,000 acres, there is a total annual recharge of something like 1,000 or 2,000 acre-feet of water—a relatively small amount. Under natural conditions. The water is discharged at the edge of the formation, largely beyond the south and east edges of Colfax County.

Like most aquifers composed of alluvium, the Ogallala is generally quite permeable, but as the composing material is a heterogeneous mixture of sizes ranging from clay to gravel in variable proportions, and with lensing beds where certain sizes predominate, the aquifer varies in permeability from place to place. Wells close to each other differ in producing capacity and attest to the variability of the aquifer. A well pumping from an area where gravel predominates obviously will be much stronger

³⁴ Theis, C. V., Amount of ground-water recharge in the southern High Plains: *Am. Geophys. Union Trans.*, pp. 565-568, 1937.

White, W. N., Broadhurst, W. L., and Lang, J. W., Ground Water in the High Plains of Texas: U. S. Geol. Survey, Water-Supply Paper 889, p. 391, 1946.

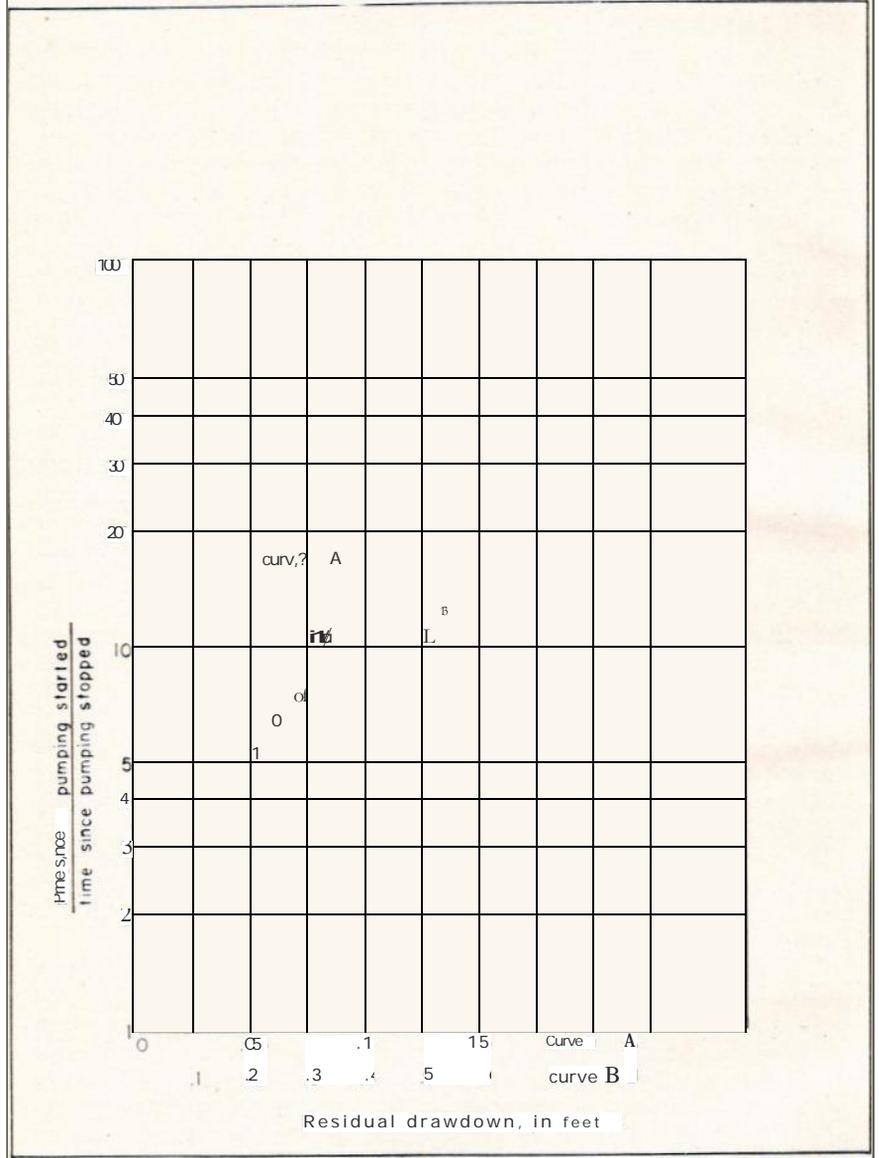


Figure 9.—Recovery curves of two wells obtaining water from the Ogallala formation. Curve A—well in sec. 30, T. 24 N., R. 27 E. Curve B—well in sec. 22, T. 25 N., R. 26 E.

than one pumping from an area underlain by clay. In terms of specific capacity (number of gallons per minute per foot of drawdown), it is possible that individual wells may range from less than 1 to perhaps as high as 30, or higher. As the rate at which a well can discharge water depends upon the permeability of the material composing the water-bearing zone, or, better, the transmissibility of the zone as a whole, the actual degree of these properties is important. Although pumping tests to determine these factors cannot be very accurate when windmills supply the power, two wells have been checked. (See fig. 9.) In both cases the wind varied in velocity during the tests, and only a small amount of water was pumped over a short period, but it is believed that the results obtained are approximately correct. The wells were shut off overnight, then pumped for periods of about 2¹/₂ hours the following day. The recovery method of Theis³⁵ was used and the transmissibilities were determined directly. One, in the NE¹/₄ NE¹/₄ sec. 30, T. 24 N., R. 27 E., indicated a coefficient of transmissibility of approximately 13,000 gallons per day per foot, the other, in sec. 22, T. 25 N., R. 26 E., a coefficient of about 3,500. At the first well, the zone of saturation is about 20 feet thick, indicating a coefficient of permeability of 650 gallons per day per square foot. At the latter well a similar saturated thickness was assumed, which indicates a permeability coefficient of 175. The specific capacities were not determined directly. Assuming that the transmissibility is roughly 1,000 times the specific capacity³⁶ the wells would be capable of producing about 13 and 3.5 gallons per minute per foot of drawdown, respectively. It is probable, with such a heterogeneous alluvial mixture as the Ogallala, that the range of permeability in the formation as a whole is somewhat wider.

As the saturated thickness of the Ogallala is slight, only small plots of ground could be irrigated by water from the formation even if material of relatively high permeability could be located where desired. Under the best of conditions, and with a battery of windmill wells and a large storage tank, garden or orchard irrigation could be practiced locally without overdeveloping the aquifer.

The quality of the water in the Ogallala is good. There is only a small amount of dissolved matter, most of which is calcium bicarbonate.

QUATERNARY ALLUVIUM

STREAM-CHANNEL ALLUVIUM

The stream-channel alluvium is the silt, sand, and gravel

³⁵ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: *Am. Geophys. Union Trans.*, op. 519-524, 1935.

³⁶ Theis, C. V., informal communication

that has been deposited by the present streams. With some exceptions such material is present in essentially continuous bands along the streams of appreciable size, and to a lesser extent along some of the small intermittent creeks. The width of the band of alluvium is in proportion to the size of the stream. There are places along the Canadian River where the alluvium extends for more than a mile from the stream. The band is narrower along smaller streams and almost entirely absent in the smallest arroyos. The band may or may not be symmetrically placed with respect to the present stream. Alluvium may be fairly well distributed on both sides of a stream course, but in places it may be all on one side. For instance, at the bridge east of Maxwell across the Canadian River there is no alluvium on the east side of the river, where it is cutting into the bedrock of shale.

The alluvium ranges in thickness from a feather edge to more than 40 feet. It may exceed 50 feet in thickness in places along the main streams. It also varies in character. Some coarse gravel occurs in nearly all of it, but finer sizes, including clay also occur and, by filling the interstices between the pebbles, decrease the permeability. In places the permeability is low for gravelly material. In other places it is high. The alluvium along the Vermejo River at Dawson and along Crow Creek at Koehler has a high permeability, and the underflow in the gravel at these localities furnishes the public supply of these two communities.

The thickness of saturated alluvium is nowhere great. In places it may exceed 10 feet, although about 5 feet is probably a good average. However, a small thickness of saturation will supply enough water for many head of cattle, provided that the gravelly material is sufficiently permeable. Most of the present wells adjacent to streams produce from alluvium, as is shown by the accompanying well tables and one of the best places to try for small ground-water supplies are in these stream deposits. This is particularly true in the area underlain by the Smoky Hill marl member of the Niobrara formation and the Pierre shale. In many places no gravel may be found, or it may be unsaturated, but, inasmuch as little water has been found in these shales and that which has been found is of poor quality, any strip of alluvium in their outcrop areas presents the best chance of obtaining water at shallow depth.

The quality of the water in the alluvium is variable and depends largely on the local character of the gravelly debris. If there is considerable admixed clay the water is apt to be of poor quality. One sample taken from a well near the outer fringe of alluvium along the Canadian River showed .over 1,100 parts per million of sulfate. Samples taken from other wells indicate water of fair to poor quality.

PEDIMENT GRAVELS

Remnants of pediments are abundant in Colfax County, particularly near the Canadian River and its larger tributaries. They stand as mesas and as flat-topped benches or spurs. The pediment gravels are the veneers of sand and gravel that cap these flat-topped remnants (or underlie the lava of some lava-capped mesas). These sand and gravel veneers have a maximum thickness of about 20 feet, but they are generally thinner than this. In some places they are not over 5 feet thick, and in some places on pediments they are absent.

The pediment gravels receive recharge from rain and snow, and a thin zone of water collects at the base of the gravel, on the underlying **pediment** surface which is usually shale. This water moves down the pediment slope, and the water evaporates or emerges as seeps or springs at the lower edge or escarpment of the pediment. Most of the discharge probably emerges as small seeps from which the water quickly evaporates. Springs do not seem to be abundant, although some are known, and a few have been visited by the writer. Two miles east of Maxwell there is a discharge of about 50 or 75 gallons per minute from pediment gravel, and directly and indirectly supplies the public system of this town. (See p. 78.) The small springs and seeps around Rayado and Gonzalitos Mesas probably issue from pediment gravel which underlies the lava caps of these mesas. The points of emergence of the latter springs are hidden by talus, but some gravel float is present on the steep slopes of Gonzalitos Mesa. Another small spring is present in sec. 24, T. 30 N., R. 24 E. This spring, flowing less than 1 gallon per minute, issues from pediment gravel at the contact with the underlying Pierre shale.

To determine the thickness of the saturated zone at the base of the pediment gravels a large number of shallow test holes would be required. Very little information concerning this thickness could be obtained from wells, as only a few in the county get their water from pediment gravel, and only one of these is known to reach the underlying pediment surface. Twelve wells have been dug on the Hayward and Hansen ranch east of Cimarron. These wells, ranging from 20 to 38 feet in depth, have been dug through a thick clay soil into the underlying pediment gravel, which caps the flat-topped benches in the locality. Only 2 to 3 feet of saturated gravel was penetrated in most of the wells, but one well was dug to the underlying shale. This well showed 8 feet of gravel, only the lower 4 feet of which was saturated. All the wells at this ranch are equipped with hand pumps, and it is said that most of them can be pumped dry in a very short time. One well in sec. 24, T. 29 N., R. 24 E., was apparently completed in pediment gravel, but it was dry in 1946.

If the pediment gravels commonly contain as much admixed

silt and clay as is indicated by the low capacities of the wells on the Hayward and Hansen ranch, at least 5 to 10 feet of saturated gravel would be necessary to supply a windmill well. As these gravels are never more than about 20 feet thick, and are generally about 10 feet thick, it does not seem possible that their lower, saturated portions can be thick enough to be of any particular importance for future wells. However, if any attempts are subsequently made to locate wells in pediment gravel, it is recommended that the holes be placed toward the lower *edges* of the pediments. As the water collects and drains in this direction, the thickness of saturated gravel will be greatest at points near the lower edges of the pediments.

The quality of the water from the pediment gravels is usually fair, although one well on the Hayward and Hansen ranch yields water of poor quality, notably with a very high concentration of sulfate.

ALLUVIUM SOUTH OF THE KING RANCH

South of the King ranch and north of Palo Blanco Mountain is a poorly drained alluviated area dotted by small lakes that grow to larger size in wet years. This area is sometimes referred to as the Capulin basin. Underlying much of the area is yellowish clay, sand, and fine gravel which were washed into the poorly drained area. Part of the sedimentation may have occurred in shallow lakes. The exact extent of this alluvium cannot be determined because of a soil cover, but it rests on truncated formations ranging from the Dakota sandstone to the shale of the Niobrara formation. At one place it is overlain by a recent Capulin-type basalt flow. The thickness of this alluvium is highly variable, ranging from the vanishing point to possibly 100 feet. In a recently drilled well in sec. 26, T. 29 N., R. 27 E., the driller reported 100 feet of the material.

Essentially all the wells in T. 29 N., R. 27 E., and several wells in the eastern part of T. 28 N., R. 27 E., obtain their water from this alluvium, but the limits of the areas in which saturation occurs cannot be determined without test holes. The thickness of saturation is believed not to be great at any place. It is about 30 feet in the well referred to above.

The recharge to this alluvium comes from small springs along the mesa at the King ranch and directly from precipitation. The discharge goes to the Dakota sandstone, which underlies the alluvium at its southern extension. The quality of the water is good, and there has been some consideration of its use for irrigation. With this in mind, the well in the SW 1/4 sec. 13, T. 29 N., R. 27 E., was pumped to determine roughly the permeability of the water-bearing alluvium. The well was pumped at a rate of 6 gallons per minute for a period of 2 hours, and the total draw-

down was approximately 1 foot. The indicated specific capacity of 6 shows that the alluvium in the vicinity of this well is not highly permeable, and it is doubtful that it is sufficiently permeable elsewhere to give wells of high specific capacity. Assuming that the general permeability of the alluvium is of the order indicated by the well, irrigation could be practiced on only a small scale, and this would rapidly deplete the water stored in the area.

LANDSLIDE MATERIALS

Landslide and talus materials cover most of the mesa slopes. These materials, because of their broken condition, absorb rainfall and particularly snow melt easily and transmit the water downward to the bedrock surface. Large landslide blocks make wide benches on the hillsides, as on the north side of Johnson Mesa and on the valley slopes above Lake Malloya, which serve to arrest the runoff and promote seepage underground. As water also moves in places from the bedrocks into these surficial materials, some springs emerging from the landslide material are permanent but many of them are distinctly seasonal. The pronounced seasonal variation in flow in many of the springs above Lake Malloya (Table 6) indicates their seasonal character.

LOESS-LIKE DEPOSITS

The loess-like deposits consist of a thin layer of wind-blown silt and clay which is present at many places on the western part of the lower plains. This surface material occurs mainly west of the Canadian River. It is gray to dirty yellowish gray in color, and it ranges up to about 20 feet in thickness. At some places in the Maxwell area it is separated from the underlying shale by a few feet of clayey gravel, apparently deposited by sheet wash prior to the deposition by wind.

This wind-laid material has a high proportion of clay and seems to have a very low permeability. On the Maxwell tract, and elsewhere, several holes are known to have penetrated it without finding more than a small amount of water. One recently bored well 3 miles northwest of Maxwell showed several feet of the clayey material underlain by clayey gravel. Although the gravel doubtless supplies most of the water for this well, the water level was lowered 1.4 feet by 5 minutes of pumping with a hand pump. Two other wells, one 4 miles southeast of Raton and one about 3 miles southwest of French, obtain their water from the loess-like deposits. Both these wells are reported as being very weak.

It appears that locally there is a few feet of available water at the base of the loess-like deposits, but in any attempts to find water in them the holed should be dug so that a sizable reservoir

will be made. If no water is obtained after the hole has penetrated the underlying weathered zone of shale, the hole should be abandoned.

IGNEOUS ROCKS

INTRUSIVE ROCKS

The intrusive rocks comprise the rocks of the sill-complex and the later basaltic dikes and plugs.

The sill-complex is mainly south of Laughlin Peak and north of Chico post office, where many sills have been emplaced in the Cretaceous shales. Most of the sills are in the Graneros shale, but some are in the Carlile shale, and they extend up to the Fort Hays limestone member. The grain boundaries of the minerals composing these intrusive masses are tightly interlocked, and the small amount of water that moves through the sills follows poorly developed fractures. Hence the sills are not important water-bearing rocks, although several small seeps or springs emerge from them. One small spring is present near the base of the most southerly point of the Peck's Mesa or Point of Rocks sill. It is near the southeast corner of sec. 3, T. 25 N., R. 26 E. The exposure in the vicinity of the spring is poor, but the water apparently emerges from fractures. The recharge for the spring is obtained from precipitation on the flat top of the sill. No wells are definitely known to produce water from the sills, and obtaining a successful well in them would be a matter of luck. It would depend on striking a large open fracture of an interconnecting fracture system.

The basaltic dikes and plugs of the later intrusive sequence contain no available water. However, under certain conditions dikes may affect groundwater movement. The steeply dipping tabular-shaped bodies, if they are of sufficient lateral extent, may impound ground water behind them. Such conditions are not known to exist in the upper part of the groundwater zone in Colfax County, and where the dikes cut across shale they probably are about as permeable, because of their fractures, as the shale itself. On the other hand, where the Dakota sandstone is buried beneath younger sediments, if, as is probable, the dikes lengthen at depth or become more numerous, they may be effective in retarding groundwater movement through the sandstone. It is also believed that the quality of the water in the Dakota sandstone in certain areas has been affected indirectly by the dike intrusions. It is probable that magmatic water rose along the boundaries of the dikes shortly after they were intruded. This water could readily have entered the Dakota, and additions of such magmatic water are most likely responsible for the quality of the water near Springer. (See p. 54.)

VOLCANIC ROCKS

Volcanic rocks cover a large area in Colfax County, but they are most abundant in the northeastern part of the county. In the main they consist of basalt flows, although other rock types are present, and some light-colored felsic rocks occur, as at Laughlin and Palo Blanco Mountains. The volcanic rocks are thickest on the high mesas along the northern edge of the county, where two to four individual flows are generally present in the caps of the mesas. Here basalt is 300 feet thick in places. On the lower mesas and plains, where only one flow is usually present in a given sequence, thicknesses of 40 to 100 feet are most common.

Connected pore spaces have been developed in most of the volcanic rocks. As the lava solidified, interconnected joint systems often formed, and where more than one flow occurred other factors caused the flow boundaries or interflow zones to have connected porosity. For instance, during solidification the more quickly chilled tops and bottoms of the flows broke up into various-sized fragments as the lava continued to move. This formed breccia. Following solidification and between eruptions, weathering developed additional rubble on the upper surfaces of the flows. Also, the molten lava, when erupted, contained dissolved water and gases. As the lava cooled these materials became insoluble, and separated as vapor. This formed bubbles in the more fluid basalts, and the bubbles rose and coalesced near the tops of the flows.

The groundwater movement in the volcanic rocks takes place through the connected openings. Vertical movement follows the joints or fractures. The horizontal movement follows both the fractures and the interflow zones.

The recharge to the volcanic rocks is gained from the precipitation on them. As the drainage is usually poor on the lava-capped mesas, little surface drainage passes over their edges, and consequently the precipitation either evaporates, is transpired by the vegetation, or soaks into the rock. Nearly all of it is transpired or evaporated in the summer, and most of the recharge is received in the winter. Even then much of the precipitation evaporates. The dark-colored surfaces absorb heat more rapidly than light-colored rocks. High rates of melting may occur around the edges of piles of snow, and where this takes place much of this melt water probably seeps down into the rock.

As the water moves down through the lavas, thin zones of saturation tend to develop at interflow zones, if more than one flow is present, but in such cases there is a continual loss of water to unsaturated lava below. On reaching the base of the lava the course followed by the water is determined by the character of the underlying rocks. If shale is present the water moves laterally down the gentle slope of the upper shale surface,

and finally emerges as springs or seeps at the lower edges of the lava flow. If a veneer of pediment gravel is present the water moves into it, and then is diverted laterally by the rocks, in most places shale, that underlie the gravel. Other rocks are involved on the high mesas near Raton, and the movement of water there is described in the section on water of the high mesas. (See p. 73.)

It is possible to develop wells in the volcanic rocks, but in general the water-bearing zones in these rocks are too thin to support wells. Springs, however, issue from the basalts, both from interflow zones and from near the bases of flows. Two of these springs are on the east side of Bartlett Mesa. Both issue from fractures that tap an interflow zone lying a few feet above. The flow of the larger spring is nearly 25 gallons per minute. The flow of the smaller spring is about 8 gallons per minute and shows little seasonal variation, as is indicated by recorder records. Three springs were visited along the south side of Johnson Mesa east of where the Trinidad sandstone pinches out. In this area basalt and immediately underlying gravel rest on the Smoky Hill marl member of the Niobrara and the Pierre shale, but because of heavy talus it was not possible to determine whether the springs issued from the base of the basalt or from the underlying gravel. Two of these springs were small, but the third, Dale spring (near boundary between secs. 28 and 29, T. 31 N., R. 26 E.) in Taylor Canyon, a large reentrant canyon on the south side of the mesa, flows about 75 gallons per minute.

A spring at the Joyce ranch flows about 80 gallons per minute. The water issues from fractures and other openings at the base of a basalt flow that is in contact with an underlying impermeable sill. A quarter of a mile east of this spring is a smaller spring that flows about 40 gallons per minute. It emerges at the same contact. North of these springs the basalt flow overlies the sill over several square miles, and the contact between the two bodies of rock slopes south. The recharge received by the permeable basalt supplies a lens of water that rests on the impermeable sill. The water of this lens moves down the gently sloping contact and feeds both springs.

Beneath and immediately east of Eagle Tail Mountain is a basalt-capped pediment remnant that slopes southwest. Several small springs are said to issue from near the base of the basalt at the Crews ranch, at the down-slope end of this pediment. Another small spring in lava is present in the SW¹/₄ sec. 13, T. 29 N., R. 24 E. It emerges from near the base of the lava at the lower end of a small pediment remnant.

The quality of the water from the lavas is good, although two analyses indicate rather high concentration of calcium bicarbonate. The calcium carbonate probably is derived from cal-



The large spring that issues from the base of the basalt flow at the Joyce ranch.

cite that developed as an alternation of feldspar after the eruption of the lava.

WATER OF THE HIGH MESAS

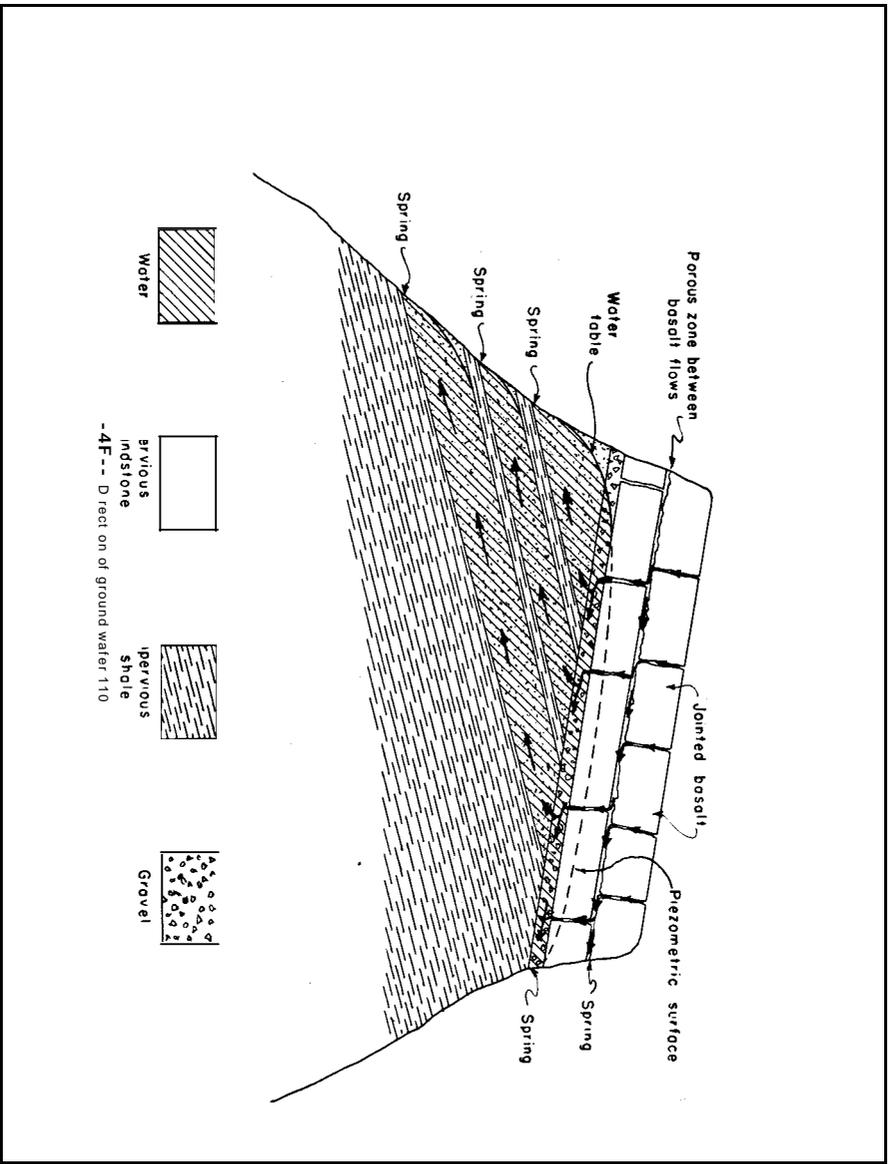
The high mesas at the north edge of Colfax County include Bartlett, Fishers Peak, Barilla, and Johnson Mesas. These mesas, the lava-capped remnants of two erosion surfaces, stand high above the surrounding plains. Bartlett Mesa, the remnant of the lower erosion surface, rises to more than 1,000 feet above the adjacent plains, and it is about 500 feet lower than nearby points on the three higher mesas which are the remnants of the higher erosion surface. The tops of the mesas slope to the southeast. In Colorado, the northwestern part of Fishers Peak Mesa is above an elevation of 9,500 feet, but Johnson Mesa, which extends eastward almost to the eastern edge of Colfax County, falls to an elevation of less than 7,500 feet at its southeastern corner, where its surface is only about 500 feet above the adjacent plains.

The caps of the mesas are basalt, which ranges from about 50 to 300 feet in thickness, and the basalt consists of one to four separate flows that range from 50 to 100 feet in thickness. The late Pliocene (?) flows of Johnson, Barilla, and Fishers Peak Mesas were poured out on a gravel-covered erosion surface. This gravel ranges from 10 to 70 feet in thickness,³⁷ and, according to unpublished diamond-drill logs of the Yankee Mining Co., there are thin zones of sand and gravel between the flows on Johnson Mesa, of which there are two to four. There are only scattered patches of gravel on the erosion surface beneath the early Quaternary basalt cap of Bartlett Mesa.

The basalt flows of the mesa caps, the underlying gravels, and the erosion surfaces beneath the gravels all dip to the southeast at about 50 feet per mile. The rocks underlying the erosion surfaces dip about 100 feet per mile to the northwest. The youngest rocks beneath the erosion surfaces are the sandstones, shales, and interbedded coals of the Raton formation. This formation is about 1,000 feet thick immediately north of the town of Raton, but much of it to the east has been eroded, and all has been removed under most of Johnson Mesa. Toward the western part of the group of mesas the Vermejo formation underlies the Raton formation, and beneath the Vermejo is the Trinidad sandstone. Under the western part of Johnson Mesa this sandstone thins to the east because of erosion, and farther east on this mesa the shales of the Pierre and Niobrara immediately underlie the gravel of the mesa.

The source of recharge to the high mesas is limited to the

³⁷ Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 8, 1922.



precipitation on them, but the recharge is probably higher on these mesas than anywhere else in the county because the precipitation is greater at the higher altitudes and because the surface drainage is poor. Another factor important to recharge is the presence of abundant perched-water lakes on these mesas. These small lakes, fed by surface drainage and, in places, by lava interflow zones, extend to within short distances of the edges of the mesas. Black and Dominguez Lakes at the north end of Barilla Mesa are within 300 yards of the mesa escarpment. These lake depressions have originated in several ways. Some are due to the damming of shallow valley-like depressions by later basalt flows. Some are due to subsidence caused by the lateral draining of lava from the lower part of a flow after the upper surface of the flow had hardened.

The moisture that escapes evaporation and transpiration seeps down from the perched lakes and from the surrounding mesa surfaces into the basalt. As this water moves downward it follows fractures, interflow zones, and coalesced gas cavities. Most of the downward movement is controlled by fractures, and when the downward-moving water reaches an interflow zone it tends to follow the zone laterally. These zones lose water to unsaturated basalt below, but as they dip to the southeast they deflect the slowly moving water in that direction. The gravel beneath the basalt of the three highest mesas also dips southeast. Where less permeable rocks lie below they likewise cause the downward-moving water to be deflected to the southeast.

On the central and eastern parts of Johnson Mesa the gravel is underlain by impermeable shale. Any downward-moving water that reaches this impermeable shale then flows southeastward to emerge on the south and east slopes of the mesa. It is estimated that about two-thirds or three-fourths of the water recharged to this part of Johnson Mesa is discharged on the south and east sides of the mesa because of the southeasterly slope of the surface at the top of the shale.

Where the Raton formation underlies the high mesas any ground water that reaches its sandstone beds changes its direction of movement to the northwest, to follow the dip of these beds. Most of this water is discharged on the north and west sides of the mesas. Figure 10 is a diagrammatic cross section showing how the structure and stratigraphy control the direction of movement of the ground water of the high mesas.

Many small springs emerge from the high mesas, and most of the springs in the vicinity of Raton and its municipal reservoir have been visited. The two springs that issue from the basalt cap on Bartlett Mesa have been described. (See p. 72.) On the south side of this mesa are other small springs which issue from the base of the basalt and the upper few feet of the Raton forma-

tion. Two of these springs are within 500 feet of each other, one on either side of the old road to the top of Bartlett Mesa. The spring on the west side of the road flows 15 gallons per minute. The one on the east side flows about 10 gallons per minute. Farther east, on the south side of this mesa, are about 10 smaller springs with flows ranging from 1 to 5 gallons per minute. The small amount of water that emerges on the south and east sides of Bartlett Mesa suggests that much of the recharge penetrates the basalt and, entering the Raton formation which underlies the complete expanse of this mesa, is deflected to the northwest down the dip of these beds.

On the east side of Fishers Peak Mesa are eight small springs, nearly all of which flow less than 5 gallons per minute. Two of these springs emerge high, the other six low, on the slope of the mesa. The higher springs issue from the Raton formation. The lower springs issue from talus that is thick and widespread on the steep mesa slopes, and seasonal variations in the flow of these lower springs indicate that they are fed in large part by the talus from which they emerge. The largest of the springs flowed 20 gallons per minute in April 1946, but its flow gradually decreased to less than 2 gallons per minute by September of that year, when the talus on the slopes above had been drained of water that it had accumulated during the winter and early spring.

Springs and seeps are abundant on the west side of Barilla Mesa. North of Lake Malloya, the municipal reservoir of the city of Raton, are 20 or more springs that emerge at various levels on the mesa slope. Most are small, and some flow only 2 or 3 gallons per minute, but one spring flows about 35 gallons per minute. These springs issue from northwest-dipping sandstone and coal beds of the Raton formation, but, as is indicated by seasonal changes in the quantity of water discharged, some of their water is derived from talus. Except during the growing season, all the discharge from these springs enters Walton Creek, and thence goes to Lake Malloya.

Springs are abundant on the west side of Barilla Mesa because of the stratigraphy and structure previously described, and it is believed that only about one-third of the mesa's recharge is diverted to the south and east sides by the lava and gravel of the mesa cap and about two-thirds is diverted to the north and west sides by the Raton formation. Furthermore, the quantity of water that can be seen to emerge on the west side of the mesa is proportional to the area of mesa top immediately above. That is, little water emerges on the slope of the narrow, southward-extending arm of Barilla Mesa, whereas farther north, where the mesa top is broad, the springs are larger. It is believed that more recharge is received on these high mesa surfaces than is received on other flat surfaces with similar rainfall on the High Plains

east of Colfax County, where the annual recharge amounts to only a small fraction of an inch. Assuming that Barilla Mesa receives 1 inch of recharge, the north and west slopes of the mesa would continually discharge about 20 gallons of water per minute per square mile of mesa top. Assuming half an inch of recharge, the discharge would be proportionately less.

PUBLIC SUPPLIES

Raton.—The city of Raton, the county seat of Colfax County, has an estimated population of 8,000 at the present time (1946) , and the city uses from about half a million to 1½ million gallons of water per day. The source of the municipally owned water-supply system is Lake Malloya, an artificial lake about 7 miles northeast of the city, on the headwaters of Chicorico Creek. This lake is impounded by an earth dam and until 1947 had a storage capacity of about 1,000 acre-feet. At that time the height of the dam was increased to give a storage capacity of 4,000 acre-feet. The city has a water right of long standing to store this quantity of flood water at its present dam site. In addition, it has a permit as of 1891 to divert, in equal partnership with a corporation which supplies the local needs of the Santa Fe Railway Co., 1 million gallons per day from the normal flow of Chicorico Creek, subject to the satisfaction of prior rights to irrigate about 514 acres of land lying below Lake Malloya.

The quality of the water now obtained from Chicorico Creek is good. It is essentially like the water of the springs in the vicinity of Lake Malloya. (See Analysis No. 1, Table No. 9.)

Springer.—The town of Springer, in the south-central part of the county, uses as much as 250,000 gallons of water per day. It obtains its water supply from the Cimarron River, but at the present time there is a lack of adequate storage. A low earth dam, 2½ miles northwest of the town, can impound only about 95 acre-feet of water. This small amount of storage imposes a hardship on the community during dry years as well as limiting its additional growth. The lake cannot be refilled when necessary in dry summers because no water is available. At these times it is frequently necessary to buy water from Eagle Nest Lake, in spite of the fact that the town's water rights seem adequate. Raising the present dam to accommodate additional storage when water is available is limited by the position of the intake ditch, which apparently cannot be changed. The height of the small dam can be increased no more than 10 feet. Such construction Probably would give adequate storage for at least a period of years but it might not be satisfactory for a long period of time.

If the quality of the water in the Dakota sandstone in the Springer area were satisfactory, well production from this aquifer

would be the cheapest and most desirable means of augmenting the present public supply. The top of this aquifer underlies the town site at a depth of 450 to 500 feet, and the hydraulic pressure within the beds at this locality is such that the wells would nearly flow. Pumping costs to the present standpipe would be reasonable. However, the water in the Dakota of this part of the county contains about 5 parts per million of fluoride, 1,000 parts of sodium chloride, and 1,000 parts of sodium bicarbonate. Such water cannot be treated for domestic use economically on a large scale.

Another source of ground water has been suggested in the springs of Gonzalitos Mesa. Lying 10 miles southwest of Springer at the nearest point are two east-west-trending lava-capped mesas —Gonzalitos and Rayado Mesas. Gonzalitos Mesa is nearest the town and the west end of Rayado Mesa is about 20 miles from the town site. The nearly flat lava caps of these hills slope gently in a direction somewhat east of south. Thin pediment sand and gravel, present beneath the lava, at least locally, rests on impermeable shale whose surface also slopes east of south. Because of the southerly slope of the surface of the impermeable shale on which the perched ground-water body of the mesa rests, and the similar gradient of the overlying water-bearing pediment material and lava, probably about three-fourths of the recharge of the mesas emerges as small springs and seeps on the south side of the flat-topped hills. Most of these springs are high on the mesa slopes, essentially at the base of the lava, but some water seeps down through the talus-covered slopes to emerge at lower elevations. The largest springs are in the canyon north of the Fernandez ranch house in sec. 25, T. 24 N., R. 20 E. Here a valley has been cut back into the south side of Gonzalitos Mesa and has thus caused a concentrated emergence of water. Several small springs yield a total of about 40 gallons per minute in this canyon, and it has been suggested that this water be piped to Springer. Laying pipe through the talus of the upper part of the canyon would be difficult and costly. The driving of a tunnel and installation of an infiltration gallery at the top of the shale surface on the south side of either or both mesas, to catch additional water, also would be costly. It may be more practical to locate another dam site for the storage of additional surface water, to which the town is understood to have rights.

Maxwell.—**This** town, with a present population of about 750, uses as much as 60,000 gallons of water per day, and is supplied directly and indirectly from pediment gravel developed on a low-lying pediment remnant formed on the Niobrara shale east of the nearby Canadian River. About 3 miles east of Maxwell a small valley has been cut back into the lower edge of this westward-sloping pediment, which has been formed on shale of

the Niobrara formation. Along the edges and at the head of this arroyo there is a discharge of about 50 or 75 gallons per minute from the pediment gravel. In part, this discharge flows directly into a small reservoir and then enters the town's supplying conduit. Some of the discharge enters alluvium which has been derived from the pediment and which is present along the arroyo. Three shallow windmill wells, located in this alluvium, also add water to the town's supply line.

Farley.—This small unincorporated village of 200 or 250 inhabitants uses from 5,000 to 8,000 gallons of water per day. It is supplied by two wells, each 250 feet deep, that are owned by a local merchant, Mr. A. C. Hoffman. The aquifer supplying the water is the Dakota sandstone, whose upper surface underlies the town site at a depth of 70 feet, and which is saturated to within about 45 feet of its top. The quality of the water from these beds is good in this part of the county (see Analysis No. 7, Table No. 9), though the fluoride content, 1.4 parts per million, approaches the amount sufficient to cause mottling of teeth in children during the period of formation of permanent teeth. Should it become necessary, through continued growth of the community, to drill additional wells, it would be wise to space them somewhat farther apart than the present two wells, which are within a few feet of each other, in order that their respective cones of depression would interfere less during pumping.

Cimarron.—This community, with a population of 750, has a small diversion dam 10 miles west of town on Cimarroncito Creek, with a conduit leading to a 500,000-gallon concrete reservoir a mile southwest of the town site. As the town uses from 50,000 to 150,000 gallons of water per day, this small reservoir capacity is insufficient for the town's needs when the supplying creek is dry. As no ground water is available for the public system, it may be necessary to provide a storage reservoir on Cimarroncito Creek. According to Mr. F. H. Alpers, the superintendent of the municipally owned system, a suitable dam site has already been surveyed on this creek. The quality of the available water is good. (See Analysis No. 3, Table No. 9.)

Miami.—This small unincorporated farming community in the southern part of the county has a population of about 150. The town's domestic water system is adequately supplied by Rayado Creek.

Dawson.—This mining camp of approximately 1,400 people has a large rectangular well about 100 by 25 feet in area and 25 feet in depth. This well, sunk in the alluvium of the Vermejo River flood plain is inadequate in dry years when the water table is low and the stream's underflow is at a minimum. The well was dug at an early date and it is not known whether it is bottomed on the underlying Pierre shale, or above the shale

within the alluvium of the river bed. An additional well should provide more water than deepening the present well. It may be necessary to drill a few test holes to the underlying shale to determine a place where the alluvium is sufficiently thick.

Koehler.—The mining camp of Koehler has a dug well about a mile east of the town site which produces from the alluvium of Big Crow Creek. This one well, approximately 12 feet square and 30 feet deep, adequately supplies the community at the present time.

MAP SHOWING AVAILABILITY OF GROUND WATER

In Plate 3, eastern Colfax County is divided into a number of areas within each of which ground water occurs under generally similar conditions. The boundaries between these areas are by necessity approximate and there is some variation in groundwater characteristics within the areas. As a consequence the text of the report and the geologic map (pl. 1) should be used with the following description and map.

Area 1.—The Pierre shale and the Smoky Hill marl member of the Niobrara formation are present at the surface over the greater part of this area, although locally they are overlain by lava or pediment gravel. In general these two stratigraphic units dip to the northwest at a rate of about 100 feet per mile; the younger Pierre shale lies at the surface in approximately the northwestern half, and the immediately underlying shale of the Smoky Hill marl member crops out in the southeastern half of this northeast-trending area. (See pl. 1.)

Where the Pierre shale, nearly impermeable black fissile shale, is present, wells can be developed in alluvium in places along the valleys. Alluvium also commonly offers the best possibility of obtaining wells where the shale of the Niobrara formation is present, but the latter shale, which is calcareous and sandy, seems generally capable of furnishing stock-water wells of small capacity, in areas of low topography. There is one conspicuously sandy zone in the shale of the Niobrara which in the future may prove a source of stock water in some areas. This zone, about 300 feet above the base of the unit, cannot be shown on the map because it is poorly exposed.

Some of the veneers of pediment gravel on the flat-topped benches or tableland may be worth exploring by means of shallow test holes. Most of the areas so veneered are too small to warrant such exploration, and on the larger benches the continuity of the gravel is obscured by soil or lava, but it is possible that some of the larger benches may contain sufficient water at the base of the gravel to supply windmill wells. (See p. 67.)

Within about 2 miles of the southeastern boundary of this area, wells may be obtained in the Fort Hays limestone member at depths less than about 200 feet. At greater depth the Fort Hays is apt to be dry. Also within the same area, the Dakota sandstone can be reached at depths less than about 700 feet. Farther north and west the Dakota is progressively deeper. (See pl. 2.)

Areas 2a, b, c, and d.—These areas comprise the high lava-capped mesas. The lava cap of Bartlett Mesa (area 2a) thickens to the northwest and ranges from about 50 to 400 feet in thickness. This cap is underlain by the Raton formation, which doubtless can supply small-capacity wells with water of good quality, but probably wells on the western half of the mesa would not be economically feasible because of the considerable thickness of the lava cap. Springs are present on the south and east sides of this mesa.

The lava cap of Barilla Mesa (area 2b), ranging from about 100 to 250 feet in thickness, is largely underlain by gravel, which in turn is underlain by the Raton formation. Only a part of the mesa lies within Colfax County, and it is possible that the gravel in this part of the mesa contains only a thin zone of saturation, particularly near the mesa edges, but the underlying Raton formation will probably supply small-capacity wells. Locally, in areas of low topography, shallow wells may be obtained from volcanic rubble on this mesa. Immediately north of Colfax County, springs are numerous on the west side of the mesa.

Areas 2c and 2d, or Johnson Mesa and one of its outliers, are capped by about 100 to 300 feet of lava which appears to be completely underlain by a layer of gravel, and some of the basalt flows composing the lava cap, at least on Johnson Mesa, are separated by thin zones of sand and gravel. Except near mesa edges, these interflow gravels can support wells furnishing good water for stock and domestic purposes, and it is possible that wells of moderate capacity may be obtained locally from the gravel beneath the mesa cap. In topographically low areas on Johnson Mesa shallow wells may be obtained in places from volcanic rubble. Seeps and springs, one of which flows about 75 gallons per minute, are fairly numerous on the south side of this mesa.

Area 3.—This is an area of complex ground-water conditions (sill-complex area). Wells can be obtained locally in the Dakota sandstone, the Greenhorn limestone, or the Quaternary alluvium, but professional advice should be obtained for suitable locations.

Areas 4a, b, c, d, e, and f.—In these areas, which lie largely between the exposure belts of the Greenhorn and Fort Hays, ground water can be obtained from the Dakota sandstone at depths ranging from about 200 to 450 feet. In areas 4a, e, and f,

wells may be obtained in Quaternary alluvium locally, in addition to the Dakota sandstone. Area 4b is an area of variable groundwater conditions. Wells can be obtained in the Dakota sandstone, but in the western part of area 4b, at least, this water is of poor quality. The Greenhorn limestone can also be expected to furnish small supplies of water for as much as 2 miles down dip from its exposures. At places along the eastern edge of T. 25 N., R. 25 E., the Fort Hays limestone member will furnish some water at depths of as much as about 150 feet. Locally water can be obtained at shallow depths from alluvium along the valleys. In area 4c wells may be obtained in the Dakota sandstone at depths of about 450 feet, and in area 4d wells may be obtained in the Dakota sandstone, Greenhorn limestone, Carlile shale, and, locally, Quaternary alluvium.

Areas 5a d 5b.—**Except** in the small areas of igneous rocks and along the Canadian Valley and the deeper valleys northeast of Tafoya post office, ground water can be obtained from the Dakota sandstone at depths ranging from about 10 to slightly more than 200 feet. In area 5b the water in this formation is generally of good quality, but in the western part of area 5a, at least, the water is of poor quality. (See p. 53.) At some places in these areas water of good quality can be obtained at shallow depth from alluvium.

Area 6.—**Except** as noted previously in the report (see p. 62), and in lava-covered portions of this area, ground-water of good quality for domestic, stock, and small irrigation supplies can be obtained at depths ranging from about 100 to 250 feet in the unconsolidated sand and gravel of the Ogallala formation, and in the Dakota sandstone at somewhat greater depths.

Area 7.—**Except** in lava-covered portions of this area, groundwater of good quality may be found at most places in alluvium (see p. 65) at depths ranging from about 15 to 100 feet. In the southeastern half of this area the water-bearing Dakota sandstone occurs at depths ranging from about 50 to 200 feet.

RECORDS OF WELLS
AND SPRINGS

RECORDS OF WELLS AND SPRINGS

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.

[Shown on p1. 3. All wells are drilled unless otherwise noted under "Remarks"]

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 31 N., R. 25 E. NW ¼ NE ¼ sec. 22	J. H. Towndrow	—	1890?	Mesa top	8,135	11.0	5.9	June 24
Do.	do.	Bill Brink	1935	do.	8,135	177.0	—	—
NE ¼ NE ¼ 26	T. J. Simons	Gile Bros.	1940	do.	8,140	200.0	164.6	June 24
T 31 N., R. 26 E. SW ¼ NW ¼ c. 14	Floyd and Arthur Lark	Bill Brink	1942	do.	7,970	225.0	186.1	Do.
SW ¼ sec. 15	Thomas Lark	do.	1942	do.	8,005	90.0	70.0	Do.
NW ¼ sec. 19	T. J. Simons	—	—	do.	8,025	150.0	—	—
NW ¼ sec. 27	F. B. Floyd	Bill Brink	1941	do.	8,000	252.0	240.0	—

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of Lift ¹	Use of Water ²	Analysis Number, See table 7	Remarks
	Depth to top of bed (feet)	Character of Material	Geologic formation				
J.H. Towndrow	0	Weathered Volcanic Debris	Pliocene(?) basalt	W	D	-	Dug well. Aquifer 11 feet thick
Do.	163	Sand Gravel	Ogallala(?) formation	N	N	-	Cased to 177 feet
T.J. Simons	190	Sandy Gravel and volcanics	Ogallala(?) and Pliocene(?) basalt	P	D,S	-	Cased to 200 feet
Floyd and Arthur Lark	224	Volcanics and sandy gravel	Pliocene(?) basalt and Ogallala(?) formation	W	S	-	Cased to 20 feet
Thomas Lark	-	Volcanics	Pliocene(?) basalt	W	D,S	-	-
T.J. Simons	-	Sandy gravel and volcanics	Ogallala(?) formation and Pliocene(?) basalt	W	N	-	Cased to 150 feet
F.B. Floyd	240	Volcanics and sandy gravel	Pliocene(?) basalt and Ogallala(?) formation	W	D,S	-	Cased to 40 feet

See footnotes at end of table.

RECORDS OF WELLS AND SPRINGS

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 30 N., R. 24 E. SW ¼ SE ¼ sec. 3	J. H. Towndrow			Plains	6,435		9.5	Feb. 19
NW ¼ sec. 13	Earl Smith			Valley	6,415	20.0	9.3	Do.
NW ¼ sec. 34	L. K. Moore			Plains	6,250	16.0	Dry	Feb. 14
SE ¼ sec. 35				do.	6,320		do.	Do.
T. 29 N., R. 24 E. SE ¼ sec. 3	L. K. Moore			Valley	6,260	34.5	29.4	Feb. 14
NW ¼ SW ¼ sec. 10				Plains	6,260			
NE ¼ sec. 24	F. L. Gumm, Jr.	C. D. Fields	1946	do.	6,460	215.0		
NW ¼ sec. 25	do.	Rube Fields		Valley	6,400	40.0		
NW ¼ sec. 26				Plains	6,385	100.0+	22.2	Feb. 19

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift	Use of water.	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
J. H. Towndrow Earl	—	Clay and silt?	Loess-like deposits (?)	W	S	-	-
Earl Smith	-	-	Quaternary alluvium	W	S	-	Dug Well
L. K. Moore	-	Shale	Pierre shale	N	-	-	Do.
-	-	-	Pediment Gravel(?)	N	-	-	-
L.K. Moore	-	Silt, sand, and gravel	Quaternary alluvium	N	N	-	Do.
-	-	-	-	-	N	-	Abandoned oil test
F.L. Gumm Jr.	-	Sandy shale	Smoky Hill marl member	W	-	41	-
Do.	-	Silt, sand, and gravel	Quaternary alluvium	W	D,S	-	-
-	-	Shale	Smoky Hill marl member	N	N	-	-

See footnotes at end of table.

Records of Wells and Springs

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 29 N., R. 25 E. SW ¹ /4 sec. 31	F. L. Gumm, Jr.	C. D. Fields	1946	Mesa top	—	200.0	—	—
T. 29 N., R. 27 E. NW ¹ /4 sec. 11	James Morrow	—	—	Plains	6,800	14.0	4.9	Mar. 12
NE ¹ /4NE ¹ /4 sec. 13	John King	—	—	do.	6,810	35.0	—	—
SW ¹ /4 sec. 13	do.	—	—	do.	6,800	18.0	12.5	Mar. 12
SW ¹ /4 sec. 14	W. G. Pinson	—	—	do.	6,825	—	—	—
SW ¹ /4 sec. 15	do.	—	—	do.	6,780	—	7.0	Mar. 12
SW ¹ /4 sec. 22	do.	—	1933	do.	6,870	56.0	—	—
NW ¹ /4 sec. 25	W. J. Pinson	—	—	do.	6,840	60.0	—	—
SW ¹ /4 sec. 25	W. G. Pinson	—	1920	do.	6,865	90.0	—	—
SE ¹ /4 sec. 26	John King	John Thomas	1946	do.	6,875	110.0	69.3	May 15

Records of Wells and Springs

Owner or name	Principal water-bearing bed			Method of lifts	Use of water=	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
F. L. Gumm, Jr.	—	Shaly sandstone	Smoky Hill marl member	—	—	—	
James Morrow	—	—	Quaternary alluvium	W	S	—	Dug well.
John King	—	—	do. (?)	W	S	-	
Do.	—	—	Quaternary alluvium	W	S	54	Do.
W. G. Pinson	—	—	do.	W	S	—	Temperature 48u F.
Do.	—	—	do.	W	S	—	Dug well.
Do.	—	Loose sand	do.	W	S	—	Do.
W. J. Pinson	—	—	do.	W	S	-	
W. G. Pinson	—	—	do.	W	S	-	
John King	0	Clay, silt, and sand	do.	—	—	—	Cased to 99 feet. Aquifer 100 feet thick.

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS. EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 29 N., R. 27 E. SE ¼ SE ¼ sec. 36	W. G. Pinson	—	—	Plains do.	6,885	140.0	94.4	Mar. 27
T. 28 N., R. 24 E. NW ¼ sec. 11	Juan C. Torres	—	—	do.	6,635	—	—	—
SW ¼ SE ¼ sec. T. 28 N., R. 25 E. sec. 8	do.	—	—	Do.	6,690	—	—	—
	W. H. Penix	—	—	Valley Plains	6,680	40.0	—	—
NW ¼ sec. 18	do.	—	—	do.	—	—	—	—
SE ¼ sec. 18	do.	—	—	do.	—	—	—	—
T. 28 N., R. 26 E. SW ¼ sec. 1	Joe Cunico	—	—	do.	7,000	120.0	—	—
sec. 4	Mrs. John Cunico	—	1909		6,975	40.0	—	—

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method (of lift)	Use of water	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
W. G. Pinson			Dakota sandstone (?)	W	D, S	11	Cased to 140 feet.
Juan C. Torres		Shale	Smoky Hill marl member	W	S		Dug well.
Do.		do.	do.	W	S		
W. H. Penix			Quaternary alluvium (?)	W	S		
Do.		Shale	Smoky Hill marl member	N	-		Do.
Do.			Fort Hays limestone member (?)	W	S		
Joe Cunico		Shale and limestone	Fort Hays limestone member	W	S		
Mrs. John Cunico		Sandy shale	Smoky Hill marl member	N	N		Dug well. Abandoned.

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 28 N., R. 26 E. sec. 4	Mrs. Fred Cunico	—	1910	Plains	6,980	125.0	—	—
SW ¼ sec. 5	Mrs. Angelo Cunico	—	—	do.	6,930	110.0	—	-
sec. 5	Chris Cunico	—	—	do.	6,960	140.0	—	—
NE ¼ sec. 8	Joe Cunico	—	—	Valley	6,900	52.0	—	-
SE ¼ sec. 10	O. F. Harris	Lee Finley	1914	Plains	7,005	58.0	41.3	May 16
SE ¼ sec. 11	do.	—	1917	do.	—	48.0	—	—
SE ¼ sec. 11	do.	—	—	do.	6,965	165.0	20.8	Mar. 25
SE ¼ SW ¼ sec. 12	Joe Cunico	—	—	Valley	6,960	45.0	35.5	Mar. 13
NE ¼ sec. 13	S. Fouree	—	—	Plains	—	60.0	29.9	Do.
SW ¼ sec. 13	E. B. Weir	—	—	do.	7,020	60.0	39.2	May 16
SE¼ SE¼ sec. 13	M. R. Cunico	—	1936	do.	7,025	89.0	34.8	Mar. 13

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lifts	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Mrs. Fred Cunico	—	Shale and limes one	Fort Hays limestone member	W	S	-	Abandoned. Dug well. Slight hydrogen sulphide taste.
Mrs. Angelo Cunico		do.	do.	W	D,S	-	
Chris Cunico	—	do.	do.	W	S	-	
Joe Cunico	—	do.	do.	W	D,S	30	
O. F. Harris	—	do.	do.	W	D,S	31	
Do.	—	—	—	N	N	—	
Do.	—	—	—	N	N	-	
Joe Cunico	—	—	Carlile shale	W	S	—	
S. Fouree	—	Shale and limestone	Greenhorn limestone	W	S	--	
E. B. Weir	—	—	do. (?)	W	S		
M. R. Cunico	—	Shale and limestone	Greenhorn limestone	N	N	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 28 N., R. 26 E. NE ¼ sec. 14	O. F. Harris	—	1920	Plains	6,995	135.0	86.3	May 17
SW ¼ SE ¼ sec. 14	E. B. Weir	—	—	do.	7,050	125.0	58.0	May 16
NE ¼ sec. 15	J. P. Zolin	—	—	do.	—	175.0	—	-
sec: 15	do.	—	1915	do.	—	—	—	—
SE ¼ sec. 22	E. B. Weir	-	1920	do.	7,280	205.0	153.0	May 13
sec. 24	Carl Hinnegan	—	—	Valley	6,995	10.0	4.4	Mar. 13
SE ¼ sec. 25	do.	Barney Isabel	1912	Plains	7,145	200.0	123.9	May 13
NE ¼ NE ¼ sec. 27	E. B. Weir	—	—	do.	7,230	180.0	159.4	Do.
NE ¼ NE ¼ sec. 34	Carl Hinnegan	John Thomas	1917	do.	7,325	185.0	—	-
T. 28 N. R. 27 E. sec. 1(?)	W. G. Pinson	—	—	do.	6,895	—	—	—

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number see table	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
O.F Harris	-	-	Carlisle shale	W	S	29	Contain hydrogen sulfide
E.B. Weir	-	-	Fort Hays limestone member(?)	W	D,S	32	-
J.P Zolin	-	Shale and limestone	Fort Hays limestone member	W	D,S	-	-
Do.	-	-	-	W	S	-	-
E.B Weir	-	-	Fort Hays limestone member(?)	W	S	-	-
Carl Hinnegan	-	Shale and limestone	Greenhorn limestone	W	S	-	Dug Well
Do.	180	Sandstone	Dakota sandstone	W	D,S	14	Cased to 20 feet
E.B. Weir	-	-	Fort Hays limestone member(?)	W	S	33	-
Carl Hinnegan	-	-	Do. (?)	W	S	-	-
W.G Pinson	-	Sandstone	Dakota sandstone	W	S	-	-

See footnotes at end of table

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 28 N., R. 27 E. NE ¼ NW ¼ sec. 7	M. R. Cunico	—	1921	Plains	6,910	68.0	—	—
SE ¼ SE ¼ sec. 10	J. S. Hotchkiss	Barney Isabel	1918	do.	6,905	—	—	—
SE ¼ SE ¼ sec. 11	A. E. Wheeler	do.	1912	do.	6,905	120.0	95.0	—
NW ¼ sec. 13	W. G. Pinson	Grover Schmitt	—	do.	6,880	87.0	—	—
NE ¼ sec. 13	J. P. Hyden	Frank Thomas	1920	do.	6,920	385.0	116.0	—
SE ¼ sec. 21	J. W. Ledbetter	John Thomas	—	do.	6,885	180.0	—	--
SW ¼ sec. 22	do.	—	1945	do.	6,845	7.5	3.8	May 16
NW ¼ NW ¼ sec. 23	A. E. Wheeler	John Thomas	1946	do.	6,840	150.0	21.3	Do.
sec. 23	do.	—	—	do.	6,895	16.0	10.0	Do.

Owner or name	Depth to top of bed (feet)	Principal water-bearing bed		Method of lifts	Use of water, ¹	Analysis number, see table 7	Remarks
		Character of material	Geologic formation				
M. R. Cunico	—	Shale and limestone	Greenhorn limestone	W	D,S	—	
J. S. Hotchkiss	—	—	—	W	S		
A. E. Wheeler	—	Sandstone	Dakota sandstone	W	D,S		
W. G. Pinson	—	do.	do.	W	S	—	Cased to 87 feet.
J. P. Hyden	—	do.	do.	W	D,S	—	
J. W. Ledbetter	180	do.	do.	W	D	—	Cased to 20 feet. Probably produces from both the Greenhorn limestone and Dakota sandstone.
Do.	—	Shale and limestone	Greenhorn limestone	H	S	25	Dug well.
A. E. Wheeler	30	Sandstone	Dakota sandstone	N	—	—	Cased to 35 feet,
Da.	—	—	Quaternary alluvium	W	S	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographical Situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of Measurement (1946)
T. 28 N., R. 27 E.	O.R. Johnson	Carson Ratliff	1925	Plains	6,880	100.0	50.	
NW ¼ SW ¼ sec. 25	Do.			Do.	6,880	470.0		
SE ¼ SE ¼ sec. 25	Do.			Do.	6,890	26.5	Dry	May 17
NE ¼ NE ¼ sec. 26	Do.			Do.	6,840	20.0	5.4	Do.
SE ¼ SE ¼ sec. 27	Allen Hill			Do.	6,945		30.2	Do.
NW ¼ sec. 28	I.W. Williams			Do.	6,980		80.0	58.7	Do.
NE ¼ sec. 29	J.W. Ledbetter	Barney Isabel Carson Ratliff	1915 1934	Do.	7,085	114.0	89.1	May 18
Sec. 30	M.L. Rice			Do.	7,105	147.0	90.	
SW ¼ NW ¼ sec. 31	I.W. Williams			Do.	6,900		35.4	May 17
NE ¼ sec. 33	Allen Hill							

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			metno or W V	Use of water	Analysis number, see table 7	Remarks
	Depth to top of (feet)	Character of material	Geologic formation				
O. R. Johnson	—	—	—	W	S	—	
Do.	—	—	—	N	N	—	Abandoned.
Do.	—	—	—	N	N	—	Dug well.
Allen Hill	—	—	Quaternary alluvium	W	S	-	
I. W. Williams	—	—	Greenhorn lime- stone	W	S	—	Do.
J. W. Ledbetter		Shale and limestone	do.	W	S	—	Do.
M. L. Rice	—	—	Greenhorn lime- stone (?)	W	D,S	28	
I. W. Williams	140	Sandstone	Dakota sandstone	W	D,S	18	Cased to 135 feet.
Allen Hill	—	—	Graneros shale (?)	N	N	—	Abandoned.

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

00

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date measurement (1946)
T. 28 N., R. 27 E. SW ¹ /4 sec. 33	Allen Hill	—	—	Valley	6,950	65.0	—	—
SW ¹ /4 sec. 34	do.	—	—	Plains	6,900	35.0	23.6	May 17
NW ¹ /4NW ¹ /4 sec. 35	do.	—	—	do.	6,850	30.0	16.9	Do.
SW ¹ /4SW ¹ /4 sec. 35	do.	—	—	do'	6,865	60.0	—	—
		—	—	do	6,845	30.0	—	—
T. 27 N., R. 24 E. SE ¹ /4SW ¹ /4 sec. 35	Sauble Ranch	—	—	do.	6,250	—	—	—
T. 27 N., R. 26 E. NW ¹ /4NE ¹ /4 sec. 1	J. A. Torres	—	—	do.	7,165	217.0	125.9	May 18
SE ¹ /4 sec. 12	Alvin Rickels	—	—	do.	7,175	127.0	115.1	May 13
sec. 13	H. T. Foree	—	—	do.	7,335	142.0	133.6	Do.
		Carson Ratliff	1924	do.	7,335	142.0	133.6	Do.

RECORDS OF WELLS AND SPRINGS

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Allen Hill	—	—	Quaternary alluvium	W	S	—	Dug well.
Do.	—	—	—	N	N	—	
Do.	—	—	Quaternary alluvium	W	D,S	—	
Do.	—	—	Dakota sandstone	W	S	13	
Do.	—	—	Quaternary alluvium	W	S	—	
Sauble Ranch	—	—	—	—	N	—	Abandoned oil test. 460 feet to top of Dakota sandstone.
T. A. Torres	—	Sandstone	Dakota sandstone	W	S	-	
Alvin Rickels	—	do.	do.	W	D,S	12	
H. T. Foree	140	do.	do.	W	S	77	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 27 N., R. 27 E. NW ¹ /4 sec. 2	John King	—	—	Valley	6,820	—	—	—
NW ¹ /4 sec. 4	E. E. Salyers	—	1915	Plains	6,990	95.0	—	—
SW ¹ /4SW ¹ /4 sec. 6	H. T. Foree	Carson Ratliff	1937	do.	7,150	100.0	78.	June 25
SW ¹ /4SW ¹ /4 sec. 6	do.	—	—	do.	7,120	90.0	—	—
SE Y4 sec. 6"	do.	Carson Ratliff	1935	do	7,115	95.0	—	—
SW ¹ /4SE ¹ /4 sec. 10	E. E. Salyers	John Thomas	192	do.	6,910	200.0	1f+	June 25
SW ¹ /4NW ¹ /4 sec. 12	John King	Carson Ratliff	1	Valley	6,745	35.0	—	—
SW ¹ /4SE ¹ /4 sec. 12	Richard Stevens	—	193	do.	6,720	—	10.6	June 25
NW ¹ /4NE ¹ /4 sec. 13	John King E. E.	—	5 —	do.	6,715	30.0	—	—
NW ¹ /4SE ¹ /4 sec. 13	Salyers	—	—	do.	6,715	30.0	21.8	June 25
			—					

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lifts	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
John King	—	—	Quaternary alluvium	W	S	-	Apparently high in iron sulfate.
E. E. Salyers	—	Sandstone	Dakota sandstone	W	S	-	
H. T. Foree	—	—	Tertiary sill(?)	W	D	-	
Do.	—	—	—	—	—	—	
Do.	—	—	—	W	S	-	Contains hydrogen sulphide.
E. E. Salyers	190	Sandstone	Dakota sandstone	W	D	-	
John King	—	—	—	W	S	-	
Richard Stevens	—	—	—	W	S	-	
John King	—	—	—	W	S	-	
E. E. Salyers	—	—	—	W	S	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 27 N., R. 27 E. sec. 14	Richard Stevens	—	—	Plains	6,785	200.0	—	—
SW ¼ SW ¼ sec. 14	E. E. Salyers	—	—	do.	6,785	22.0	7.6	May 17
sec. 15	do.	—	1913	do.	6,790	94.0	—	—
NE ¼ sec. 22	do.	—	1914	do.	6,825	125.0	—	—
sec. 24	do.	—	1930	do.	6,725	170.0	—	-
T. 26 N., R. 24 E. NW ¼ NW ¼ sec. 2	Tex Mex	—	—	—	6,275	—	—	—
NW ¼ sec. 24	Frank Sauble	—	—	Valley	6,250	16.5	11.6	May 13
T. 26 N., R. 25 E. sec. 14	C. W. Roundtree	H. G. Smith	1946	do.		26.5	15.3	April 7

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift	Use of waters	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Richard Stevens	—	—		W	S	-	
E. E. Salyers	3	Sandstone	Dakota sandstone	W	S	10	
Do.	—	do.	Do	W	S		
Do.	—	do.	Do	W	S		
Do.	—	—	Do	W	S	3	
Tex Mex	—	—		—	—	—	Abandoned oil test. Reported 442 feet to top of Dakota sandstone.
Frank Sauble	—	Silt, sand, and gravel	Quaternary alluvium	W	—	—	Dug well.
C. W. Roundtree	—	—	Quaternary alluvium(?)	W	S	—	

See footnotes at end of table

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year com-	Topographi situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 26 N., R. 26 E. sec. 32	Roe Seward	H. G. Smith	1940	Plains	6,445	100.0	37.3 June	
NW ¹ /4SE ¹ /4 sec. 33	R. O. Gaines	do.	1945	do.	6,450	76.0	54.2	June 20
T. 26 N., R. 27 E. sec. 29	Harry McCalla	do.	1938	do.	6,370	64.0	28.	—
NW ¹ /4 sec. 31	E. B. Langley	do.	—	do.	6,390	80.0	23.0	—
SE ¹ /4 sec. 33	Tafoya School	—	—	do.	6,290	38.0	30.6	May 25
SW ¹ /4SE ¹ /4 sec. 34	Virgil Coffee	—	1919	do.	6,290	169.0	—	—
T. 25 N., R. 24 E. SW ¹ /4 sec. 5	Frank Sauble	C. E. Stine- baugh	1945	do.	6,100	450.0	61.8	Apr. 3
T. 25 N., R. 25 E. SW ¹ /4 sec. 1	Roe Seward	H. G. Smith	1946	do.	—	—	—	—
NE ¹ /4NE ¹ /4 sec. 24 sec. 24	Pleasant Smith do.	Flake Fisher ---	1938 1915	do. do.	6,430 6,425	135.0 150.0	41.6 —	May 24 —

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lifts	Use of water, ¹	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Roe Seward	60	Sandstone	Dakota sandstone	W	S	-	
R. O. Gaines	—	Clay, silt, and sand	Ogallala formation	W	S	—	Cased to 76 feet.
Harry McCalla	0	Sandstone	Dakota sandstone	H	D,S	-	
E. B. Langley	0	do.	do.	W	D,S	—	
Tafoya School	0	do.	do.	H	D	—	
Virgil Coffee	0	do.	do.	W	S	5	Cased to 14 feet
Frank Sauble	430	do.	do.	W	S	22	Cased to 450 feet.
Roe Seward	—	Clay, silt, and sand	Ogallala formation	W	S		
Pleasant Smith	0	Silt, sand, and gravel	do.	W	S	—	Cased to 65 feet Aquifer 60 feet thick.
Do.	—	Shale	Carlile shale	W	S	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographical situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 25 N., R. 25 E. NW ¼ sec. 25	Joe Vocasek	—	1921	Plains	6,440	100.0	80.0	—
NE ¼ sec. 25	Pleasant Smith	—	1930	do.	6,400	130.0	89.5	May 24
NE ¼ NE ¼ sec. 26	Joe Vocasek	—	1916	do.	6,465	148.0	100.0	—
SW ¼ sec. 28	G. D. Gillespie	C. E. Stinebaugh	1945	Valley	6,225	148.0	18.9	Apr. 4
NW ¼ sec. 30	do.	—	1917	do.	6,085	—	10.0	Do.
SE ¼ NE ¼ sec. 31	do.	C. E. Stinebaugh	1945	Plains	6,125	49.0	24.4	Apr. 3
NW ¼ NW ¼ sec. 34	do.	do.	1945	do.	6,290	40.0	20.0	

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift].	Use of water ¹	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Joe Vocasek	—	—	Fort Hays limestone member or Carlisle shale	W	S	—	Cased to 80 feet. Probably produces from both the Fort Hays limestone member and "fossil zone" of Carlisle shale.
Pleasant Smith	—	—	—	W	S	-	
Joe Vocasek	—	—	Fort Hays limestone member or Carlisle shale	W	D,S	—	Cased to 90 feet. Probably produces from both the Fort Hays limestone member and "fossil zone" of Carlisle shale.
1. D. Gillespie	—	—	Greenhorn limestone	W	S	-	
Do.	—	Shale and limestone	do.	W	D,S	26	Dug well.
Do.	—	Shale and limestone	Greenhorn limestone	W	S	27	
Do.	—	Sand and gravel	Quaternary alluvium	W	S	—	Cased to 40 feet

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year com- pleted	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measure- ment (1946)
T. 25 N., R. 26 E. sec. 7	C. V. Coulter	I. G. Smith	1916	Plains	—	498.0	—	—
Center sec. 9	do.	do.	1945	do.	6,420	127.0	93.2	Mar. 29
NE ¼ sec. 10	R. O. Gaines	do.	1940	do.	6,385	130.0	71.1	June 5
NW ¼ SE ¼ sec. 13	do.	do.	1945	do.	6,330	137.0	120.0	—
SW ¼ NW ¼ sec. 14	T. A. Weishaar	do.		do.	6,370	120.0	97.2	June 5
SE ¼ NE ¼ sec. 16	Roe Seward	do.		do.	6,390	130.0	110.0	—
SW ¼ sec. 17	Robert Auras	do.	1927	do.	6,455	126.0	116.0	—
SE ¼ SW ¼ sec. 19	A. L. Smith	do.	—	do.	6,415	110.0	91.6	May 24
SW ¼ sec. 22	H. G. Smith	do.	—	do	6,310	130.0	113.0	June 20

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
C. V. Coulter	318	Sandstone	Dakota sandstone				
Do.	0	Sand and gravel	Ogallala formation			42	Cased to 127 feet. Aquifer 126 feet thick
R.O. Gaines			Ogallala formation and Dakota sandstone	W	D, S	6	Cased to 86 feet.
Do.		Sand and gravel	Ogallala formation	W	S		Cased to 137 feet. Aquifer 137 feet thick.
T. A. Weishaar	0	d o .	d o .				Aquifer 120 feet thick.
Roe Seward	0	d o .	d o .		D, S		Aquifer 130 feet thick.
Robert Auras	0	d o .	d o .	W	D, S		Cased to 126 feet. Aquifer
A. L. Smith	0	d o .	d o .	W	D, S		Cased to 110 feet. Aquifer 102 feet thick.
H. G. Smith	0	Clay, sand, and gravel	d o .	W	D, S	45	Cased 130 feet. Aquifer 130+ feet thick.

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year COM- pleted	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measure- ment (1946)
T. 25 N., R. 26 E. NE ¼ NE ¼ sec. 31	Walden Ingram	C. E. Stine- baugh	1913	Plains	6,365	115.0	98.0	—
NW ¼ NW ¼ sec. 36	G. D. Westfall	H. G. Smith	1944	do.	6,255		113.3	June 18
T. 25 N., R. 27 E. NW ¼ SE ¼ sec. 8	Virgil Coffee	do.	1942	do.	6,225	59.0	42.0	May 25
NW ¼ SE ¼ sec. 9	do.	—	1929	do.	6,200	90.0	—	—
SW ¼ SE ¼ sec. 9	do.	—	—	Valley	6,170	17.0	16.2	May 25
SW ¼ NW ¼ sec. 27	J. A. Rodgers	--	1917	Plains	6,170	150.0	125.0	—
SE ¼ sec. 28	do.	H. G. Smith	1941	do.	6,160	—	120.8	June 18
NW ¼ sec. 31	M. L. Thorne	do.	1946	do.	6,190	125.0	115.0	—
NW ¼ sec. 34	Mrs. Leila Lewis		—	do.	6,107	100.0	80+	June 18

Owner or name	Principal water-bearing bed			Method of lift'	Use of water	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
							0
Walden Ingram		Sand and gravel	Ogallala formation	W	D,S		Cased to 115 Feet. Aquifer 113 feet thick.
G. D. Westfall	0	do.	do.	W	D,S	43	
Virgil Coffe	0	Sandstone	Dakota sandstone	W	S		Cased to 10 feet.
Do.	0	do.	do.	W	D,S		
Do.	0	do.	do.	N	N		Dug well.
J. A. Rodgers			Ogallala formation	W	S		Probably produces from both the Ogallala and the Dakota
Do.	0	Sand and gravel	do.	W	S		
M. L. Thorne	0	do.	do.	W	D,S		Cased to 125 feet.
Mrs. Leila Lewis	0	do.	do.	W	D,S		Cased to 100 feet.

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 25 N., R. 27 E. sec. 35	James Saunders	H. G. Smith	1945	Plains	6,060	175.0	112.2	May 1
sec. 35	A. C. Hoffman	do.		do.	6,060	240.0		
sec. 35	Tom Davenport	do.		do.	6,060	181.0	45.9	May 1
T. 24 N., R. 21 E. NW ¹ / ₄ SE ¹ / ₄ sec. 35	Farmers Development Company		1945	do.	6,045	20.0	13.6	June 3
T. 24 N., R. 22 E. SE ¹ / ₄ SE ¹ / ₄ sec. 28	Jesse White		1916	do.	6,045	45.0	-	-
NW ¹ / ₄ NW ¹ / ₄ sec. 34	Hawes and Thompson			do.	6,045	45.0	24.0	Jan. 19
T. 24 N., R. 23 E. NE ¹ / ₄ SE ¹ / ₄ sec. 13	Mrs. A. H. Allison			do.	5,865	-	75.1	Apr. 24
T. 24 N., R. 24 E. SE ¹ / ₄ SW ¹ / ₄ sec. 1	Oliver Clay	Clyde Stine- baugh	1945	do.	6,040	140.0	-	-

RECORDS OF WELLS AND SPRINGS

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of Water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Formation Remarks				
James Saunders	72	Sandstone	Dakota sandstone	W	D,S	4	Cased to 72 feet
A. C. Hoffman	72	do.	do.	P	P	1	
Tom Davenport	—	—	—	W	—	—	
Farmers Development Company	—	Shale	—	N	N	—	Dug well.
Jesse White	14	Shale and limestone	Fort Hays limestone member	W	D,S	34	Do.
Hawes and Thompson	15+3	do.	do.	W	S	-	
Mrs. A. H. Allison	—	—	Graneros shale(?)	W	S	-	
Oliver Clay	—	Shale	do. (?)	W	S	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1996)
T. 24 N., R. 24 E. NW1/4 sec. 15	Ben Floersheim	Clyde Stinebaugh	1945	Plains	5,960	130.0	45.	I Mar. 30
SWIANW1/4 sec. 21	do.	do.	1945	do.		84.0	9.5	
T. 24 N., R. 25 E. sec. 6	R. E. Messick			do.	6,065	—	-	
sec. 7	do.			do.	6,065	29.0	13.8	
NW1/4NE1/4 sec. 15	J. P. Messick			Valley	6,190	25.0	20.0	
sec. 16	W. E. Jones			Plains	6,130	400.0		
NW1/4NE1/4 sec. 21	do.		1946	do.		40.0	38.0	
SEY4SE1/4 sec. 21	R. E. Grob	U. G. Smith	1945	do.	6,070	94.0	32.5	
NE1/4SE1/4 sec. 25	A. H. Newton	Grover Ellis	1921	do.	6,130	70.0	47.6	Do.

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Ben Floersheim	—	Shale	Graneros shale(?)	W	S	24	
Do.	—	do.	do. (?)	N	—	—	Cased to 84 feet
R. E. Messick	0	do.	do. (?)	W	S	—	Dug well.
Do.	—	Shale and limestone	Greenhorn limestone	W	S	—	Do.
J. P. Messick	—	Silt, sand, and gravel	Quaternary alluvium	W	D,S	—	Do.
W. E. Jones	—	Sandstone	Dakota sandstone	W	S	23	
Do.	0	Shale and limestone	Quaternary alluvium	W	D,S	—	Do.
R. E. Grob	—	—	Greenhorn limestone (?)	W	S	—	Cased to 94 feet
A. H. Newton	27	Shale and limestone	Greenhorn limestone	W	D,S	—	Cased to 70 feet

see footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONCLUDED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 24 N., R. 25 E. SE 1/4 SE 1/4 sec. 26	A.H. Newton		1936	Broad Valley	6,070	55.0	33.9	Apr. 24
sec. 27	Jack Randall	H. G. Smith	1935	Plains	6,100	148.0		
T. 24 N., R. 26 E. SW1/4 SW 1/4 sec. 2	Trig Brown	Terrol Randel	1946	Plains	6,250	325.0	280.7	Mar. 29
SW1/4 SE1/4 sec. 2	Ira Ingram	H. G. Smith	—	do.	6,240	165.0		
NE1/4 SE1/4 sec. 5	D. MacFadden	do.	1929	do.	6,305	130.0	115.0	
NE1/4 SE1/4 sec. 6	M. W. McConnell	Clyde Stinebaugh	1943	do.	6,413	175.0	153.9	Apr. 26
SW1/4 sec. 7	do.	do.	1945	do.	6,350	450.0		
NE1/4 NE1/4 sec. 8	N. T. Ward	H. G. Smith	—	do.	6,330	163.0		

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of 11ft ¹	Use of waters	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
A. H. Newton	0	Silt, sand, and gravel	Quaternary alluvium	N			Cased to 55 feet Bored well.
Jack Randall			Graneros shale(?)	1	S		Cased to 148 feet.
Trig Brown	287	Sandstone	Dakota sandstone	V	S	9	Cased to 141 feet.
Ira Ingram		Silt, sand, and gravel	Ogallala formation	W			Aquifer 164 feet thick.
D. MacFadden	0	do.	do.				Cased to 130 feet.
M. W. McConnell	0	do.	do.				Cased to 173 feet. Aquifer 168 feet thick.
Do.	400	Sandstone	Dakota sandstone		D,S		Cased to 170 feet.
N. T. Ward	0	Silt, sand, and gravel	Ogallala formation	w	D,S		Cased to 163 feet.
				W			

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 24 N., R. 26 E. NE1/4 SE1/4 sec. 16	—	—	—	Plains	6,270	185.0	165.3	May I
sec. 20	Ben Blade	H. G. Smith	—	Valley	—	130.0	115.0	-
sec. 21	do.	do.	1945	Plains	6,270	205.0	193.4	May 24
SW1/4NW1/4 sec. 22	Wilber Newton	do.	1945	do.	6,275	205.0	—	—
sec. 23	N. S. Jordan	—	—	do.	6,210	—	—	—
SW1/4NW1/4 sec. 27	George Ray	—	—	do.	6,215	—	—	—
NE1/4NW1/4 sec. 31	A. H. Newton	—	1944	do.	6,085	17.0	14.2	Apr. 24
NE1/4SE1/4 sec. 34	F. C. Kidder	Jake Stinebaugh	1936	do.	6,205	485.0	—	—
SE1/4NW1/4	do.	Clyde Stinebaugh	1946	do.	6,140	490.0	—	—
sec.35 sec. 35	Cecil Wood	—	1920	do.	—	480.0	—	—

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
—	U	Silt, sand, and gravel	Ogallala formation	W	S	—	Cased to 185 feet. Aquifer 185(?) feet thick.
Ben Blade	0	do.	do.	W	D,S	—	Cased to 205 feet. Aquifer 204 feet thick
Do.	0	do.	do.	W	D,S	—	
Wilber Newton	0	do.	do.	W	D,S	—	Do.
N. S. Jordan	0	do.	do.	W	D,S	—	
George Ray	0	do.	do.	W	S	—	Dug well. Cased to 200 feet.
. H. Newton	0	do.	do.	W	S	—	
F. C. Kidder	290	Sandstone	Dakota sandstone	W	D,S	—	
Do.	—	do.	do.	—	S	—	Do.
Cecil Wood	—	do.	do.	W	D,S	—	

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 24 N., R. 27 E. NW1/4 NW 1/4 sec. 15	A. M. McCarty	H. G. Smith	1946	Plains	6,020	85.0	52.4	June 7
NE1/4 NW1/4 sec. 19	J. R. Davenport	Terrol Randel	1945	do.	6,120	196.0	189.0	-
SE1/4 NE1/4 sec. 23	W. H. Griffis	—	1930	do.	5,980	140.0	86.3	June 7
SE1/4 sec. 25	F. W. Beard	—	—	do.	6,010	225.0	160.5	June 18
NE1/4 NE1/4 sec. 30	J. R. Davenport	Terrol Randel	1945	do.	6,120	200.0	177.3	May 1
do.	do.	do.	1945	do.	6,095	205.0	Dry	-
NE1/4 NE1/4 sec. 31 sec. 31	do.	H. G. Smith	1946	do.	—	300.0	—	-
T. 23 N., R. 22 E. NE1/4 sec. 3	Farmers Development Company	Fred Mortimer	1945	do.	5,990	427.0	78.3	Jan. 19

Owner or name	Principal water-bearing bed			Method of lift	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
A. M. McCarty	0	Silt, sand, and gravel	Ogallala formation	W	D,S	—	Cased to 69 feet
J. R. Davenport	0	do.	do.	W	S	—	Cased to 196 feet. Aquifer 196 feet thick
W. H. Griffis	0	do.	do.	W	D,S	—	Cased to 140 feet.
F. W. Beard	—	do.	do.	W	S	44	
I. R. Davenport	0	do.	do.	W	S	—	Cased to 200 feet. Aquifer 200 feet thick.
Do.	0	do.	do.	—	—	-	
Do.	282	Sandstone	Dakota sandstone	W	S	—	Cased to 282 feet.
Farmers Development Company	388	do.	do.	W	S	—	Cased to 427 feet.

RECORDS OF WELLS AND SPRINGS

See footnotes at end of table.

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 23 N., R. 22 E. NE1/4 sec. 6	Farmers Development Company	Fred Mortimer	1945	Plains	6,020	67.0	30.6	June 3
T. 23 N., R. 23 E. NW1/4 sec. 1	Ben Floersheim	Clyde Stinebaugh	1945	do.	5,865	143.0	81.9	May 14
sec. 4	John Whooten	do.	1945	do.	5,825	250.0	—	-
T. 23 N., R. 24 E. NW 1/4 sec. 1	Ben Floersheim	do.	1945	Valley	5,915	36.0	17.1	May 19
SW1/4SE1/4 sec. 5	do.	do.	1945	Plains	5,845	76.0	29.5	Do.
sec. 10	do.	do.	1945	Valley	5,820	85.0	—	-
sec. 10	do.	—	—	do.	5,815	7.5	3.1	May 14
SW1/4 sec. 15	Jaritas Dome oil test	California Co.	1925	—	—	2,556.0	—	-

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
Farmers Development Co.			Quaternary alluvium(?)				
Ben Floersheim		Sandstone	Dakota sandstone	N	-		Cased to 70 feet.
John Whooten	50	do.	do.	W	S		
Ben Floersheim	0	Sand and gravel	Quaternary alluvium	N	-		
Do.	40	Sandstone	Dakota sandstone	N	-		Cased to 40 feet.
Do.	0	do.	do.	W	D	7	Do.
Do.	0	do.	do.	W	D	8	Dug well.
Jaritas Dome oil test							Abandoned; struck non-combustible gas.

See footnotes at end of table

TABLE 1. RECORDS OF WELLS EAST AND SOUTH OF MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
							Depth below land surface (feet)	Date of measurement (1946)
T. 23 N., R. 25 E. NW ¼ NW ¼ sec. 11	H. B. Lusk	Clyde Stinebaugh	1915	Plains	5,955			
T. 23 N., R. 26 E. SE ¼ sec. 4	W. C. Halferty	do.	1946	do.	6,190	445.0	239.2	Apr. 26
NW ¼ SW ¼ sec. 8	J. C. Tarpley	Clyde Stinebaugh		Valley	6,035	30.0	16.5	May 28
sec. 9	R. H. Shaw			Plains	6,150	220.0	200.0	
SW ¼ NW ¼ sec. 17	John Bauler	do.	1944	do.	6,130	110.0	73.4	May 28
T. 23 N., R. 27 E. NE ¼ NE ¼ sec. 3	A. M. Van Dyke			do.	6,065	225.0	211.8	June 7
NW ¼ sec. 4	Francis Hephner			do.	6,065		192.0	Do.
SE ¼ SE ¼ sec. 9	Roy Powell	H. G. Smith	1942	do.	6,050	250.0	242.0	

RECORDS OF WELLS AND SPRINGS

RECORDS OF WELLS AND SPRINGS

Owner or name	Principal water-bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
H. B. Lusk			Dakota sandstone	W	S		
W. C. Halferty	330	Sandstone	do.	N			Cased to 215 feet.
J. C. Tarpley		Shale and limestone	Greenhorn limestone	W	D,S		Dug well.
R. H. Shaw	0	Silt, sand, and gravel	Ogallala formation	W	D,S		
John Bauler		Shale and limestone	Greenhorn limestone	W	D,S		Cased to 110 feet.
A. M. Van Dyke	0	Silt, sand, and gravel	Ogallala formation	W	D,S		
Francis Hephner	0	do.	do.	W	D,S		
Ray Powell	0	do.	do.	W	D,S		Cased to 250 feet.

1 B, bucket; H, hand pump; N, none; P, gasoline-driven pump; W, wind mill.
 2 D, domestic; N, none; P, public supply; S, stock.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
 [Shown on pl. 3. All wells are drilled unless otherwise noted under "Remarks"]

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of measurement (1046)
1	3 miles southwest of Raton	Clarence and Frank Stockton	Rube Fields	1942?	Valley	6,485	71.0	29.0	Feb. 20
2	5 miles southwest of Raton	do.		1900?	do.	6,590	40.0		
3	4 miles southwest of Raton	do.	Rube Fields	1940?	do.	6,555	59.0	21.7	Feb. 20
4	6 miles south of Raton	do.		1908?	do.	6,305	45.0	37.1	Jan. 29
5	Do.	do.	John Thomas	1930?	do.	6,295	81.0	35.0	Do.
6	1 mile east of Van Houten	F. L. Gumm, Jr.			do.	6,560	15.0	10.0	Mar. 11
7	2 miles southeast of Raton	Beatrice Howarth			Plains	6,460	15.0	Dry	Feb. 14
8	Do.	do.	C. D. Fields	1946	do.	6,475	290.0		Do.
9	2 ½ miles southeast of Raton	Earl Smith			do.	6,430	14.5	Dry	Feb. 19

Well No.	Principal water-bearing bed			Method of lift.	Use of water ²	Analysis number, See table 7	Remark..
	Depth to top of bed (feet)	Character of material	Geologic formation				
1		Silt, sand, and gravel	Quaternary alluvium	W			Cased to 70 feet.
2		do.	do.	W	S		Dug well.
3		do.	do.	W	S		Cased to 50
4		do.	do.	W	S		Dug well.
5				W	S		
6		Silt, sand, and gravel	Quaternary alluvium	W	S		Do.
7		Shale	Pierre shale	N	—		Dug well. No water.
8		do.	do.		N		Driller reports well yields a small amount of, highly mineralized
9		do.	do.	N	N		Dug well. No water.

See footnotes at end of table

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

No. Well	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of measurement (1946)
10	4 miles southeast of Raton	Earl Smith	—	—	Plains	6,390	24.0	20.6	Feb. 19
11	½ mile southeast of Koehler	Stockton Ranch	C. D. Fields	1945	do.	6,365	C77.0	43.0	-
12	1 mile southeast of Koehler	C. S. Cattle Co.	—	—	do.	6,325	40.0	35.4	Mar. 23
13	2 miles southeast of Koehler	do.	—	—	Valley	6,280	—	—	-
14	2 miles north of Hebron	Gene Stockton	—	1940	do.	6,225	28.0	—	—
15	2 ½ miles northwest of Hebron	J. M. Crews	Rube Fields	1943	Plains	6,330	150.0	—	—
16	1 ½ miles east of Van Houten	F. L. Gumm, Jr.	—	—	Valley	6,490	17.0	14.3	Mar. 11
17	1 ½ miles north of Hebron	Gene Stockton	—	—	do.	—	—	—	-
18	½ mile northwest of Hebron	J. M. Crews	Rube Fields	1943	do.	6,200	58.0	20.4	Feb. 11

Well No.	Principal water-bearing bed			Method of lift	Use of water	Analysis number see table?	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
10		Clay and silt(?)	Loess-like deposits	W		40	Dug well.
11		Weathered shale	Pierre shale		S		Do.
12			Quaternary alluvium(?)	W	S		
13		Silt, sand, and gravel	Quaternary alluvium	W	S	D,S	
14		do.	do.	W			
15		Shale	Pierre shale	W		51	Dry well?
16		Silt, sand, and gravel	Quaternary alluvium	W	S		Dug well.
17		do.	do.	N			Well abandoned.
18		do.	do.		S		

See footnotes at end of table

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of measurement (1946)
19	3 miles west of Hebron	J. M. Crews	—	—	Valley	6,325	50.0	15.7	Feb. 11
20	Hebron	do.	Rube Fields	1943	do.	6,185	53.0	21.7	Do.
21	½ mile south of Hebron	do.	do.	1943	do.	6,160	48.0	22.6	Do.
22	3 ½ miles southeast of Koehler	do.	—	—	Plains	6,250	31.0	27.2	Do.
23	4 miles southeast of Koehler	Howard Lackey	Carl Taylor	1944	Valley	6,235	40.0	28.7	May 11
24	3 ½ miles northeast of Hebron	L. K. Moore	—	—	do.	6,200	17.5	10.8	Feb. 14
25	Do.	do.	Carl Taylor	1944	Plains	6,225	59.0	42.0	Feb. 11
26	7 miles east of Dawson	C. S. Cattle Co.	C. D. Fields	—	do.	6,335	175.0	—	-
27	Crow Creek ranch	do.	—	—	do.	6,160	30.0	—	-
28	7 miles north of Maxwell	do.	—	—	do.	5,995	—	—	—

RECORDS OF WELLS AND SPRINGS

Well No.	Principal water bearing bed			Method of lift ¹	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
19	0	Silt, sand, and gravel	Quaternary alluvium	w	S	48	Dug well.
20		do.	do.	N	-		
21		do.	do.	w	S		
22		do.	do.	W	D,S		
23		do.	do.	N	-	50	Do. Cased to 59 feet.
24		do.	do.	P	S		
25		Shale	Pierre shale	N	-		
26		Shale	Quaternary alluvium	w	S		
27	Shale	Smoky Hill marl member(?)	w	S	50	Dug well.	
28	Shale	Smoky Hill marl member(?)	w	S			

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

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Well No.	Location	Owner or name	Driller	Year Completed	Topographic situation	Altitude above sea level (feet)	Depth to top of bed (feet)		Date of measurement
							Depth below land		
29	8 miles northeast of Maxwell	Anita van Bruggan	—		Plains	6,175	10.0	2.5	Feb. 27
30	3 miles northwest of Maxwell	C. E. Atchley	-		do.		18.0	14.6	Feb. 22
31	Do.	do.	—	1946	do.		17.0	14.4	Do.
32	6 miles northwest of Maxwell	W. Libbey Estate	—		do.				
33	5 ½ miles northwest of Maxwell	W. J. McKinley	-		do.		15.0	10.0	Feb. 22
34	2 ¾ miles northwest of Maxwell	C. E. Atchley	—		do.		16.0	13.3	Do
35	½ mile south of Maxwell	Goodrich Farm	-	1915	do.	5,934	28.0	28.0	Mar. 18
36	5 miles northeast of Maxwell	Anita van Bruggan	—		do.	6,000	25.0	19.7	Feb. 27
37	4 miles northeast of Maxwell	J. B. Jackson	—	15	do.	6,000	30.0	27.3	Do.
38	Do.	Dom Kuchan	—		do.	5,995	20.0	9.8	Do.

Well No.	Principal water-bearing bed			Method of lift ¹	Use of waters	Analysis number. see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
29		Clay, silt, and gravel	Quaternary alluvium	W	S		Dug well.
30				P	S		
31			Quaternary alluvium(?) and wind-blown deposits	H	D,S	46	Bored well.
32				W	—	76	Dug well.
33				H	D	—	Do.
34				H	D,S		Do.
35				W	S		Do.
36				Quaternary alluvium	W	D,S		Do.
37		do.	W	D,S		Do.	
38			N	N		Do.	

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Well	
								Depth below land surface (feet)	Date of Measurement (1946)
39	4 miles northeast of Maxwell	Dom Kuchan			Plains	5,980	20.0	14.5	Feb. 27
40	3 ½ miles northeast of Maxwell	do.		1908	Do	5,990	36.0		
41	3 miles northeast of Maxwell	do.		1906	do.	5,985	34.2	32.7	
42	3 miles southwest of Cimarron	Philmont Scout Ranch			Valley	6,755	15.0	11.0	
43	7 miles east of Cimarron	W. J. Gourley		1946	Plains	6,290			May 29
44	7 miles southeast of Cimarron.	E. W. Swope		1946	do.	6,180			
45	Do.	do.			do.	6,180	38.0		
46	Do.	Neal Hansen		1926	do.		18.0	13.6	
47	7 ¾ miles southeast of Cimarron	L. N. Swope			do.	6,165	20.0	16.0	

Well No.	Principal water-bearing bed			Method of lift)	Use of water ²	Analysis number, see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
39			Quaternary alluvium	N	N	47	Dug well.
40		do.		W	S		Do
41		do.		W	S		.
42		do.		H	D		Do
43						Drilled as an oil test. Well abandoned. 2,224 feet to top of Dakota sandstone.	
44		Sandy gravel	Pediment gravel				Dug well.
45		do.	do.	H	D	62	Do.
46		Cemented gravel	do.	H	D	63	Do.
47		Sandy gravel	do.	H	D,S	61	Do.

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT. COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of Measurement (1946)
48	7 ¾ miles south-east of Cimarron	E. G. Hayward		1930	do.	6,145	20.0	12.0	
49	7 miles northwest of Springer	W. C. Holland		1930.	Plains	6,040	150.0		
50	8 miles northwest of Springer	R. R. Hudson		1937	do.	—	20.0		
51	7 miles northwest of Springer	Mr. Starnes		1940	do.	5,985	25.0	7.4	June 6
52	6 ¾ miles northwest of Springer	Mrs. Parello			do.	5,965	40.0	28.0	
53	2 ¾ miles southwest of French	W. O. Price			do.	5,945	26.5	14.7	Mar. 18
54	6 ½ miles northwest of Springer	J. A. Thomas			do.	6,025	24.0	21.5	Mar. 19
55	Do.	Cleo Decker			do.	—	—		
56	5 ¾ miles north of Springer	S. W. Pelphrey		1940	do.	5,960	25.0		

Well No.	Principal water-bearing bed			Method of lift	Use of water ²	Analysis number, sec table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
48		Sandy gravel	Pediment gravel	H	D		Dug well. Cased to 20 feet.
49		Sandy shale	Smoky Hill marl member	W	S	35	
50				W	S		Bored well.
51				W	S		
52		Shale	Smoky Hill marl member	P	S	36	
53		do.	do.	H	S		Dug well.
54		do.	do.	W	D,S		Do.
55		do.	do.	P	D,S		
56		do.	Loess-like deposits	H	S		Do.

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Water level		
							depth of well (feet)	Depth below land surface (feet)	Date of measurement (1996)
57	5 ¾ miles north of Springer	S. W. Pelphrey	—	1943	do.	5,935	11.5	10.4	Apr. 24
58	5 ½ miles north of Springer	T. F. Conway	—	1930	do.	5,935	15.0	10.5	Do
59	6 miles southwest of Cimarron	Philmont Scout Ranch	C. D. Fields	1945	Plains	6,885	119.0	51.9	May 31
60	8 miles southwest of Cimarron	do.	—	1945	do.	6,715	87.0	42.2	Do.
61	6 miles north of Miami	Hayward and Hansen	—	1944	do.	6,180	20.0		
62	5 ½ miles north of Miami	d .	—	1935	do.	6,180	20.0		
63	5 1/3 miles north of Miami	do.	—	1931	do.	6,180	20.0		
64	5 miles north of Miami	do.	—	1946	do.	6,175	23.0	19.6	Feb. 25

Well No.	Principal water-bearing bed			Method of lift ¹	Use of water ¹	Analysis number. see table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
57		Clay and silt	Loess-like deposits Smoky	w	S	38	Dug well.
58		Shale	Hill marl member Pierre	W	N		Do.
59		do.	shale	w	S		
60		do.	do.	W	S		
61		Sandy gravel	Pediment gravel	H	D		Do.
62		do.	do.		D		Do.
63		do.	do.	H	D		Do.
64		do.	do.				Do.

See footnotes at end of table

TABLE 2. RECORDS OF WELLS WITHIN MA XWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of measurement (1946)
65	5 miles north of Miami	do.		1919	do.	6,175	20.0		
66	6 miles of Miami	Andrew Hansen		1922	do.	6,185			
67	5 miles north of Miami	Hayward and Hansen			do.	6,175	20.0		
68	Miami	L. N. Bell		1936	do.	6,220	16.0		
69	½ mile east of Miami	Richard Pair			Plains	6,200		9.1	Mar. 21
70	7 ¼ miles east of Miami	A. M. Van Dyke			do.	6,085	29.5	21.4	Mar. 19
71	4 miles of Springer	7-Bar Ranch	Virgil Carver		do.	5,890	975.0		
72	5 ½ miles west of Springer	Mr. Broadhurst	J. A. Torrey	1946	Valley	6,020		92.1	Dec. 7

Well No.	Principal water-bearing bed			Method of test	Use of waters	Analysis number, see table?	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
65	—	Sandy gravel	Pediment gravel	H	D	—	Dug well.
66	—	—	do.	H	D,S	75	Do.
67	—	Sandy gravel	do.	H	D	-	
68	--	do.	Quaternary alluvium	W	S	—	Do.
69		Shale	Pierre shale	P	S	—	Do,
70	—	do.	do.	W	D,S	37	Do.
71	963	Sandstone	Dakota sandstone	F	D	17	Cased to 963 feet
72	1,040	do.	do.	—	—	—	

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or Name	Driller	Year Completed	Topographical Situation	Altitude Above Sea Level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of Measurement (1946)
73	3 1/3 miles north of Springer	-	Virgil Carver	-	Plains	6,125		59.2	Jan. 19
74	3 miles north of Springer	Sidney Dennis	Carl Taylor	1945	do	6,100	882.0	150.0	
75	3 miles northeast of Springer	Mrs. L.L. Crawford	-		do	5,880		28.2	Mar. 18
76	2 1/2 miles northwest of Springer	Benjamin Clayton	J.R. Watson	1941	do	5,870	-	-	-
77	1 mile southeast of Springer	P.M. Bowen	-	-	do	5,810	610.0	30.0	-
78	2 1/2 miles north of Taylor Springs	James Curtis	Carl Taylor	1945	do	5,945	438.0	117.6	Apr. 4
79	1 1/2 miles southeast of Miami	Bob Watson	-		Plains	6,240	25.0	16.1	Mar. 21
80	1 mile southeast of Miami	John Hunter	-	1937	do	6,265	20.0	12.9	Do.

RECORDS OF WELLS AND SPRINGS

Well No.	Principal water-bearing bed			Method of lift	Use of water ²	Analysis number <small>see table 7</small>	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
73	—	—	—	W	S	-	
74	869	Sandstone	Dakota sandstone	W	S	16	
75	—	—	—	H	—	-	Cased to 869 feet.
76	840	Sandstone	Dakota sandstone	F	S	20	Cased to 928 feet. Flowed 25+/- g.p.m. January 1946.
77	435	do.	do.	—	—	21	
78	424	do.	do.	W	S	15	Cased to 435 feet.
79	—	Shale	Pierre shale	H	S	—	Cased to 422 feet. Dug well.
80	—	do.	do.		S	—	Do.

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY, N. MEX.
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Water level	
								Depth below land surface (feet)	Date of measurement (1996)
81	Miami	Miami Church		1946	do.	6,220	15.0	13.8	Do.
82	1 mile west of Miami	Floyd Hooker			do.	6,285		16.	May 29
83	Do.	Harley Coppock		1946	do.	6,260	17.0	14.2	Mar. 21
84	4 miles southwest of Springer	Benjamin Clayton	Virgil Carrier	1943	do.	6,005	574.0		
85	4 ½ miles southwest of Springer	do.	J. R. Watson	1943	do.	6,020	625.0		
86	1 ½ miles southeast of Springer	P. M. Bowen		1946	do.	5,805	420.0	26	
87	2 ½ miles south of Springer	Benjamin Clayton	Virgil Carrier	—	do.	5,970	553.0		

Well No.	Principal water-bearing bed			Method of lift	Use of water ²	Analysis number, See table 7	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
81	—	Silt, sand, and gravel	Quaternary alluvium		—		Dug well.
82	—	—	—		—	—	Reported to have flowed when well originally completed.
83	3	Shale	Pierre shale	B	D	39	Dug well.
84	547	Sandstone	Dakota sandstone	F	S	13	Cased to 547 feet. Flowed 20-i- g.p.m in January 1946.
85	597	do.	do.	N	N	—	Cased to 625 feet.
86	385	do.	do.	N	N	—	Cased to 386 feet.
87	450	do.	do.	N W	S	—	Cased to 450 feet.

See footnotes at end of table.

TABLE 2. RECORDS OF WELLS WITHIN MAXWELL GRANT, COLFAX COUNTY
(CONTINUED)

Well No.	Location	Owner or name	Driller	Year completed	Topographic situation	Altitude above sea level (feet)	Depth Of Well (feet)	Depth below land surface (feet)
88	½ mile northwest of Taylor Springs	J. O. Harrison	do.	—	do.	5,725	228.0	18.0
89	½ mile south of Taylor Springs	Mrs. C. Duchanois	Than Guffey	1933	Valley	5,675	210.0	-

Well No.	Principal water-bearing bed			Method of lift ¹	Use of water ³	Analysis number, see table?	Remarks
	Depth to top of bed (feet)	Character of material	Geologic formation				
88	213	Sandstone	Dakota sandstone	w	S		Cased to 213 feet.
89	125	do.	do.	F	S		Flows approximately 7 g.p.m.

B, bucket; H, hand pump; N, none; P, gasoline-driven pump; W, windmill; F, natural flow. 2 D, domestic; N, none; P, public supply; S, stock.

TABLE 3. RECORDS OF SPRINGS IN LAS ANIMAS COUNTY, COLO.
 [Shown on p1. 3]

Spring No.	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of water
S1	East slope Fishers Peak Mesa: T. 34 S., R. 62 W. sec. 33	—	—	Mesa slope	Sandstone	Shallow trench	Raton formation	5-8 ²	—	S
S2	do.	—	—	do.	Talus	Small area of talus	Talus, largely	3 ²	—	S
S3	T. 35 S. R. 62 W. sec. 4	Mr. Walton	—	do.	do.	do.	do.	1 ²	—	S
S4	do.	do.	—	do.	do.	do.	do.	1-2 ²	—	S
S5	do.	do.	—	do.	do.	—	do.	1-2 ²	—	S
S6	do.	do.	—	do.	Sandstone	Shallow trench	Raton formation	3-4 ²	—	S
S7	do.	do.	Walton Barn Spring	do.	Talus	do.	Talus, largely	Highly variable ³	—	S

Spring No.	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date measurement	Use of water'
S8	West slope Barilla Mesa: T. 35 S., R. 62 W. sec. 4	Mr. Walton	—	Mesa slope	Sandstone	Shallow trench	Raton formation	1-2 ²	—	S
S9	sec. 3	do.	—	do.	do.	do.	do.	5-8 ²	—	S
S10	do.	do.	—	do.	do.	do.	Raton formation and talus	10-20 ²	—	S
S11	do.	do.	—	do.	do.	Two shallow trenches	Raton formation	1-2 ²	—	S
S12	do.	do.	—	do.	do.	Shallow trench	do.	1.5	5-30-46	S
S13	do.	do.	—	do.	do.	do.	do.	3	do.	S
S14	do.	do.	—	do.	do.	do.	do.	3	do.	S
S15	do.	do.	—	do.	do.	do.	do.	3	do.	S
S16	do.	do.	Sear Spring	do.	do.	Landslide sear	do.	1 ²	—	S

See footnotes at end of table.

TABLE 3. RECORDS OF SPRINGS IN LAS ANIMAS COUNTY, COLO.
(CONTINUED)

Spring No.	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of water
S17	West slope Barilla Mesa: T. 35 S., R. 62 W. sec. 3	Mr. Walton	Little Rock Spring	Mesa slope	Sandstone	Shallow trench	Raton forma-	6	2-28-46	S
S18		do.	Rock Spring	do.	do.	do.	do.	33	do.	S
S19		do.	do.	—	do.	do.	do.	Raton formation and talus	Vali-able ³	—
S20	do.	do.	—	ϕ	ϕ	do.	do.	do.	—	S
S21	do.	d	—	ϕ	ϕ	do.	do.	do.	—	S
S22	sec. 10	do.	—	ϕ	ϕ	do.	do.	5	—	S

1 S, stock.
2 Estimated.
3 See table 6.

TABLE 4. RECORDS OF SPRINGS IN COLFAX COUNTY, N. MEX. [Shown
on pl. 3]

Spring No.	Local ion	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of waters
S23 S24	West slope Barilla Mesa: T. 32 N., R. 24 E. sec. 23 (north spring)	Lewis Tretter	Turkey Creek Spring	Mesa slope	Sandstone	Shallow trench	Raton forma- tion and talus	3-5 ³		
	do. (south spring)	do.	do.	do.	Coal Sandstone	do, do.	do. Raton forma- tion	1-2 ³ 8 ³		
	sec. 26 East slope Bartlett Mesa: 5 miles north- east of Raton do.		Snake Gulch	Mesa cap do.	Basalt do.	Fractures do.	Quater- nary basalt do.	8 ³ 25 ³		

See footnotes at end of table.

TABLE 4. RECORDS OF SPRINGS IN COLFAX COUNTY, N. MEX.
(CONTINUED)

Spring No.	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of water'
S25	South slope Bartlett Mesa: 2 miles north of Raton (west of road)	—	—	Base of mesa cap	Basalt and sand- stone	—	Quater- nary basalt and Raton for- mation do.	15	—	—
S26	2 miles north of Raton (east of road)	—	Sunshine Dairy	do.	do.	—	do.	10 ³	—	—
—	South slope Johnson Mesa: T. 31 N., R. 26 E. SW ¼ sec. 28	—	Dale Spring	Mesa slope	Gravel(?)	Small area of talus	Pliocene gravel (?)	75 ³	—	—
—	T. 30 N., R. 24 E. SW ¼ sec. 24	Mr. Barnum	—	Edge of pedi- ment	Gravel	—	Pediment gravel	1 ³	1-1-46	D

Spring No. ¹	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g. m.)	Date of measurement	Use of water ²
S27	2 miles east of Maxwell T. 26 N., R. 25 E.	— C. W.	— Chico	Edge of pediment Edge of	Gravel	Several	Pediment gravel Quaternary alluvium	50-75 ³		P D,S,I
—	sec. 12 (west spring) do.	Roundtree do.	Spring	basalt flow	Basalt	—	do.	80+/- 40 ³	4-7-46 —	S,I
—	(east spring)		Rocky Arroyo Spring	do.	do.	—				
S28	4 miles southeast of Miami	J. T. Fernandez	—	Mesa slope	Gravel(?)	Small area talus	Pediment gravel (?)	10-15 ³	—	-
S29	do.	do.	—	do.	do.	do.	do.	1-2 ³	—	-
S30	do.	do.	—	do,	do.	do.	do.	5-10 ³	—	—

TABLE 4. RECORDS OF SPRINGS IN COLFAX COUNTY, N. MEX.
(CONTINUED)

Spring No. ¹	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of water ²
—	T. 24 N., R. 20 E. NW $\frac{1}{4}$ sec. 25	J. T. Fernandez	—	Mesa slope	Gravel(?)	Small area talus	Pedi-ment gravel (?)	3-5 ³	—	—
—	NE $\frac{1}{4}$ sec. 25	do.	—	do.	Talus	do.	do.	7	—	D
S31	1 mile southeast of Springer	P. M. Bowen	West Spring	Edge of valley	Gravel	—	Quaternary alluvium	12 \pm	3-8-46	—

1 Springs in sectionized land not numbered.

2 D, domestic; P, public supply; S, stock; I, irrigation.

3 Estimated.

TABLE 5. RECORD OF SPRING IN HARDING COUNTY, N. MEX.

Spring No.	Location	Owner	Name	Topographic situation	Kind of rock	Opening	Source of water	Yield (g.p.m.)	Date of measurement	Use of water
—	T. 23 N., R. 24 E. SE $\frac{1}{4}$ sec. 21 (3 miles south of Jaritas Ranch)	Ben Floer-sheim	Gato Spring	Plains	Sandstone	—	Dakota sandstone	—	—	—

TABLE 6. VARIATION IN FLOW OF FOUR SPRINGS
NORTH OF LAKE MALLOYA, COLO.

Location of spring	Sec. 4, T. 35 S., R. 62 W.	Sec. 9, 1' 35 S., R. 62 W.	Sec. 9, T. 35 S., R. 62 W.	Sec. 9, T. 35 S., R. 62 W.
Date of measurement	Flow in gallons per minute			
Dec. 3, 1945	2.4	7.4	9.1	9.1
Jan. 3, 1946	2.4	7.4	9.1	9.1
Jan. 16, 1946	3.2		9.1	9.1
Feb. 28, 1946	4.2		9.1	9.1
Apr. 8, 1946	20.5	16.0		
Apr. 25, 1946	13.5	10.0	19.0	10.0
May 3, 1946	11.5	10.0	18.5	9.5
May 23, 1946	8.5	8.7	17.0	9.1
May 30, 1946	8.5			
June 4, 1946	7.3	7.0	14.5	8.7
June 17, 1946	7.2	6.1	13.8	7.8
July 4, 1946	4.7	5.2	12.0	7.0
July 11, 1946	3.5		11.5	7.0
July 31, 1946	3.1		9.1	6.5
Aug. 19, 1946	2.3		8.8	6.5
Sept. 23, 1946	1.8		8.7	6.5

ANALYSES
 TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.
Analyses by Geological Survey, United States Department of the Interior
 [Parts per million]

Analysis number	1	2	3	4	5	6
Date of collection	12 / 16 / 46	6 / 19 / 46	6 / 25 / 46	5 / 25 / 46	5 / 25 / 46	6 / 5 / 46
Silica (SiO ₂).....	-	-	-	-	-	-
Iron (Fe).....	-	-	-	-	-	-
Calcium (Ca).....	48	40	80	98	17	50
Magnesium (Mg).....	21	15	30	35	12	14
Sodium (Na).....						
Potassium (K).....	38	24	35	39	241	34
Bicarbonate (HCO ₃).....	292	222	411	289	561	256
Sulfate (SO ₄).....	35	20	35	71	126	30
Chloride (Cl).....	7	6.2	16	66	14	7.2
Fluoride (F).....	1.4	1.2	1.0	1.0	1.9	1.8
Nitrate (NO ₃).....	.1	0	.7	82	1.3	0
Borate (BO ₃).....	-	.2	-	-	-	.8
Dissolved solids:						
-ppm.....	294	216	400	534	690	263
-tons/a. ft. ....	.40	.29	.54	.73	.94	.36
Hardness as CaCO ₃ :						
Total.....	206	162	323	388	92	182
Noncarbonate.....	0	0	0	152	0	0
Percent sodium.....	29	25	19	18	85	29
Specific conductance.....						
(Kx10 ⁵ , at 25° C.) ----	51.7	40.2	73.6	94.2	109	45.9

- n H
1. Water-bearing formation: Dakota sandstone. Source of sample: Well of A. C. Hoffman, Farley public supply, sec. 35, T. 25 N., R. 27 E.
 2. Water-bearing formation: Dakota sandstone. Source of sample: Well of Trig Brown, SW1/4SW1/4 sec. 2, T. 24 N., R. 26 E.
 3. Water-bearing formation: Dakota sandstone. Source of sample: Well of E. E. Salyers, sec. 24, T. 27 N., R. 27 E.
 4. Water-bearing formation: Dakota sandstone. Source of sample: Well of James Saunders, sec. 35, T. 25 N., R. 27 E.
 5. Water-bearing formation: Dakota sandstone. Source of sample: Well of Virgil Coffee, SW1/4SE1/4 sec. 34, T. 26 N., R. 27 E.
 6. Water-bearing formation: Dakota sandstone and Ogallala formation. Source of sample: Well of R. O. Gaines, NE1/4 sec. 10, T. 25 N., R. 26 E.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior

Analysis number	7	8	9	10	11	12
Date of collection	12/7/46	12/7/46	5/14/46	5/17/46	7/3/46	7/3/46
Silica (SiO ₂).....						
Iron (Fe).....						
Calcium (Ca) -----						
Magnesium (Mg) -----	104	64	21	68	37	
Sodium (Na).....	21	9.7	3.2	14	16	112
Potassium (K).....	38	32	8.7	27	26	21
Bicarbonate (HCO ₃).....	157	145	55	250	199	26
Sulfate (SO ₄).....	169	62	22	37	31	466
Chloride (Cl).....	42	34	7.5	25	8	18
Fluoride (F).....	.3	.4	.3	.4		8
Nitrate (NO ₃) -----	80	44	5.9	6.1	9.2	
Borate (B ₉)				-	-	14
Dissolved solids:						
- ppm -----						
- tons/a. ft -----	532	318	96	301	225	429
Hardness as CaCO ₃ :		.72	.43	.41	.31	
Total .....		.13		227	158	58
Noncarbonate				22	0	366
Percent sodium.....	346	200	66	20	26	0
Specific conductance	218	80	20	20		14
(Kx10 ₄ at 25° C.).....	19	26	22			
pH ---	81.5	53.0	18.6	55.7	40.3	73.3

7. Water-bearing formation: Dakota sandstone. Source of sample: Well of Ben Floersheim (85 feet deep), sec. 10, T. 23 N., R. 24 E.
 8. Water-bearing formation: Dakota sandstone. Source of sample: Well of Ben Floersheim (7.5 feet deep), sec. 10, T. 23 N., R. 24 E.
 9. Water-bearing formation: Dakota sandstone. Source of sample: Gato Spring, 3 miles south of Jaritas ranch, 5E¹/₄ sec. 21, T. 23 N., R. 24 E.
 10. Water-bearing formation: Dakota sandstone. Source of sample: Well of E. E. Salyers, SW1/4SW1/4 sec. 14, T. 27 N., R. 27 E.
 11. Water-bearing formation: Dakota sandstone (7). Source of sample: Well of W. G. Pinson, 5E¹/₄5E1/4 sec. 36, T. 29 N., R. 27 E.

Analysis number	13	14	15	16	17	18
Date of collection	7 /3 /46	7/3/46	7 /2 /46	7/2 /46	7 /2 /46	7 /3 /46
Silica (SiO ₃)	—	—	—	—	—	-
Iron (Fe)	—	—	—	—	—	-
Calcium (Ca)	52	7.2	17	27	24	30
Magnesium (Mg) -----	32	4.3	9.8	9	7.6	20
Sodium (Na)	35	122	1,060	1,300	1,100	49
Potassium (K)						
Bicarbonate (HCO ₅)	249	335	1,340	1,040	8	277
Sulfate (SO ₄)	77	16	34	97	102	21
Chloride (Cl)	29	6	895	1,390	1,160	10
Fluoride (F)	—	—	—	5	7	-
Nitrate (NO ₃)	15	1.1	2.5	.7	1.8	1.9
Borate (B0 ₃)	—	—	—	4	8	-
Dissolved solids:						
—ppm.....	363	321	2,680	3,340	2,830	268
—tons/a. ft. ---	.49	.44	3.64	4.54	3.85	.36
Hardness as CaCO ₃ :						
Total	261	35	83	104	91	157
Noncarbonate.....	57	0	0	0	0	0
Percent sodium	23	88	97	96	96	41
Specific conductance (Kx10 ₃ at 25° C.).....	62.2	54.2	474	561	489	48.3
pH						

13. Water-bearing formation: Dakota sandstone (?). Source of sample: Well of Allen Hill, (60 feet deep), sec. 35, T. 28 N., R. 27 E.
14. Water-bearing formation: Dakota sandstone. Source of sample: Well of Carl Hinnegan, SE1/4, sec. 25, T. 28 N., R. 26 E.
15. Water-bearing formation: Dakota sandstone. Source of sample: Well of James Curtis. Well number 78, Maxwell Grant.
16. Water-bearing formation: Dakota sandstone. Source of sample: Well of Sidney Dennis. Well number 74, Maxwell Grant.
17. Water-bearing formation: Dakota sandstone. Source of sample: Well at 7 Bar ranch. Well number 71, Maxwell Grant.
18. Water-bearing formation: Dakota sandstone. Source of sample: Well of I. W. Williams, SW1/4NW1/4 sec. 31, T. 28 N., R. 27 E.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.
(CONTINUED)

[Parts per million]

Analysis number	19	20	21	22	23	24
Date of collection	1 /23/46	1 /23/46	4 /21 /46	2 /10 /47	2 /11 /47	6 /8 /46
Silica (SiO ₂)	11	11				
Iron (Fe) .....	.02	.02				
Calcium (Ca)	29	20	23	24	4	36
Magnesium (Mg)	9.4	7.9	13	14	7.8	30
Sodium (Na).....						
Potassium (K).....	899	1,100	1,010	2,200	248	1,180
Bicarbonate (HCO ₃).....	844	872	945	2,120	679	2,690
Sulfate (SO ₄)	101	112	101	11	4.5	446
Chloride (Cl).....	890	1,170	1,000	2,240	13	82
Fluoride (F)	5.2	5.6	4.8	.9	.8	.8
Nitrate (NO ₃) .....	.1	.2	.6	.7	.3	0
Borate (BO ₃)	12	15				4
Dissolved solids:						
- ppm.	2,369	2,870	2,620	5,530	613	3,100
-tons/a. ft.	3.21	3.90	3.56	7.52	.83	4.22
Hardness as CaCO ₃ :				118	42	
Total.....	111		111			214
Noncarbonate	0	0	0	0	0	0
Percent sodium	95	97	95	98	93	92
Specific conductance (Kx10 ₅ at 25° C.)	406	486	456	910	107	442
pH	7.3	7.4				

19. Water-bearing formation: Dakota sandstone. Source of sample: Well of Benjamin Clayton. Well number 84, Maxwell Grant. of Benjamin Clayton. Well number 76,
 20. Water-bearing formation: Dakota sandstone. Source of sample: Well Maxwell Grant. of P. M. Bowen. Well number 77,
 21. Water-bearing formation: Dakota sandstone. Source of sample: Well Maxwell Grant. of Frank Sauble, SW¹/₄ sec. 5, T. 25
 22. Water-bearing formation: Dakota sandstone. Source of sample: Well N., R. 24 E. of W. E. Jones, sec. 16, T. 24 N., It. 25
 23. Water-bearing formation: Dakota sandstone. Source of sample: Well E. Ben Floersheim. NWIA sec. 15, T. 24 N., R. 24 E.
 24. Water-bearing formation: Graneros shale. Source of sample: Well of

Analysis number	25	26	27	28	28	30
Date of collection	7 /3 /46	6 /8 /46	6 /8 /46	7 /3 /46	7 /3 /46	
Silica (SiO ₂).....	—	—	—	—	—	7/3/46
Iron (Fe)	—	—	—	—	—	
Calcium (Ca).....	68	194	267	60	11	246
Magnesium (Mg)	14	45	98	14	7.9	70
Sodium (Na)	13	130	787	22	616	
Potassium (K)						
Bicarbonate (HCO ₃)	251	269	835	226	150	271
Sulfate (SO ₄)	28	679	1,890	28	9.1	699
Chloride (Cl).....	10	13	90	23	33	66
Fluoride(F)	—	.6	.3	—	-	.2
Nitrate (NO ₃).....	9.6	4.5	0	11	0	26
Borate (B ₂ O ₃).....	—	1.6	1	—	-	-
Dissolved solids:						
—PPm.....	266	1,200	3,540	269	1,450	1,320
—tons/ a. ft.....	.36	1.63	4.81	.37	1.97	1.80
Hardness as CaCO ₃ :						
Total	227	669	1,070	207	60	902
Noncarbonate	22	448	385	22	0	680
Percent sodium	11	30	62	19	96	15
Specific conductance (Kx10, at 25° CO.....	47.6	160	453	48	211	176
pH						

25. Water-bearing formation: Greenhorn limestone. Source of sample: Well of J. W. Ledbetter, SW1/4 sec. 22, T. 28 N., R. 27 E.
26. Water-bearing formation: Greenhorn limestone. Source of sample: Well of George D. Gillespie, NW1/4 sec. 30, T. 25 N., R. 25 E.
27. Water-bearing formation: Greenhorn limestone. Source of sample: Well of George D. Gillespie, SE1/4NE1/4 sec. 31, T. 25 N., R. 25 E.
28. Water-bearing formation: Greenhorn limestone. Source of sample: Well of M. L. Rice, sec. 30, T. 28 of E. N., R. 27 E.
29. Water-bearing formation: Carille shale. Source of sample: Well of O. F. Harris, NE1/4 sec. 14, T. 28 N., R. 26 E.
30. Water-bearing formation: Fort Hays limestone member. Source of sample: Well of Joe Cunico, NE1/4 sec. 8, T. 28 N., R. 26 E.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior

[Parts per million]

Analysis number	31	32	32	34	35	36
Date of collection	7 /3 /46	7 /3 /46	7 /3 /46	6 /3 /46	6 /6 /46	6 /6 /46
<i>Silica</i> (SiO ₂).....						
Iron (Fe)						
Calcium (Ca)	104	41	32	75	523	524
Magnesium (Mg).....	11	19	4.6	12	151	333
Sodium (Na).....						
Potassium (K)	34	45	9	21	116	301
Bicarbonate (HCO ₃)	258	246	121	214	3 2 6	518
Sulfate (SO ₄).....	93	62	10	56	1 , 7 9 0	2,650
Chloride (Cl).....	39	7	4	27	2 6	94
Fluoride (F)				2	1 . 6	.3
Nitrate (NO ₃)	20	1.7	4.1	12	9 . 5	18
Borate (B0 ₃).....				2		
Dissolved solids:						
-PPm.	428	297	123	309	2,780	4,180
-tons/a. ft. ....	.58	.40	.17	.42	3.78	5.68
Hardness as CaCO ₃ :						
Total	304	180	99	236	1,930	2,680
Noncarbonate	93	0	0	61	1,660	2,250
Percent sodium.....	20	35	16	16	12	20
Specific conductance (Kx10 ₃ at 25 ⁰ C.) pH	70.3	62.3	22.8	53.2	302	443

31. Water-bearing formation: Fort Hays limestone member. Source of sample: Well of O. F. Harris. SE₄/4 sec. 10, T. 28 N., R. 26 E.
 32. Water-bearing formation: Fort Hays limestone member (?). Source of sample: Well of E. B. Weir, SW₄SE₄/4 sec. 14, T. 28 N., R. 26 E.
 33. Water-bearing formation: Fort Hays limestone member (?). Source of sample: Well of E. B. Weir, NE₄NE₄/4 sec. 27, T. 28 N., R. 26 E.
 34. Water-bearing formation: Fort Hays limestone member. Source of sample: Well of Jesse White, SE₄SE₄/4 sec. 28, T. 24 N., R. 26 E.
 35. Water-bearing formation: Smoky Hill marl member. Source of sample: Well of W. C. Holland. Well number 49, Maxwell Grant.
 36. Water-bearing formation: Smoky Hill marl member. Source of sample: Well of Mrs. Parrello. Well number 52, Maxwell Grant.

Analysis number			39	40	41	42
Date of collection	6/6 /46	5 /31 /46	5/29 /46	7 /3 /46	2 /11 /47	6 /20 /46
Silica (SiO ₂)	—	—	—	—	—	—
Iron (Fe)	—	—	—	—	—	—
Calcium (Ca)	143	244	484	14	62	42
Magnesium (Mg)	71	215	92	5.9	23	14
Sodium (Na)		-	221	409	86	21
Potassium (K)	83	489				
Bicarbonate (HCO ₃)	304	512	183	368	447	213
Sulfate (SO ₄)	418	2,030	1,720	538	44	17
Chloride (Cl)	78	16	49	47	14	6
Fluoride (F)	2.6	.3	.2	—	.8	.6
Nitrate (NO ₃)	35	.2	69	0	3.2	7.5
Borate (B ₂ O ₃)	—	—	—	—	—	.8
Dissolved solids:						
—ppm	980	3,250	2,730	1,210	446	213
—tons/a. ft	1.33	4.42	3.71	1.65	.61	.29
Hardness as CaCO ₃ :						
Total	649	1,490	1,590	60	249	162
Noncarbonate	400	1,070	1,440	0	0	0
Percent sodium	22	42	23	94	43	22
Specific conductance (Kx10 ₅ at 25° C.)	148	385	304	180	82.5	38.3
pH						

37. Water-bearing formation: Pierre shale. Source of sample: Well of A. M. Van Dyke. Well number 70, Maxwell Grant.

38. Water-bearing formation: Pierre shale. Source of sample: Well of Philmont Scout ranch. Well number 59, Maxwell Grant.

39. Water-bearing formation: Pierre shale. Source of sample: Well of Rarley Coppock. Well number 83, Maxwell Grant.

40. Water-bearing formation: Pierre shale. Source of sample: Well of Stock ton ranch. Well number 11, Maxwell Grant.

41. Water-bearing formation: Smoky Hill marl member. Source of sample: Well of F. L. Gumm, Jr., NE¼ sec. 24, T. 29 N., R. 24 E.

42. Water-bearing formation: Ogallala formation. Source of sample: Well of C. V. Coulter, center of sec. 9, T. 25 N., R. 26 E.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior
 [Parts per million]

Analysis number	43	44	45	46	47	48
Date of collection	6/18/46	6/18/46	6/20/46	2/6/46	5/31/46	7/2/46
Silica (SiO ₂)	—	—	—	—	—	-
Iron (Fe)	—	—	—	—	—	-
Calcium (Ca)	34	49	36	188	142	94
Magnesium (Mg).....	20	18	21	130	34	32
Sodium (Na).....						
Potassium (K)	12	10	16	174	22	84
Bicarbonate (HCO ₃)	208	204	205	540	215	259
Sulfate (SO ₄)	12	19	23	858	342	258
Chloride (Cl)	3	14	7.8	28	7.5	17
Fluoride (F).....	.8	.3	.8	1.2	.0	-
Nitrate (NO ₃)	4.3	14	7.9	4.4	0	55
Borate (BO ₃)	—	—	.2	—	.2	-
Dissolved solids:						
—ppm	189	225	214	1,650	653	668
—tons/a. ft .....	.26	.31	.29	2.24	.89	.91
Hardness as CaCO ₃ :						
Total	167	196	176	1,000	494	366
Noncarbonate.....	0	30	8	561	318	154
Percent sodium.....	13	10	17	27	9	33
Specific conductance (Kx10 ₅ at 25° C.)..... v.....	35.7	41.5	39.0	219	90.2	99.2
pH _						

43. Water-bearing formation: Ogallala formation. Source of sample: Well of C. D. Westfall, NW_{1/4}NW_{1/4} sec. 36, T. 25 N., R. 26 E.

44. Water-bearing formation: Ogallala formation. Source of sample: Well of F. W. Beard, SE_{1/4} sec. 25, T. 24 N., R. 27 E.

45. Water-bearing formation: Ogallala formation. Source of sample: Well of H. G. Smith, SW_{1/4} sec. 22, T. 25 N., R. 26 E.

46. Water-bearing formation: Quaternary alluvium and wind-blown deposits. Source of sample: Well of C. E. Atchley. Well number 31, Maxwell Grant

47. Water-bearing formation: Quaternary alluvium. Source of sample: Well of Philmont Scout ranch. Well number 42, Maxwell Grant.

48. Water-bearing formation: Quaternary alluvium. Source of sample: Well of J. M. Crews. Well number 22, Maxwell Grant.

Analysis number	49	50	51	52	53	54
Date of collection	3 / 8 / 46	2 / 14 / 46	2 / 11 / 47	2 / 11 / 47	4 / 5 / 47	4 / 5 / 47
Silica (SiO ₃)	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-
calcium (Ca)	346	180	142	188	67	65
Magnesium (Mg)	152	139	92	65	14	37
Sodium (Na)						
Potassium (K)	128	210	202	211	39	11
Bicarbonate (HCO ₃)	332	284	274	293	186	291
Sulfate (SO ₄)	1,390	1,140	893	866	136	118
chloride (Cl)	30	36	12	32	9.0	49
Fluoride (F) .....	.5	.6	.3	.4	.5	0.3
Nitrate (NO ₃)	3.8	7.1	.2	9.6	.8	7.6
Borate (B ₀ ₃) .....	.2	.2	-	-	.2	.2
Dissolved solids:						
-ppm.	2,210	1,850	1,480	1,520	358	431
-tons/a. ft.	3.01	2.52	2.01	2.07	.49	.59
Hardness as CaCO ₃ :						
Total	1,490	1,020	733	736	224	314
Noncarbonate	1,220	788	508	496	72	176
Percent sodium	16	31	37	38	27	7
Specific conductance (Kx10 ₃ at 25° C.)	260	232	200	201	56.3	85.9
pH						

49. Water-bearing formation: Quaternary alluvium. Source of sample: Spring of P. M. Bowen, 1 mile southeast of Springer. Spring number 31.
50. Water-bearing formation: Quaternary alluvium. Source of sample: Well of L. K. Moore. Well number 25. Maxwell Grant.
51. Water-bearing formation: Quaternary alluvium. Source of sample: Well of J. M. Crews. Well number 18. Maxwell Grant.
52. Water-bearing formation: Quaternary alluvium. Source of sample: Well-public supply of Koehler
53. Water-bearing formation: Quaternary alluvium. Source of sample: Well-public supply of Dawson.
54. Water-bearing formation: Quaternary alluvium. Source of sample: We:1 of John King, SW1/4 sec. 3, T. 29 N., R. 27 E.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior

Analysis number	55	56	57	58	59	60
Date of collection	5/1/4 6	2 /25 46	2 /25 46	2 /25 46	2/25/46	2 /25 /46
Silica (SiO₂)						
Iron (Fe)	—	—	—	—		
Calcium (Ca)	40	54	48	56	53	119
Magnesium (Mg)	17	34	36	42	46	104
Sodium (Na)	7.1	72	101	80	73	217
Potassium (K)	195	308	326	314	340	350
Bicarbonate (HCO₃)	10	146	174	188	166	704
Sulfate (SO₄)	6	14	22	17	13	110
Chloride (Cl)	5	1	1.7	1.5	1.7	2.4
Fluoride (F)	6	2.8	4.4	6.7	7.2	18
Nitrate (NO₃)						1.2
Borate (BO₃)						
Dissolved solids:						
—ppm.	183	476	548	546	527	1,
—tons/a. ft .....	.25	.65	.75	.74	.72	1.97
Hardness as CaCO₃:						
Total	170	274	268	312	321	724
Noncarbonate	10	22	1	54	42	438
Percent sodium	8	36	45	36	33	39
Specific conductance (Kx10₅ at 25° C.)	35.3	74.4	85.1	81.6	82.1	203
pH						

55. Water-bearing formation: Ogallala formation. Source of sample: Well of J. R. Davenport, N VANE% sec. 30, T. 24 N., R. 27 E
 56. Water-bearing formation: Pediment gravel. Source of sample: Well on Hayward and Hansen ranch. Well number 61, Maxwell Grant.
 57. Water-bearing formation: Pediment gravel. Source of sample: Well on Hayward and Hansen ranch. Well number 62, Maxwell Grant.
 58. Water-bearing formation: Pediment gravel. Source of sample: Well on Hayward and Hansen ranch. Well number 63, Maxwell Grant.
 59. Water-bearing formation: Pediment gravel. Source of sample: Well on Hayward and Hansen ranch. Well number 65, Maxwell Grant.
 60. Water-bearing formation: Pediment gravel. Source of sample: Well of E. G. Hayward. Well number 48, Maxwell Grant.

Analysis number	61	62	63	64	65		66
Date of collection	2/25 /46	2/25/46	5/29/46	10/15	/46	9/24/45	2/28/46
Silica (SiO ₂).....	—	—	—	-			
Iron (Fe).....	—	--		-			
Calcium (Ca).....	98	108	428	82		137	36
Magnesium (Mg).....	86	109	348	27		36	10
Sodium (Na).....	129	152	296	23		70	6.9
Potassium (K) •							
Bicarbonate (HCO ₃).....	416	410	404	366		236	150
Sulfate (SO ₄).....	435	625	2,570	55		329	17
Chloride (Cl).....	49	37	85	5		74	2
Fluoride (F).....	1.8	1.5	1.3	.2		.5	.6
Nitrate (NO ₂).....	15	8.3	14	.2		.2	1.4
Borate (B ₂ O ₃).....	.5	.6	—	-			.2
Dissolved solids:							
—ppm.....	1,020	1,240	3,940	373		770	148
—tons/a. ft.....	1.39	1.69	5.36	.51		1.05	.20
Hardness as CaCO ₂ :							
Total.....	598	718	2,500	316		490	131
Noncarbonate.....	257	382	2,170	16		296	8
Percent sodium.....	32	32	20	14		24	10
Specific conductance (Kx10 ₅ at 25° C.).....	150	177	453	64.1		116	26.9
pH.....							

61. W

ater-bearing formation: Pediment gravel. Source of sample: Well of L. N. Swope. Well number 47, Maxwell Grant.

62. Water-bearing formation: Pediment gravel. Source of sample: Well of E. W. Swope. Well number 45, Maxwell Grant.

63. Water-bearing formation: Pediment gravel. Source of sample: Well of Neal Hansen. Well number 46, Maxwell Grant.

64. Water-bearing formation: Pediment gravel. Source of sample: Spring on south side of Gonzalitos Mesa, J. T. Fernandez, NE1/4 sec. 25, T. 24 S., R. 20 E.

65. Water-bearing formation: Pediment gravel. Source of sample: Spring—public supply of Maxwell. 3 miles east of Maxwell, spring number 27.

66. Water-bearing formation: Raton formation and slope debris. Source of sample: Spring on east slope of Fisher's Peak Mesa above Lake Malloya. spring number 7.

TABLE 7. ANALYSES OF GROUND WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior

[Parts per million]

Analysis number	67	68	69	70	71	72
Date of collection	9 /26 /45	2 /12 /46	2 /12 /46	9 /26 /45	9 /26 /45	2 /13 /46
Silica (SiO ₂)	23	27	23	27	21	-
Iron (Fe) .....	.05	.01	.04	.01	.01	-
Calcium (Ca)	23	29	30	34	22	34
Magnesium (Mg).....	8	7.2	7.5	8.7	9.6	8.5
Sodium (Na)						
Potassium (K)	4.6	5.1	5.8	4.4	4.8	19
Bicarbonate (HCO ₃)	110	127	132	148	117	170
Sulfate (SO ₄)	5.3	5.8	5.8	4.9	5.3	12
chloride (Cl)	2	1.5	1.5	2.2	1.5	4
Fluoride (F).....	.2	.1	.1	.2	.2	.2
Nitrate (NO ₃)	1.7	.9	2.5	.7	1	3.2
Borate (BO ₃)	-	.1	.1	-	-	-
Dissolved solids:						
-ppm	122	139	141	155	123	165
-tons/a. ft.....	.17	.19	.19	.21	.17	.22
Hardness as CaCO ₃ :						
Total	90	102	106	121	94	120
Noncarbonate	0	0	0	0	0	0
Percent sodium	10	10	11	7	10	25
specific conductance (Kx10 ₃ at 25 ^o C.)	17.6	21.3	22.1	23.2	18.8	28.5
pH		7.8	7.7	-		

67. Water-bearing formation : Raton format on. Source of sample: Spring on west slope of Barilla Mesa above Lake Malloya. Spring number 20.
 68. Water-bearing formation E., (north spring) : Raton format on. Source of sample: Spring on west slope of Barilla Mesa above Lake Malloya, sec. 23, T. 32 N., R. 24
 69. Water-bearing formation E., (south spring) : Raton formation. Source of sample: Spring on west slope of Barilla Mesa above Lake Malloya, sec. 23, T. 32 N., R. 24
 70. Water-bearing formation Raton format on. Source of sample: Spring on west slope of Barilla Mesa above Lake Malloya. **Spring number 19?**
 71. Water-bearing formation Raton format on. Source of sample: Spring on west slope of Barilla Mesa above Lake Malloya. **Spring number 8?**
 72. Water-bearing formation Raton format on and Quaternary basalt. Source of sample: Sunshine Dairy Spring on south side of Bartlett Mesa. Spring number 26.

Analysis number	73	74	75	76	77
Date of collection	2 /13 /46	4/6/46	2 /25 /46	1/7/46	6 /25/46
Silica (SiO ₂)	30		17		
Iron (Fe) .....	.01				
Calcium (Ca)	33	77	232	484	212
Magnesium (Mg)	9.6	20	182	1,010	46
Sodium (Na)					
Potassium (K)	16	20	238	558	24
Bicarbonate (HCO ₃)	173	361	372	462	746
Sulfate (SO ₄)	7	8.6	1,210	5,860	89
Chloride (Cl)	2.8	5.2	167	64	38
Fluoride (F)	2	3	1.2		.1
Nitrate (NO ₃)	3.8	3.8	52	5	15
Borate (BO ₃)	0		.8		
Dissolved solids:					
—pima	188	313	2,280	8,210	792
—tons/a. ft. ....	.26	.43	3.10	11.2	1.08
Hardness as CaCO ₃ :					
Total	122	274	1,330	5,360	718
Noncarbonate	0	0	1,020	4,980	106
Percent sodium.	22	13	28	18	7
Specific conductance (Kx10 ₃ at 25° C.)	28.4	58.0	290	790	131
pH -----	7.8				

73. Water-bearing formation: Quaternary basalt. Source of sample: Snake Gulch Spring on east side of Bartlett Mesa. Spring number 23.
74. Water-bearing formation: Quaternary basalt. Source of sample: Spring, Joyce ranch headquarters, C. W. Rountree. SW1/4 sec. 12. T. 26 N., Chico FL 25 E.
75. Water-bearing formation: Pediment gravel. Source of sample: Well of Andrew Hansen. Well number 66, Maxwell Grant.
76. Water-bearing formation: Wind-blown deposits (?). Source of sample: Well at W. Libby Estate. Well number 32, Maxwell Grant.
77. Water-bearing formation: Early Tertiary sill (?). Source of sample: Well of H. T. Foree (100 feet deep), SWIASW1/4 sec. 6, T. 27 N., R. 27

TABLE 8. ANALYSES OF SURFACE WATER FROM COLFAX COUNTY, N. MEX.

Analyses by Geological Survey, United States Department of the Interior

(Parts per million)

	1	2	3	4	5	6
	-	4 / 5 / 46	-	4 / 5 / 46	8 / 20 / 46	1 / 14 / 46
Silica (SiO ₂) -----						
Iron (Fe).....						
Calcium (Ca)	127	29	200	58		344
Magnesium (Mg)	68	12	104	31		197
Sodium (Na).....						
Potassium (K)	110	27	102	60		297
Bicarbonate (HCO ₃)	308	141	256	181	171	324
Sulfate (SO ₄).....	547	58	854	228	849	1,860
Chloride (Cl).....	10	2	34	8		78
Fluoride (F).....						
Nitrate (NO ₃) .....	.9	2.6	.6	6.2		2.5
Borate (BO ₃)						
Dissolved solids:						
—PPm.	1,010	200	1,420	480		2,940
—tons/a. ft	1.37	.27	1.93	.65		4.00
Hardness as CaCO ₃ :						
Total	596	122 926		272		1,670
Noncarbonate	344	6 716		124		1,400
Specific conductance (Kx10 ⁶ , at 25° C.)				70.6	174	341
pH	142	33.1 187				

ANALYSES OF SURFACE WATER

1. Chicorico Creek at iron bridge on old Raton-Clayton highway. Composite sample Dec 1, 14, 21, 28, 1945.
2. Chicorico Creek at same place as analysis number 1.
3. Una de Gato Creek. 1 mile east of intersection with Chicorico Creek. Composite sample Nov. 16, 23, 30, 1943.
4. Una de Gato Creek at same place as analysis number 3.
5. Canadian River at Taylor Springs.
6. Canadian River at same place as analysis number 5.

Analysis number	7	8	9	10	11	12
Date of collection	9/25/45	9 /25 /45	9 /25 /45	1 /11 /46	4 /10 /46	10/26/45
Silica (SiO ₂)						23
Iron (Fe)						
Calcium (Ca)	28	32	30	74	53	16
Magnesium (Mg)	9.3		11	17	14	6.3
Sodium (Na)	6.2	8.3	9.0	36	30	2.1
Potassium (K).....						
Bicarbonate (HCO ₃).....	138	162	158	200	175	78
Sulfate (SO ₄)	6.2	13	7.6	154	92	4.9
Chloride (Cl).....	.8	1.2	1.2	5	11	1
Fluoride (F)						
Nitrate (NO ₃)	1.1	.3	.4	.6		.1
Bolate (BOO-----						
Dissolved solids:						
- p.p.m	120	147	137	385	286	92
-tons/a. ft.....	.16	.20	.19	.52	.39	.13
Hardness as CaCO ₃ :						
Total	108	130	120	254	190	66
Noncarbonate.....	0	0	0	90	46	2
Specific conductance						
(Kx10 ₅ at 25° C.) -----	22.7	26.9	25.7	61.1	46.2	13.6
pH.....						

7. Schwacheim Creek, Cole. above Lake Malloya. R. Riegstrom Creek, Colo. above Lake Malloya.
9. Walton Creek, Colo. above Lake Malloya.
10. Vermejo River near Dawson. 11 Vermejo River near Dawson, 12. Rayado Creek near Cimarron.

TABLE 8. ANALYSES OF SURFACE WATER FROM COLFAX COUNTY, N. MEX.

(CONTINUED)

Analyses by Geological Survey, United States Department of the Interior

[Parts per million]

Analysis number	13	14	15	16	17
Date of collection	-			9 /26 /95	1 /19 /46
<i>Silica</i> (SiO ₂) -----	12	17	13		
Iron (Fe).....	.94	.09	.04		
Calcium (Ca).....	31	43	41	365	400
Magnesium (Mg).....	6.6	9.7	8.5	125	209
Sodium (Na).....					
Potassium (K).....	10.5	16	14.3	149	216
Bicarbonate (HCO ₃).....	132	177	169	272	316
Sulfate (SO ₄).....	13	16	16	1,400	1,880
Chloride (Cl).....	3.0	4.1	4.1	47	78
Fluoride (F).....	.4	.4	.4	.3	
Nitrate (NO ₃).....	.4	.7	.4	.8	1.1
Borate (BO ₃).....	.1	.1	.1		
Dissolved solids:					
-ppm	142	194	181	2,220	2,940
-tons/a. ft._ ..	.19	.26	.25	3.02	4.00
Hardness as CaCO ₃ :					
Total -----	104	148	138	1,420	1,860
Noncarbonate -----	0	0	0	1,200	1,600
Specific conductance (Kx10 ₅ at 25° C.)	23.7	31.9	30.3	262	332
PH	7.6	7.6			

13. Cimarron River at Ute Park. Composite sample Apr. 1-10, 1996 (period of minimum concentration). 19.

Cimarron River at Ute Park. Composite sample Aug. 21-31, 1946 (period of maximum concentration)

15. Cimarron River at Ute Park. weighted average for 1945-96.

16. Cimarron River at Springer.

17. Cimarron River at Springer.

TABLE 9. ANALYSES OF PUBLIC SUPPLIES IN COLFAX COUNTY, N. MEX.

Analyses by Geological Survey, United States Department of the Interior

[Parts per million]

Analysis number	1	2	3	4	5	6
Date of collection		9 / 2 / 45	5 / 31 / 46	4 / 5 / 47	2 / 11 / 47	9 / 24 / 45
Silica (SiO ₂)	15					
Iron (Fe) -----	.04					
Calcium (Ca)	24	73	32	67	188	137
Magnesium (Mg)	8.8	22	6	14	65	36
Sodium (Na)	5.5	38	5.3	39	211	70
Potassium (K)						
Bicarbonate (HCO ₂)	114	210	111	186	293	236
Sulfate (SO ₄)	9.9	167	21	136	866	329
Chloride (Cl)	2	6	1.8	9.0	32	74
Fluoride (F)	2	4	.2	.5	.4	.5
Nitrate (NO ₂)	1	.4	0	.8	9.6	.2
Borate (BO ₃) .....			.2	.2		
Dissolved solids:						
-ppm.	123	410	121	358	1,520	770
-tons/a. ft. ....	.17	.56	.16	.49	2.07	1.05
Hardness as CaCO ₃ :						
Total	96	272	104	224	736	490
Noncarbonate	3	100	14	72	496	296
Percent sodium	12	23	10	27	38	24
Specific conductance (Kx10 ⁵ at 25° C.)	19.3	63.8	21.4	56.3	201	116
pH						

1. Raton public supply. Source of sample: Lake Malloya. Composite sample, Aug. 2, 4, 6, 8, 10, 12, 14, 1945.
2. Springer public supply. Source of sample: Highland ditch, furnishing water to reservoir.
3. Cimarron public supply. Source of sample: Town reservoir.
4. Dawson public supply. Source of sample: Phelps Dodge Co. well, 1/2 mile northeast of Dawson
5. Koehler public supply. Source of sample: Well 1 mile east of Koehler.
6. Maxwell public supply. Source of sample: Spring 3 miles east of Maxwell.

**TABLE 9. ANALYSES OF PUBLIC SUPPLIES IN COLFAX COUNTY, N. MEX.
(CONTINUED)**

*Analyses by Geological Survey, United States Department of the Interior
[Parts per million]*

Analysis number	7	8			
Date of collection	12 /16 /46	5/29/46			
Silica (SiO ₂)	—				
Iron (Fe)	—				
Calcium (Ca)	48	49			
Magnesium (Mg)	21	15			
Sodium (Na)	38	13			
Potassium (K)					
Bicarbonate (HCO ₃)	292	163			
Sulfate (SO ₄)	35	71			
Chloride (Cl)	7	2			
Fluoride (F)	1.4	.5			
Nitrate (NO ₃) .....	.1	1.1			
Borate (B ₀₃)	-	-			
Dissolved solids:					
—ppm.	294	232			
—tons/a. ft .....	.40	.32			
hardness as CaCO ₃ :					
total.	206	184			
Noncarbonate	0	50			
Percent sodium	29	14			
Specific conductance (Kx105 at 25° C.)	51.7	39.5			
pH.....					

7. Farley public supply. Source of sample: Well of A. C. Hoffman. sec. 35. T. 25 N., It 27 E

8. Miami public supply. Source of sample: Town reservoir.

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PUBLICATIONS OF THE MINERAL RESOURCES SURVEY

No.	<i>Title and Author</i>	<i>Date</i>	<i>Price</i>
1	The Mineral Resources of New Mexico; Fayette A. Jones-----	1915	Out of print
2	Manganese in New Mexico; E. H. Wells -----	1918	Out of print
3	Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico; E. H. Wells	1919	Out of print

PUBLICATIONS OF THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

BULLETINS

No.	<i>Title and Author</i>	<i>Date</i>	<i>Price</i>
4	Fluorspar in New Mexico; W. D. Johnston, Jr. (Superseded by Bulletin 21)		Out of print
5	Geologic Literature of New Mexico; T. P. Wootton (Superseded by Bulletin 22)	1930	Out of print
6	Mining and Mineral Laws of New Mexico; Charles H. Fowler (Superseded by Bulletin 16)	1930	Out of print
7	The Metal Resources of New Mexico and their Economic Features; S. G. Lasky and T. P. Wootton		.50
8	The Ore Deposits of Socorro County, New Mexico; S. G. Lasky	1932	.60
9	The Oil and Gas Resources of New Mexico; Dean E. Winchester (First edition; superseded by Bulletin 18)	1933	Out of print
10	The Geology and Ore Deposits of Sierra County, New Mexico; G. Townsend Harley	1934	.60
11	The Geology of the Organ Mountains, with an Account of the Geology and Mineral Resources of Dona Ana County, New Mexico; Kingsley Charles Dorman		1.00
12	The Non-Metallic Mineral Resources of New Mexico and their Economic Features (Exclusive of Fuels); S. B. Talmage and T. P. Wootton	1936	.50
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Topographic map of New Mexico. Scale about 8

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