GEOLOGY OF CUSTER COUNTY, OKLAHOMA

Frontispiece. Foss Dam and Reservoir across Washita River valley, looking north.

OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, *Director*
BULLETIN 114

GEOLOGY AND MINERAL RESOURCES (EXCLUSIVE OF PETROLEUM) OF CUSTER COUNTY, OKLAHOMA

PART I.—STRATIGRAPHY AND GENERAL GEOLOGY OF CUSTER COUNTY

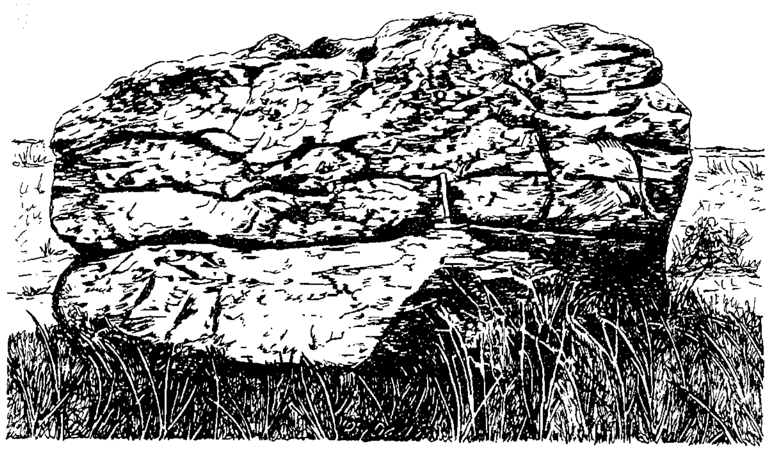
ROBERT O. FAY

PART II.—ECONOMIC GEOLOGY OF CUSTER COUNTY

ROBERT O. FAY

PART III.—GROUND WATER IN CUSTER COUNTY

D. L. HART, JR.



The University of Oklahoma
Norman
1978

Title Page Illustration

Ink drawing by Roy D. Davis from a photograph (fig. 43, p. 44) of a massive sandstone block of the Dakota Group of Cretaceous age, resting upon covered beds of the Elk City Sandstone of Permian age.

This publication, printed by Edwards Brothers, Inc., Ann Arbor, Michigan (book), and Stafford-Lowdon Co., Fort Worth, Texas (map), is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes, 1971, Section 3310, and Title 74, Oklahoma Statutes, 1971, Sections 231-238. 1,000 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $16,633.

CONTENTS

	Page
Abstract	1
Part I.—Stratigraphy and General Geology	
Introduction	3
Acknowledgments	4
Stratigraphy	4
Introduction	4
Permian System	5
Custerian Series	6
Whitehorse Group	6
Marlow Formation	7
Rush Springs Formation	9
Foss Group	19
Cloud Chief Formation	20
Doxey Shale	32
Post-Foss rocks	35
Elk City Sandstone	35
Cretaceous System	37
Comanchean Series	37
Washita Group	37
Kiowa Formation	37
Dakota Group	43
Quaternary System	44
Pleistocene Series	44
Part II.—Economic Geology	
Introduction	47
Clay	47
Gypsum	49
Volcanic ash	49
Dolomite	50
Sandstone	50
Sand and gravel	50
Salt	54
Uranium and vanadium	54
Part III.—Ground Water	
Introduction	61
Source, occurrence, and movement	61
Storage	61
Availability	62
Use	65
Municipal use	65
Irrigation use	65
Rural use	66
Potential development	66
References cited	67
Appendix to Part I—Measured stratigraphic sections	71
Index	85

ILLUSTRATIONS

Figures

1. Index map showing location of Custer County ... 2
2. Nomenclatural diagram of rock units ... 4
3. View of Emanuel Bed of Marlow Formation ... 8
4. View of Relay Creek Bed of Marlow Formation ... 9
5. View of Rush Springs Formation ... 12
6. View of Old Crow Bed of Rush Springs Formation ... 12
7. View of type locality of One Horse Gypsum Bed and Old Crow Bed of Rush Springs Formation ... 12
8. View of Old Crow Bed of Rush Springs Formation ... 13
9. View of Weatherford Bed of Rush Springs Formation ... 13
10. View of Weatherford Bed of Rush Springs Formation ... 13

		Page
11.	View of Weatherford Bed of Rush Springs Formation	13
12.	View of Weatherford Bed of Rush Springs Formation	14
13.	View of Weatherford Bed of Rush Springs Formation	14
14.	Butte capped by Weatherford Bed of Rush Springs Formation	14
15.	Escarpment capped by Weatherford Bed of Rush Springs Formation	14
16.	View of One Horse Bed (now Weatherford) of Rush Springs Formation	15
17.	View of interval between Weatherford Bed of Rush Springs Formation and Moccasin Creek Bed of Cloud Chief Formation	15
18.	View of Rush Springs sandstone between Weatherford Bed and Moccasin Creek Bed of Cloud Chief Formation	16
19.	Buttes capped by Moccasin Creek Bed of Cloud Chief Formation	16
20.	Butte capped by Moccasin Creek Bed of Cloud Chief Formation, with Weatherford Bed of Rush Springs Formation	16
21.	Sugar Loaf Mound, south of Thomas	16
22.	View of Moccasin Creek Bed of Cloud Chief Formation on sandstone of Rush Springs Formation	22
23.	Quarry in Moccasin Creek Bed of Cloud Chief Formation	22
24.	Quarry in Moccasin Creek Bed of Cloud Chief Formation	22
25.	Quarry in Moccasin Creek Bed of Cloud Chief Formation	23
26.	Hill of Moccasin Creek Bed of Cloud Chief Formation, with orange-brown siltstone above	24
27.	View of Moccasin Creek Bed of Cloud Chief Formation, with sandstone of Rush Springs Formation below and siltstone and shale of Cloud Chief above	24
28.	View of siltstone and shale of Cloud Chief Formation	25
29.	View of Day Creek Bed of Cloud Chief Formation	26
30.	View of Day Creek Bed of Cloud Chief Formation	26
31.	View of Day Creek Bed of Cloud Chief Formation in sandstone	27
32.	Cloud Chief topography	27
33.	Cloud Chief Formation in Red Hills northwest of Clinton	28
34.	View of pink shale in orange-brown sandstone, Cloud Chief Formation	28
35.	View of siltstone of Doxey Shale resting on shale, sandstone, and satin spar of Cloud Chief Formation	29
36.	View of Doxey–Cloud Chief contact	33
37.	Doxey topography	33
38.	View of Elk City Sandstone on Doxey Shale	33
39.	View of purple and greenish-gray shale in Elk City Sandstone	35
40.	Three views of Cretaceous units near type Neocomian locality of Marcou	40
41.	View of Kiowa Formation	41
42.	Gravel pit of probable Pleistocene sediments overlying Permian red beds	41
43.	Dakota sandstone block on outcrop of Elk City Sandstone	44
44.	Pleistocene gravel pit	45
45.	View of Pearlette volcanic ash, overlain by sandstone and gravel	45
46.	View of Pleistocene caliche overlying sandstone of Rush Springs Formation	46
47.	View of Pleistocene pebbles on gypsum of Moccasin Creek Bed of Cloud Chief Formation	46
48.	View of tan Pleistocene(?) sandstone	46
49.	View of Acme Brick Co. plant and pit	48
50.	Map showing distribution of dolomites in Custer County	53
51.	Radiometric map of basal Doxey Shale in Custer County	59
52.	Hydrograph and precipitation data near Weatherford	62
53.	Geologic section across Washita River valley	64

Plates

1.	Geologic map and sections of Custer County	pocket
2.	Isopach and structure contour maps of Permian red beds, Custer County	pocket
3.	Correlation diagrams of Permian red beds in Custer County	pocket

TABLES

1.	Reserves and analyses of volcanic ash	51
2.	Reserves and analyses of dolomites	52
3.	Analyses of sand and gravel deposits	55
4.	Uranium and vanadium analyses	58

GEOLOGY AND MINERAL RESOURCES (EXCLUSIVE OF PETROLEUM) OF CUSTER COUNTY, OKLAHOMA

Abstract—The geologic section of Custer County, central western Oklahoma, consists of 750 feet of Upper Permian red beds, overlain by a veneer of Pleistocene deposits less than 100 feet thick, with small areas of slumped Lower Cretaceous rocks in the western part of the County. The Permian beds dip from 10 to about 80 feet per mile southward, being on the north flank of the Anadarko basin.

The oldest group of rocks represented at the surface in Custer County is the Whitehorse Group, comprising the Marlow Formation and the overlying Rush Springs Formation. The Marlow consists mostly of orange-brown fine-grained sandstone; the upper 50 feet crops out along the Canadian River in the northeastern part of the County. In the subsurface the Marlow is about 85 to 140 feet thick, and the Relay Creek and Emanuel Beds of dolomite and gypsum are discernible at the top. The overlying Rush Springs Formation, 300 feet thick in the northeastern part of the County and 430 feet thick in the southeastern part, is mostly orange-brown fine-grained sandstone, with the Old Crow Bed of gypsum and dolomite occurring about 120 feet below the top in the northern part and the Weatherford Bed of gypsum and dolomite about 40 feet below the top.

Overlying the Whitehorse Group is the Foss Group (name new), comprising the Cloud Chief Formation at the base (175 feet thick) and the Doxey Shale at the top (195 feet thick). The Cloud Chief is mainly orange-brown shale and siltstone, and the Doxey is mainly red-brown shale and siltstone. In southeastern Custer County, the lower 118 feet of the Cloud Chief is gypsum. The Moccasin Creek Bed of gypsum and dolomite occurs at the base of the Cloud Chief, overlain by the Kiger Member of shale and siltstone (about 50 feet thick), with the Day Creek Bed above the Kiger. The Day Creek Dolomite occurs east of Clinton and northward but appears to be absent in the southwestern part of the County. The overlying Big Basin Member is mostly orange-brown shale and siltstone, with some sandstone. The base of the Doxey can be correlated with the Alibates Dolomite of the Texas Panhandle, and the Guadalupean-Ochoan boundary is probably between the lower and upper dolomites of the Alibates.

The Elk City Sandstone, overlying the Foss Group, is about 50 feet thick in Custer County. The top is eroded, and the formation occurs in the southwestern part of the County. The Sandstone Creek Lentil (name new) occurs in northeastern Beckham County, a few miles west of Custer County, and is a series of well-indurated coarse-grained sandstones with calcite cement, about 80 feet thick. Some of this coarse sandstone occurs in Custer County. The Elk City may be younger than known Ochoan rocks in North America.

The Lower Cretaceous Kiowa Formation occurs as small slumped areas in Permian red beds in the western part of Custer County. The Kiowa is mostly dark-gray and yellow-brown shale, with *Texigryphaea* limestones, representing the lower 50 feet of the Kiowa farther north. In southwestern Custer County, slumped blocks of brown to gray cross-bedded sandstone and quartzite conglomerate rest upon the Doxey Shale and Elk City Sandstone. These blocks are classed as part of the lower sandstone of the Lower Cretaceous Dakota Group, above the Kiowa Formation.

The Pleistocene sediments are classed into three systems: (1) Canadian River, (2) Deer Creek, and (3) Washita River. Each system has several sets of terrace levels, and stream piracy in early Pleistocene time is indicated. The Deer Creek deposits contain volcanic ash (Pearlette) and were probably deposited by the ancient Canadian River in Kansan time and earlier. The main gravels of the Canadian River are on the northeast side, indicating that this river has since shifted southwestward downdip since Kansan time. The Washita River gravels are mainly north of the present-day stream, indicating that the Washita has shifted southward downdip and laterally during Pleistocene time.

The main geologic products of Custer County are oil and gas, water, clay, gypsum, dolomite, sand and gravel, volcanic ash, uranium and vanadium, and salt. Brick is produced by one company at Clinton from clay and shale in the Cloud Chief Formation, which has possibly been reworked. Clay reserves are ample for many years at the current production rate of 20 million bricks per year. The gypsum is 91 to 95 percent pure, with about 1.3 billion tons of reserves. The associated anhydrite reserves are about 523 million tons. Several hundred thousand tons of volcanic ash occurs in the Custer City area. Thin dolomites, 1 to 3 feet thick, occur in the eastern part of the County, with estimated reserves of 1.4 million cubic yards. Sandstones have been quarried locally for building purposes and ballast. Sand and gravel pits have been opened in many areas, and the material has been used for road metal, railroad ballast, and concrete. Several pure salt beds, 150 to 175 feet thick, occur 950 to 1,600 feet underground near Custer City, with reserves estimated at about 3 billion tons. Uranium and

vanadium minerals have been found in the upper Cloud Chief Formation and the lower Doxey Shale near Clinton and Foss but have not been found commercial.

Ground water is the principal source of supply for municipal, industrial, irrigation, and domestic water use in Custer County. The cities of Clinton and Weatherford are the largest users of ground water for municipal supply. The development of large wells for irrigation has been primarily in the eastern third of the County and along the bottom lands of the Washita River.

Most of the ground water in Custer County is derived from precipitation falling directly on the area. Mean annual precipitation is about 25 inches; hence approximately 1,300 acre-feet of water falls on each square mile each year.

Aquifers capable of supplying moderate to large quantities of water to wells are sandstones of the Marlow and Rush Springs Formations (Whitehorse Group) in the eastern part of the County and alluvium along the Washita River. Wells tapping bedrock aquifers in the western part of the County generally produce sufficient water for domestic and stock needs, but extended dry periods may reduce well yields. The water quality is generally poorer than in eastern Custer County because of higher concentrations of dissolved solids, mainly sulfates.

Although no areas of serious overdevelopment of ground-water resources are known to exist in Custer County, the area most likely to be so affected is east of Weatherford in the vicinity of that city's well field (T. 12 N., R. 14 W.). Otherwise, the Whitehorse aquifer (Marlow and Rush Springs) should have the potential to supply water to a great many more wells in eastern Custer County.

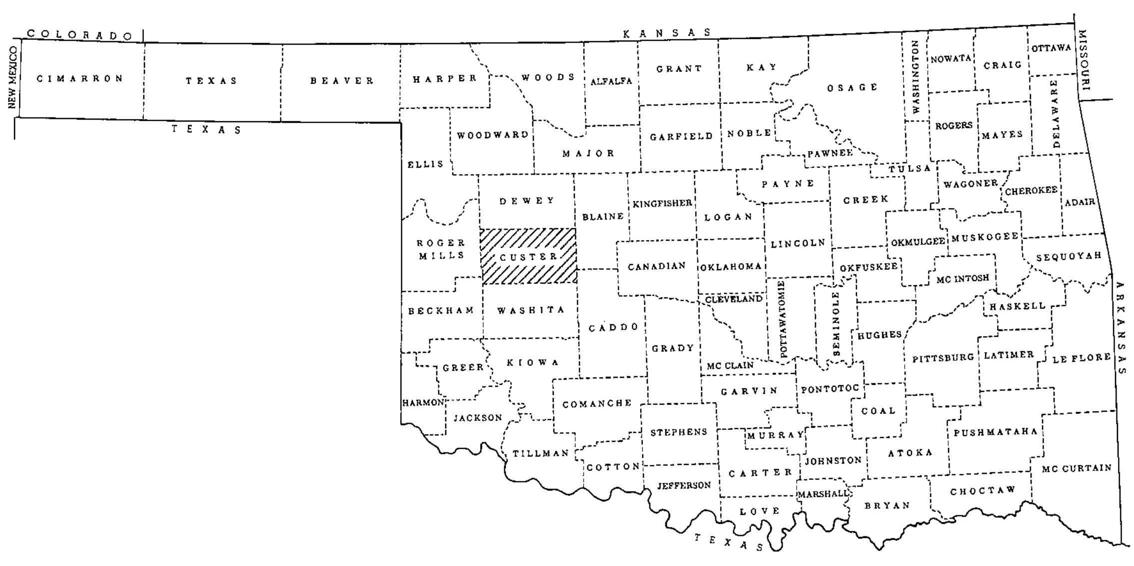


Figure 1. Index map of Oklahoma showing location of Custer County.

PART I.—STRATIGRAPHY AND GENERAL GEOLOGY OF CUSTER COUNTY

ROBERT O. FAY[1]

INTRODUCTION

Custer County, in west-central Oklahoma, comprises an area of approximately 1,000 square miles (fig. 1). The county seat is Arapaho, located centrally, with a population of 700. Weatherford is the largest city (8,800), and Clinton is next (8,600). Smaller towns are Thomas (1,350), Custer City (450), Butler (300), Moorewood, Stafford, Indianapolis, and Anthon. Hammon (650), in Roger Mills County, is on the western border of Custer County.

U.S. Highway 66 (Interstate 40) crosses the southern part of the County from east to west, and U.S. Highway 183 crosses the center of the County from north to south. State Highways 47 and 33 extend from east to west through the northern and central parts, and State Highways 34 and 54 extend from north to south through the western and eastern parts of the County, respectively. Clinton is known as the "hub city" because U.S. Highways 66 and 183 intersect here, and the Chicago, Rock Island & Pacific Railway, the St. Louis-San Francisco Railway, and the Atchison, Topeka & Santa Fe Railway pass through the city.

The principal raw products of the County are cotton, wheat, cattle, and oil and gas. Foss Reservoir State Park, in the southwestern part of the County, is a well-equipped recreational area of about 30 square miles around Foss Lake, which was created by a dam 3.5 miles long across the Washita River (frontispiece). The reservoir is to provide water for Clinton, for Bessie and Cordell in Washita County, and for Hobart in Kiowa County, and may be used for irrigation of 10,000 acres of farm land, in addition to affording protection from floods.

Two rivers flow southeastward through Custer County: the Canadian River in the northeastern corner, and the Washita River in the southwestern part. The elevation of the Canadian River is about 1,500 feet above sea level, and that of the Washita River is 1,700 feet near Hammon and 1,440 feet southeast of Clinton (pl. 1, cross sections). Deer Creek and Barnitz Creek flow southeastward into the Canadian and Washita Rivers in the eastern and central parts of the County, respectively, and have wide valleys with Pleistocene gravels beneath and along the sides, with Pearlette volcanic-ash deposits along tributaries of Deer Creek. Pleistocene deposits in several terrace levels occur along the Canadian and Washita Rivers, and scattered remnants may be found over high areas (pl. 1). Quartermaster Creek, a tributary to the Washita River in the western part of the County, also has a wide valley flanked by Pleistocene deposits and may be an underfit stream similar to Barnitz and Deer Creeks.

Custer County is in the Red-Bed Plains region of the Great Plains, the highest parts being about 2,040 feet in the southwest corner and 1,820 to 1,860 feet in the eastern buttes. The total relief in the County is about 600 feet. Most of the county is underlain by red-brown to orange-brown sandstone with much gypsum in the Clinton-Weatherford area and red-brown to orange-brown shale in the southwestern part. Sandstone is also present in the southwest corner of the County, but it is stratigraphically higher in the section than is the sandstone to the north and east. In the northern and eastern parts are many buttes and escarpments formed by erosion of weakly resistant beds adjacent to dolomites and gypsums. Some of the prominent buttes near Thomas are capped by dolomites; two have been named Sugar Loaf Mound and Indian Hill (pl. 1,

[1]Geologist, Oklahoma Geological Survey.

cross-section *E-E'*), these and others having been used as markers along the Santa Fe Trail by the Josiah Gregg expedition of 1839-40.

Structurally, Custer County is on the north flank of the Anadarko syncline, with a general south dip of 10 to 80 feet per mile and a strike changing from northwest in the eastern part of the County to west and southwest in the western part. In the Putnam (Dewey County) and Custer City areas, the beds are almost flat, and the dip in the northern part of the county is about 10 to 20 feet per mile (pl. 2). The dip increases from 20 to about 80 feet per mile along an area between Hammon and Weatherford, with an irregular swale south of Butler. In the southwestern part of the County the dip is about 20 to 30 feet per mile to the southeast. The irregular structures common over large areas may not extend to depth and may be caused by collapse of underlying beds owing to solution of salt and gypsum. Many erratic features may be unrelated to known tectonic structures and should not be used indiscriminately for exploration of oil and gas.

Acknowledgments

Carl C. Branson field-checked the final map and gave helpful suggestions, and Alex. Nicholson, Edith Flood, and Carl C. Branson edited the manuscript. William E. Ham helped with drafting problems, and Roy D. Davis drafted the plates. Leon Hill, John Thompson, Fred Chambers, and Philip Kensley of the U.S. Bureau of Reclamation kindly supplied information on Foss Dam and supplied the photograph for the frontispiece. William H. Bellis supervised the work on chemical analyses.

STRATIGRAPHY

INTRODUCTION

The geologic section of Custer County consists of approximately 750 feet of Permian red beds of the Custerian (Upper Permian) Series, overlain by a veneer of Pleistocene deposits generally less than 100 feet thick, with small slumped areas of Cretaceous rocks in the western part of the County (fig. 2).

SYSTEM	SERIES	GROUP	FORMATION	THICKNESS (FEET)
Quaternary	Pleistocene		Alluvium	0-132
			Terrace deposits, including Pearlette ash	0-100
Cretaceous	Comanchean		Dakota Group (lower sandstone)	0-10
			Kiowa Shale	0-10
Permian	Upper Permian		Elk City Sandstone	50 exposed
		Foss	Doxey Shale	195
			Cloud Chief shale and gypsum, with some dolomite	175
		Whitehorse	Rush Springs sandstone and dolomite, with some shale	247-310
			Marlow sandstone and impure dolomite	50 exposed

Figure 2. Nomenclatural diagram of named rock units in Custer County.

The red beds are here classed under the Custerian Series, because it is difficult to correlate exact boundaries of Guadalupean and Ochoan rocks from the type areas in Texas and New Mexico. The Custerian Series in Custer County consists of the Whitehorse Group, the Foss Group (name new), and the Elk City Sandstone at the top.

The Whitehorse Group is mainly sandstone, with the Marlow Formation at the base, overlain by the Rush Springs Formation. Only the upper 50 feet of the Marlow crops out along the Canadian River bluffs in the northeastern part of the County. In the subsurface, the Marlow is 90 to 140 feet thick (pl. 2). Several thin, persistent impure dolomites or gypsums occur in the upper part of the Marlow, termed the Relay Creek Bed and the Emanuel Bed (at top), and these are used as markers for separation of the Marlow from the Rush Springs. The Rush Springs is 300 to 430 feet thick (surface), with the Old Crow Bed about 120 feet below the top and the Weatherford Bed about 40 feet below the top, occurring mostly in the eastern and northern parts of the County.

The Foss Group is mainly shale, with the Cloud Chief Formation at the base, overlain by the Doxey Shale. The term Quartermaster Formation is here rejected because of a lack of grouping of the Doxey Shale and Elk City Sandstone. Also, the rocks exposed along Quartermaster Creek are Rush Springs and Cloud Chief. The Cloud Chief is about 175 feet thick, the lower 118 feet of which is gypsum in the southeastern part of the County. Elsewhere, the basal part of the Cloud Chief is a multiple gypsum unit termed the Moccasin Creek Bed, with about 50 feet of shale, siltstone, and sandstone of the Kiger Member above, overlain in places by a dolomite termed the Day Creek

Bed, with the Big Basin Member at top. The Doxey Shale is about 195 feet thick and occurs in the southwestern part of the County. At the base is a greenish-gray calcitic or dolomitic siltstone, interbedded with red-brown shale, resting upon orange-brown shale of the Cloud Chief Formation.

The Elk City Sandstone occurs above the Foss Group in the southwestern corner of the County, and only the lower 50 feet is preserved. No unconformities were noted in the section.

The Cretaceous deposits consist of two different lithologic facies: (1) the fossiliferous *Texigryphaea* limestones and dark-gray to yellow-brown fossiliferous shales, and (2) the brown to gray unfossiliferous sandstones and conglomerates, commonly cross-bedded and grading into quartzite. The first facies is classed as the lower part of the Kiowa Formation and is the common Cretaceous rock seen in the western part of the County. The Kiowa may be 30 feet thick, and all exposures are limited to slumped areas less than 1 acre in area. The second facies (*Kd* on map, pl. 1) occurs as blocks up to 8 feet thick in the southwestern part of the County. The rocks rest upon the Doxey Shale and the Elk City Sandstone and are classed as the lower sandstone of the Dakota Group.

The Pleistocene sediments may be classed into three systems: (1) the Canadian River deposits in the eastern part of the County, (2) the Deer Creek deposits with Pearlette volcanic ash along Deer Creek and its tributaries east of a line from Custer City to Weatherford, and (3) the Washita River deposits, mainly north of the Washita River. Each system has several sets of terrace levels, and the distribution of gravels indicates that stream piracy operated in early Pleistocene time.

PERMIAN SYSTEM

The Permian System is subdivided into an Upper Permian Series and a Lower Permian Series, according to Moore (1966, p. xxix). The Upper Permian of Russia is subdivided into the Tatarian (at top), Kazanian, and Kungurian Stages, and the Upper Permian of North America is subdivided into the Ochoan (at top) and Guadalupean Stages. It is also stated that the Tatarian includes some Lower Triassic strata and is equivalent to upper Thuringian (Zechstein) deposits of Germany, and that the Kazanian is equivalent to lower Thuringian (Zechstein) deposits. The stage units are considered unfirm, being provincial in application. Dunbar (1940, p. 263) used the name Tartarian, and American geologists have since followed this spelling. Marcou (1858, p. 9-10) first recognized Permian rocks in Oklahoma.

The type Guadalupean rocks of west Texas contain marine fossils of little value in correlation with nonmarine red beds. At present the base of the Guadalupean is correlated into north-central Texas at the base of the San Angelo Formation, and this unit is correlated into Oklahoma at the base of the Chickasha Formation or upper Duncan Sandstone, in the middle of the Flowerpot Shale. Thus the Flowerpot Shale of Texas is only upper Flowerpot, and the San Angelo is middle Flowerpot.

The type Ochoan rocks of southeastern New Mexico are mainly unfossiliferous marine evaporites, containing much salt, and almost pinch out eastward and northward in the southern part of the Texas Panhandle. The entire Ochoan appears to correlate with the Doxey Shale, and the Ochoan-Guadalupean boundary is probably within the lower part of the Doxey. The Elk City Sandstone would thus be considered post-Ochoan.

Preliminary palynologic studies indicate that the upper part of the Flowerpot Shale may correlate with the lower Zechstein Z_1 of Europe or the lower Kazanian of Russia or the lower Guadalupean of Texas. Olson (1962, p. 156) correlated the upper San Angelo vertebrates as lower Guadalupean and lower Kazanian at the top of Zone I of the Russian section after detailed discussion and comparison with many of the type-Russian sections and study of Russian material. Newell (1940, p. 277) studied Whitehorse invertebrates and compared the fossils with the Guadalupean Capitan fauna and the Russian Kazanian and Bakmuth dolomite faunas. Thus the red beds of Custer County would be upper Kazanian and lower Tatarian, or upper Guadalupean, Ochoan, and post-Ochoan.

The term Custerian Series was introduced by Fay (1965, p. 39) for Permian red beds from the base of the Whitehorse Group to the top of the Elk City Sandstone, in order to eliminate questionable usage of series designations from Texas into Oklahoma. Also, if the Elk City is post-Ochoan, another series name would be desirable to include the Elk City. The Kansas Geological Survey has adopted Custerian Stage (not series), according to Zeller (1968, p. 52), but the Texas Bureau of Economic Geology prefers to wait until completion of current red-bed studies before considering adoption of the term Custerian, according to Dr. Virgil E. Barnes (personal communication).

Custerian Series

The red beds of Oklahoma may be classed into two units, considered Permian in age. The Cimarronian (lower) Series includes beds from the base of the Wellington Formation through the El Reno Group. This is roughly Artinskian, Kungurian, and lower Kazanian of Russia, or Leonardian and lower Guadalupean of Texas.

The Custerian (upper) Series extends from the base of the Whitehorse Group through the Elk City Sandstone. This is tentatively correlated as upper Kazanian and lower Tatarian of Russia, or upper Guadalupean, Ochoan, and post-Ochoan of Texas.

This usage allows a natural division of the Midcontinent Permian red beds. The instability of boundaries and the theoretical basis for establishment of the Permian were discussed by Dunbar (1940), Moore (1940), and Tomlinson and others (1940). An excellent discussion is given by Gregory (1958) in the San Angelo Geological Society's guidebook, *The Base of the Permian—a Century of Controversy*. It is pointed out that the type Ochoan is defined on a different basis than the type Guadalupean and older series, and that Russian geologists disagree on the base of the Permian in Russia. A chart is shown by Moore (1940, p. 304) in which about 50 different authors placed the Lower Permian boundary at 13 different stratigraphic positions in Texas.

The Custerian red beds of Custer County belong to a marginal basin facies, with thicker sections southward and thinner sections northward, the region of breakover with the northern platform being in northern Dewey County and southern Major and Woodward Counties, as shown by Fay (1965, pl. 3) and on plate 2 herein. The Marlow Formation averages about 100 feet in thickness, being somewhat thicker (130–140 feet) nearer the axis of the Anadarko basin southward. The overlying Rush Springs is about 430 feet thick in southeastern Custer County and is thinner northward (250–300 feet) and westward (200 feet), being about 87 feet thick near Quinlan, Woodward County, and 80 feet thick near Borger, Hutchinson County, Texas, where more shale is present. The Cloud Chief is about 175 feet thick in Custer County, being thinner in Ellis County to the northwest, where it is 124 feet thick, and in Hutchinson County, Texas, where it is 104 feet thick. In southwestern Custer County, the Cloud Chief is about 310 feet thick, and farther south in Beckham County it is almost 430 feet thick, according to Ham and Jordan (1961, p. 6). The Doxey Shale is about 195 feet thick in Custer County but is reported to be only 165 feet thick in eastern Beckham County, to the south, by Ham and Jordan (1961, p. 6). It is quite possible that the unusual thickness of the underlying Cloud Chief is incorrect and that some of the Doxey is included in the Cloud Chief. A gypsum 40 feet below the top of their Cloud Chief might better serve as the base of the Doxey. The top of the Elk City is everywhere eroded, so little is known about basin-platform relationships of this formation.

WHITEHORSE GROUP

The term "Red Bluff beds" was first used by Cragin (1896, p. 40) for the sequence of rocks between the Dog Creek Shale below and the Day Creek Dolomite above. The sequence was named for Red Bluff post office near Protection, Comanche County, Kansas. The name was preoccupied, so Gould (1905, p. 55) proposed that the sequence be named Whitehorse Sandstone Member for Whitehorse Springs, Woods County, Oklahoma. Sawyer (1929, p. 11) changed the name to Whitehorse Group, subdividing it into the Marlow Formation below and the Rush Springs Sandstone above, a usage followed at present. The type section of the Whitehorse Group is that on Moccasin Creek, Woods County, which is also the type section for the Rush Springs Formation (Fay, 1965, p. 40). The type section of the Marlow Formation is that northwest of Greenfield, Blaine County (Fay, 1962, p. 67), and this is also the type section for the Emanuel and Relay Creek Beds, used for separation of the Marlow from the Rush Springs.

The Whitehorse Group, primarily red-brown to orange-brown sandstone in Custer County, is about 560 feet thick in the southeastern part of the County and 400 feet thick in the northeastern part. Only the upper 50 feet of the Marlow is exposed in the northeastern part of the County, so these thicknesses include subsurface data where differences from 85 to 140 feet can be observed for total Marlow thicknesses. The Rush Springs is about 430 feet thick in the southeastern part of the County, 300 feet thick in the northern part, and 200 feet thick in the western part. At the type section in Woods County, the Whitehorse is 194 feet thick, and near Borger, Hutchinson County, Texas, it is about 170 feet thick. Along the Red River in Hall County, Texas, the Whitehorse is about 270 feet thick. The Whitehorse is reported to be 385 feet thick in eastern Beckham County, according to Ham and Jordan (1961, p. 8).

The base of the Whitehorse Group in Oklahoma, Kansas, and Texas is a greenish-gray to orange-brown sandstone, grading into gypsum from northern Woodward County, Oklahoma, to Cave Creek, Comanche County, Kansas. The underlying Dog Creek is primarily a red-brown shale, and the contact is sharply delineated where observed. A map showing the present structure at the base of the Whitehorse Group in northwestern Oklahoma (including Custer County) and adjacent parts of Kansas and Texas is included with a report on the revision of the Whitehorse Group by Fay (1965, pl. 3).

The upper boundary of the Whitehorse Group was revised by Fay (1965, p. 40–41) because (1) marker beds previously used for mapping purposes were inconsistently used from one county to another, (2) the Whitehorse should be considered primarily a sandstone group, (3) gypsums and dolomites can occur in the Whitehorse, and (4) the overlying Cloud Chief Formation is primarily a shale and siltstone body, grading into gypsum in the Clinton-Weatherford-Eakly area, and is not defined on the basis of the presence of gypsums and dolomites.

The term Moccasin Creek Bed was introduced by Fay (1965, p. 73) for a dolomite, gypsum, or multiple zones at the base of the Cloud Chief Formation, greenish-gray where leached, resting upon Rush Springs sandstone. A map resulting from the use of this new concept would show a much smaller outcrop area for the Cloud Chief from Dewey County southward through Custer County (where the Weatherford Bed was previously used) and a somewhat larger area of outcrop in the region north of Dewey County (where the Day Creek Bed was previously used) than is shown on the geologic map of Oklahoma by Miser and others (1954). A structure-contour map of this horizon in northwestern Oklahoma and adjacent parts of Kansas and Texas will be presented in a later paper. Essentially, the Moccasin Creek is intermediate between the Weatherford Bed below and the Day Creek Bed above and is persistent over a wider area than the latter two. Preliminary regional correlations are shown by Fay (1965, pl. 3).

Marlow Formation

Name.—The name Marlow Formation was first used by Sawyer (1924, p. 313–315) for 120 feet of sandstone and shale between the Duncan Sandstone (now Chickasha) below and the Whitehorse Sandstone of Reeves (1921) (now Rush Springs) above. The formation was named for Marlow, Stephens County, Oklahoma. Evans (1931, p. 416) proposed the name Relay Creek Dolomites for the previously used name Greenfield Limestones (preoccupied) of Stephenson (1925, p. 629–630), and Fay (1962, p. 69) named the upper dolomite the Emanuel Bed and the lower dolomite the Relay Creek Bed, with the type section northwest of Greenfield, Blaine County. The Emanuel Bed, currently used as the marker for the top of the Marlow Formation, is included in the Marlow.

Type sections.—The type section for the Marlow Formation is that designated by Fay (1962, p. 67) in the Red Bluffs northwest of Greenfield, Blaine County, in the NW¼ sec. 29, T. 15 N., R. 11 W., and the NE¼ sec. 25, T. 15 N., R. 12 W. The type section for the Emanuel and Relay Creek Beds is that designated by Fay (1962, p. 70) in the NE¼NE¼ sec. 25 and the SE¼SE¼ sec. 24, T. 15 N., R. 12 W., northwest of Greenfield, Blaine County.

Description in Custer County.—The Marlow Formation is exposed along the Canadian River bluffs of northeastern Custer County, and only the upper 50 feet is exposed to water level. It is mostly orange-brown fine-grained quartzose sandstone, with a 1-inch maroon to light-gray thinly laminated crinkly bedded Emanuel Bed of impure dolomite at the top (fig. 3). The Relay Creek Bed is maroon to dark-gray impure dolomite about 1 inch thick, being about 18 feet below the Emanuel Bed, and is described in measured section 3 (Appendix). In the subsurface, the Marlow ranges in thickness from about 85 feet in the north to 140 feet in the southwestern part of the County, with apparent conformity upon the underlying Dog Creek Shale. Isopach and structure maps of the Blaine and the Dog Creek indicate southward thickening of these units, with thickening in the upper Dog Creek being four times greater than in the lower Dog Creek (pl. 2). On electric logs, the basal Marlow contact is easily picked by a flaring out above the pinched-in Dog Creek (pl. 3). The Emanuel and Relay Creek Beds also have high resistivity kicks where anhydrite or dolomite is suitably thick, and these kicks flare outward from the sandstone kicks.

Description in southeastern Dewey County.—An important transition takes place in the Relay Creek Bed just north of Custer County. About 30 feet of upper Marlow is exposed along the Canadian River in southeastern Dewey County in the NW¼ sec. 25, T. 16 N., R. 15 W. (measured section 16). The Emanuel Bed is a 1-inch maroon to light-pink impure dolomite. About 27 feet below is the thin Relay Creek Bed, which is gradational into a 1-foot white to pink gypsum. Farther north the gypsum is almost 10 feet thick in the NW¼ sec. 4 and the NE¼ sec. 5, T. 16 N., R. 15 W., and in the NW¼ sec. 6, T. 17 N., R. 15 W. (fig. 4). In the subsurface, the Marlow is estimated to be about 80 to 100 feet thick in Dewey County.

Age and correlation.—The Marlow is here correlated with beds between the Childress Dolomite below to the Eskota Gypsum above, as mapped on the Lubbock sheet of Texas by Barnes (1967). On the Plainview Sheet (Barnes, 1968), the Marlow is 135 feet thick. The lower and upper Eskota correspond to the Relay Creek and Emanuel Beds, respectively. In New Mexico, the Marlow is correlated with the Grayburg and Artesia Formations, as revised by Ahlen and others (1960) of the Roswell Geological Society's stratigraphic committee. It was mentioned that Lewis (1938, p. 1711) was one of the first to suggest Whitehorse correlations into New Mexico. DeFord and Lloyd

Figure 3. Emanuel Bed of Marlow Formation, showing crinkly bedded ledge of dolomite and sandy limestone. South side of State Highway 33, looking southeast, in NW¼NW¼NE¼ sec. 22, T. 15 N., R. 14 W., Custer County. Rush Springs (above) and Marlow (below) are composed of fine-grained orange-brown sandstone.

(1940, p. 8) quoted a statement by Lewis that the Marlow is correlated with the Grayburg, considered Guadalupean in age.

Beede (1907) first studied Whitehorse fossils. Newell (1940, p. 271) compared the Whitehorse fossils with those from the Capitan of Texas and with the Kazanian and Bakmuth faunas of Russia. The Marlow fossils were collected from three different lenses: (1) basal Doe Creek Lentil, Whitehorse Springs, Woods County; (2) upper Doe Creek Lentil, east of Woodward, Woodward County; and (3) Verden Lentil, near Chickasha, Grady County. The fauna comprises *Dozierella gouldii* (1-3), *Conocardium oklahomense* (1), *Myalina* sp. (1), *Gryphellina sellardsi* (1), *Schizodus oklahomensis* (1), *Aviculopecten vanvleeti* (1), *Permophorus albequus* (1-3), *P. a. longus* (1), *Spirorbis* sp. (1), *Baylea capertoni* (1), *Cyclites depressus* (1), *Naticopsis transversus* (1), *Girtyspira? alvaensis* (1), *Cyclobathmus haworthi* (1), *Pakistania schucherti* (1), *Pseudodielasma perplexa* (1), *Composita mexicana* (1), *C. subcircularis* (1), and *Lioclema dozierense* (1–2).

Origin.—Traced northward from Custer County, the Marlow contains much gypsum and shale. The sand was probably derived from the east or southeast. For instance, the basal Marlow sandstone grades northwestward into 27 feet of gypsum in Harper County, and the upper Marlow sandstone grades into shale in this area. In Beaver County along the Cimarron River, the upper Marlow is gypsum and shale. In Caddo County the Marlow is mainly sandstone, but farther south in northern Stephens County much shale is in the Marlow, which suggests an eastern rather than a southern origin for the sand. Near Anadarko, Caddo County, the Emanuel and Relay Creek Beds are gypsums, but farther east and southeast they are dolomites, probably toward land.

From the preceding information, I would guess that the source of the Marlow sand was east of the present outcrop in Canadian and Grady Counties and that the breakover with the northern platform was in northern Woodward County. Custer County would be near the middle of the basin.

Rush Springs Formation

Name.—The name Rush Springs Member was first used by Sawyer (1929, p. 11) for the sandstone between the Marlow Member below and a gypsum above. The name is for Rush Springs, Grady County, Oklahoma. The Weatherford dolomite, a 1-foot dolomite bed about 40 feet below the thick gypsum at the type section, was named by Sawyer for the town of Weatherford, Custer County, Oklahoma. This usage is followed in the present report, the Weatherford being considered as a bed within the upper part of the Rush Springs Formation. The lower contact of the Rush Springs was

Figure 4. Relay Creek Bed of Marlow Formation. Massive 5-foot gypsum occurs on east side of creek in NE¼NE¼ sec. 5, T. 16 N., R. 15 W. (measured section 16), southeastern Dewey County, and persists for about 5 miles southeastward along west bank of Canadian River, where gypsum grades into thin maroon crinkly bedded dolomite.

not firmly defined by Sawyer, and Evans (1931, p. 416) redefined the contact to be that at the top of the upper Relay Creek Dolomite (now Emanuel Bed), a usage now followed. The term Rush Springs Formation was used by Fay (1965, p. 56) for the Woods County area of northern Oklahoma because gypsum, dolomite, and shale are present in the section, but the term Rush Springs Sandstone is almost as appropriate because the main lithology is fine-grained orange-brown sandstone.

The upper boundary of the Rush Springs Formation has been inconsistently defined from one county to another in Oklahoma, and various authors have used separate terms for beds in order to define this boundary locally for mapping purposes. To gain uniformity of terminology, Fay (1965, p. 73) proposed the name Moccasin Creek Bed for a dolomite or gypsum, or multiple dolomites and gypsums, at the base of the Cloud Chief and marking the top of the Rush Springs. The name is for Moccasin Creek, northwestern Woods County, Oklahoma. The type sections for the Whitehorse Group and the Rush Springs Formation were also placed together along Moccasin Creek, and this new concept was treated in detail in various counties in Oklahoma, Kansas, and the Texas Panhandle so that no misunderstandings of local usages would occur. A resulting map would show a much larger area of Rush Springs outcrops south of the Canadian River, including Custer County, and slightly smaller areas of outcrops north of the river, as compared with the present geologic map of Oklahoma (Miser and others, 1954).

The old terminology for the defined top of the Whitehorse starts with Gould (1905, p. 55), who used the name Day Creek Dolomite for the bed at the upper boundary and included the Day Creek in the Cloud Chief in Woods, Woodward, and Harper Counties. As presently defined, the Day Creek is a bed in the Cloud Chief about 30 feet or more above the top of the Whitehorse.

Sawyer (1929, p. 11) used the name Weatherford dolomite for a bed in Dewey, Custer, and Washita Counties, occurring about 25 to 40 feet below the base of the Cloud Chief Formation, within the Rush Springs Formation. This usage is now followed, but in the past the Weatherford was the marker bed at the top of the Rush Springs, as used on the geologic map of Oklahoma by Miser and others (1954); and where the Weatherford was slumped, missing, or confused with the overlying Moccasin Creek Bed, the Moccasin Creek was used (but not then named).

Clapp (1920) named a 2- to 80-foot gypsum in the Cyril-Cement area of Caddo County the Cyril Gypsum, and Reeves (1921, p. 48–50) stated that the Cyril is two beds, an upper gypsum 0 to 85 feet thick and a lower gypsum 1 to 40 feet thick, with 15 to 20 feet of sandy shale between. The lower gypsum has a 1-foot dolomite at the base, a bed correlated with the Weatherford Bed and thus a member of the Rush Springs Formation. In the past, any gypsum in this area was used as a marker for the base of the Cloud Chief, and, where the lower gypsum was missing, the upper gypsum (Moccasin Creek) was used. As now defined, only the upper gypsum can be used as a marker at the base of the Cloud Chief in this area, the lower gypsum being included in the Rush Springs Formation. In Custer County the Weatherford and Moccasin Creek Beds are gypsums in similar areas, having the same relationships as the lower and unper Cyril beds.

Gould (1924, p. 337) defined the Cloud Chief Formation from outcrops in Washita County but considered the dolomite (now Weatherford) to be the defined base and correlated this as the Day Creek Bed. Thus by original definition of the Cloud Chief, the Weatherford Bed was used as marker for the top of the Rush Springs. This is now altered so that the base of the Cloud Chief is at the base of the Moccasin Creek Bed, recognizing that the Day Creek is about 60 feet or more above the Weatherford Bed.

In southeastern Dewey County, two thin gypsum units occur about 30 and 120 feet below the top of the Rush Springs; these were named One Horse Gypsum and Old Crow Gypsum, respectively, by Cragin (1897, p. 363) for indian crossings of the Canadian River, the upper one being named One Horse crossing. The Old Crow Bed occurs in adjacent parts of Custer County and extends into northwestern Dewey County. It probably extends westward and southwestward into the Texas Panhandle, in the subsurface. The One Horse is here correlated with the

Weatherford Bed, and the name One Horse is suppressed in favor of the name Weatherford because of popular usage of the latter term.

Type locality.—The type locality for the Rush Springs is the area of Rush Springs, Grady County, Oklahoma. The top part is eroded, so Davis (1955, p. 68) selected a type locality in sec. 36, T. 7 N., R. 10 W., south of Anadarko, Caddo County. Here the Emanuel Bed is a gypsum near the base of the cliff, overlain by 280 feet of sandstone, with a few inches of Weatherford gypsum and dolomite on top, according to O'Brien (1963, p. 27, 29). Thus this section is incomplete, so Fay (1965, p. 57) selected the area of Moccasin Creek for a type section in Woods County, being the type Whitehorse section also. The type Weatherford area is the region south of Weatherford, Custer County, and the type locality for the Old Crow and One Horse Beds is the area west of Butte (now a ghost town), southeastern Dewey County.

Type section.—The type section for the Rush Springs Formation is in the SE¼ sec. 8, T. 28 N., R. 18 W., Woods County, Oklahoma, along West Moccasin Creek. Here the Rush Springs is 77 feet thick and is an orange-brown fine-grained sandstone with interbedded red-brown shale and a massive sandstone near the top. The overlying Moccasin Creek is a 3-foot bed of dolomites and greenish-gray to orange-brown siltstones and sandstones, eroding into an escarpment. The base of the Rush Springs is marked by the Emanuel Bed, which is a white to greenish-gray calcitic sandstone. The underlying Marlow is 117 feet thick, and the total type-Whitehorse thickness is 194 feet.

The type section for the Weatherford Bed is in the SE¼SE¼ sec. 18 and the SW¼SW¼ sec. 17, T. 12 N., R. 14 W., about 1 mile south of Weatherford, Custer County. Here the Weatherford is a 1-foot pink dolomite bed, about 38 feet below the base of the Cloud Chief gypsum, with much siltstone and sandstone above (measured section 1).

The type section for the One Horse Bed is in the SE¼ sec. 22, T. 16 N., R. 15 W., where the bed is about 4 feet thick (measured section 16). The type Old Crow Bed is in the SW¼NE¼NE¼ sec. 22, T. 16 N., R. 15 W., southeastern Dewey County. Here the Old Crow is a 2.5-foot pink to white gypsum with a 4-foot pink to orange-brown gypsum and sandstone below, the top being about 88 feet below the top of the One Horse Bed (now Weatherford).

Description in Custer County.—The Rush Springs Formation is primarily an orange-brown fine-grained quartzose sandstone, ranging in thickness from 430 feet in the southeastern part of the County to 300 feet in the northeastern part and 200 feet in the western part (pls. 2, 3). In many places the sandstone is cross-bedded (fig. 5) and erodes into badlands with many evergreens and cactus plants. In places the sandstone weathers into small sand balls, the cementing material being calcite and locally clay. Mostly the sandstone is friable, with hematite-stained sand grains, but where it is well indurated the cementing material is commonly gypsum or calcite.

The Old Crow Bed is primarily a 0.5- to 10-foot gypsum ranging from 120 to 178 feet below the top of the Rush Springs. In the Clinton area, in the subsurface, the bed is about 10 feet thick and about 178 feet below the top (measured section 6). In the Thomas area, a 0.1-foot bed of impure dolomite is tentatively identified as the Old Crow, about 139 feet below the top (measured section 3). Northwest of Thomas, the Old Crow is a 1- to 2.5-foot gypsum underlain by a gypsiferous sandstone, eroding into a mappable escarpment about 120 feet below the top of the Rush Springs (figs. 6–8). In northwestern Custer County, in the subsurface, a 2.0-foot gypsum occurs about 110 feet below the top of the Rush Springs and is here identified as the Old Crow (measured section 8). The bed is absent in southeastern Custer County.

The Weatherford Bed is a gypsum or a dolomite as much as 8 feet thick, occurring 24 to 42 feet below the top of the Rush Springs, with sandstone and some siltstone and shale above. In the type region south of Weatherford, the bed is a dolomite about 1 foot thick, occurring about 38 feet below the top of the Rush Springs, eroding into a prominent mappable escarpment (fig. 9). In this same area, in the NE¼NW¼SE¼ sec. 18, T. 12 N., R. 14 W., the bed is 3.25 feet thick and grades into gypsum in the lower part (fig. 10). This section is now being filled in by the Weatherford city dump.

In the eastern part of Custer County,

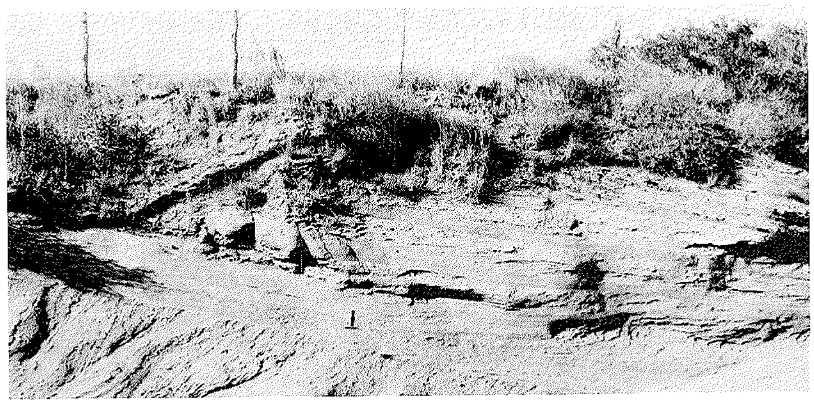


Figure 5. Rush Springs Formation. View, looking northeast, of cross-bedded sandstone about 120 feet below Weatherford Bed in SW¼SE¼SE¼ sec. 23, T. 12 N., R. 14 W., southeastern Custer County.

Figure 6. Old Crow Bed of Rush Springs Formation. View, looking northeast, at type section east of road in SW¼NE¼NE¼ sec. 22, T. 16 N., R. 15 W., southeastern Dewey County (measured section 16). Upper gypsum is 2.5 feet thick (dashed line at base) and grades into 4 feet of gypsiferous sandstone below.

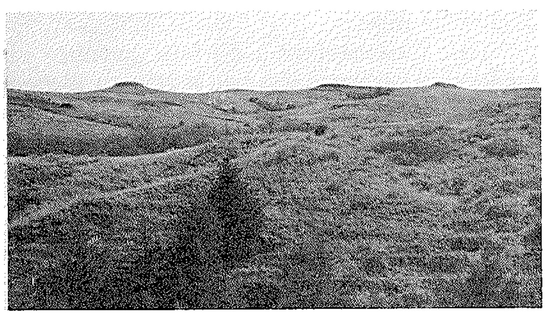


Figure 7. Type locality of One Horse Gypsum Bed (high knobs) and Old Crow Bed (rounded knobs in middle of picture, about 90 feet below One Horse) of Rush Springs Formation. View, looking south, in NE¼ sec. 27, NW¼ sec. 26, SE¼ sec. 22, and SW¼ sec. 23, T. 16 N., R. 15 W., southeastern Dewey County (measured section 16).

the Weatherford is primarily a dolomite. In the Thomas area to the northeast, the Weatherford dolomite occurs in four mounds. In Sugar Loaf Mound, about 3 miles south of Thomas, the bed is 1.5 feet thick and occurs about 24 feet below the top of the Rush Springs. The first mound north of Thomas, named Indian Hill, is capped by the Weatherford, which is about 1 foot thick. Two higher hills occur father northwest, each capped by the Moccasin Creek dolomite, with 42 feet of sandstone below to the Weatherford, which is about 1.5 feet thick (fig. 11). Two smaller hills of slumped Weatherford dolomite occur in this region but are not as prominent as the three mounds. In the 1830's, Josiah Gregg mentioned these landmarks on his expedition to Santa Fe, New Mexico, from Fort Smith, Arkansas. In the East Clinton core, the Weatherford is a 5.8-foot pink to white dolomite, with 33 feet of sandstone above to the Moccasin Creek dolomite. A few miles north, in the Dripping Springs Boy Scout Camp area (abandoned), the Weatherford is a dolomite at least 2 feet thick (fig. 12) and grades into gypsum between this area and the East Clinton site (fig. 13). In southeastern Custer County, in the NE¼SW¼ sec. 36, T. 12 N., R. 14 W., the Weatherford dolomite caps a butte, with several impure dolomites occurring in the next underlying 50 feet (fig. 14). This is one of the westernmost "Caddo County Buttes," indicating that the Weatherford caps all of these buttes to the east. If this is true, these isolated areas should be mapped as Rush Springs.

In the West Eakly core of east-central Washita County, the Weatherford is a 0.7-

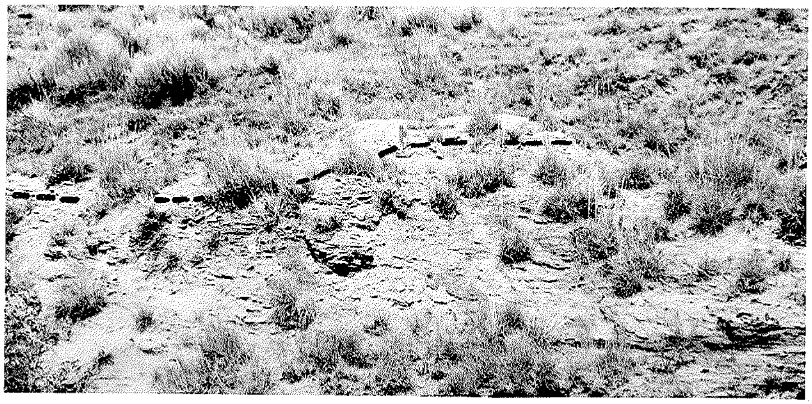


Figure 8. Old Crow Bed of Rush Springs Formation. View, looking northeast, of 1-foot gypsum resting upon gypsiferous sandstone, eroding into escarpment, in NE¼SW¼ sec. 3, T. 15 N., R. 15 W., northeastern Custer County. Base of gypsum indicated by dashed line.

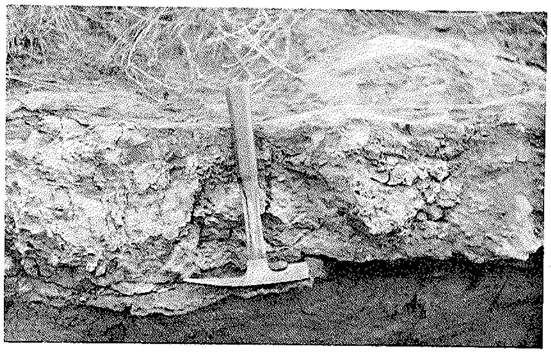


Figure 9. Weatherford Bed (dolomite) of Rush Springs Formation. View, looking west, at type section 1 mile south of Weatherford on west side of road in SE¼SE¼ sec. 14, T. 12 N., R. 14 W., southeastern Custer County. About 38 feet of sandstone and siltstone occurs above this bed to base of Cloud Chief gypsum (measured section 1).

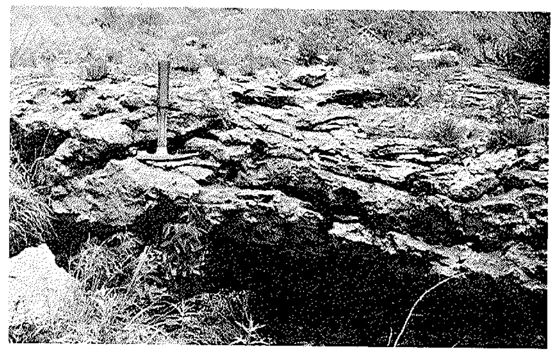


Figure 11. Weatherford Bed (dolomite) of Rush Springs Formation. View, looking northeast, on west side of second butte north of Thomas, in SE¼NE¼ sec. 24, T. 15 N., R. 15 W., northeastern Custer County (measured section 3). This bed caps Indian Hill directly to south and is near base of hill to north.

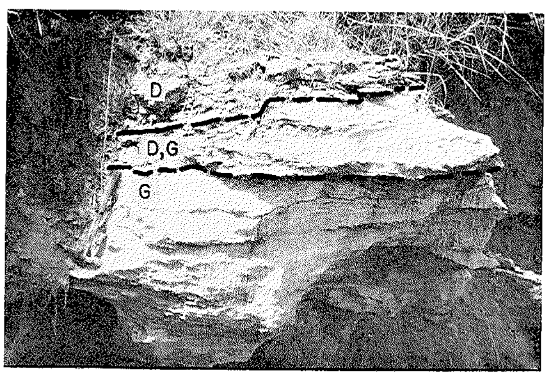


Figure 10. Weatherford Bed of Rush Springs Formation. View, looking southwest, of 3.25-foot bed of gypsum (*G*) and dolomite (*D*), at south end of Weatherford city dump southwest of road in NE¼NW¼SE¼ sec. 18, T. 12 N., R. 14 W., southeastern Custer County. This is evidence to show that gypsum north of this area grades into dolomite south of this region and that dolomite occurs at top of gypsum.

foot maroon to pink and greenish-gray dolomite that is fine to medium grained, thinly laminated, crinkly bedded, and well indurated, with about 44 feet of sandstone above to the thick Cloud Chief gypsum (measured section 14). In most of eastern Washita County, the Weatherford is a dolomite.

In western Custer County and most of Dewey County, the Weatherford is a gypsum as thick as 8 feet, eroding into a prominent mappable escarpment (figs. 15, 16). The Weatherford is apparently absent in the western tier of Custer County townships (R. 20 W.).

The interval between the Weatherford Bed and the Moccasin Creek Bed (base of the Cloud Chief Formation) is 24 to 42 feet, the rocks consisting mainly of orange-brown quartzose sandstone and siltstone with some

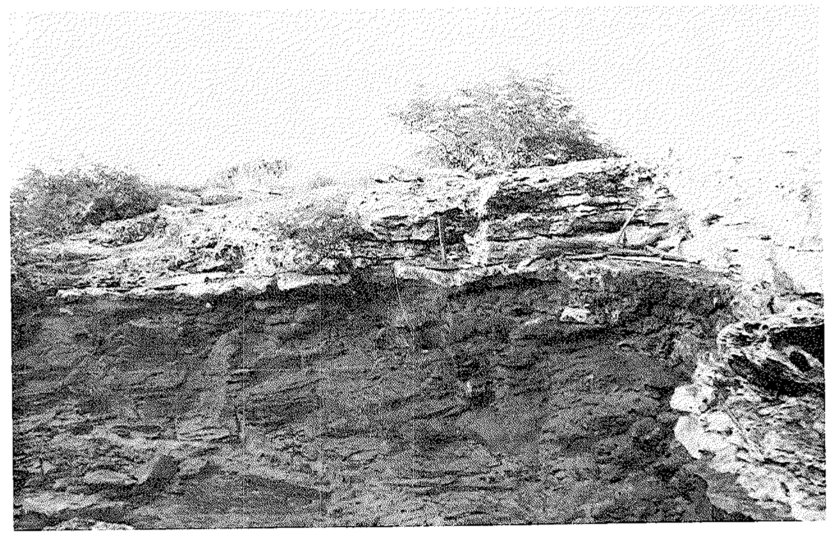


Figure 12. Weatherford Bed (dolomite) of Rush Springs Formation. View, looking northeast, of dolomite on sandstone just north of old Dripping Springs Boy Scout Camp in NE¼NE¼NE¼ sec. 28, T. 13 N., R. 16 W., central Custer County. A few hundred yards southward, this bed grades into gypsum.

Figure 13. Weatherford Bed (gypsum) of Rush Springs Formation. View, looking east, along railroad tracks in SW¼SW¼NW¼ sec. 8, T. 12 N., R. 16 W., south-central Custer County. This bed is typically gypsum in this area.

Figure 14. Butte capped by Weatherford Bed (dolomite) of Rush Springs Formation. Two beds of calcitic sandstone and impure dolomite occur 24 and 47 feet below top, in NE¼SW¼ sec. 36, T. 12 N., R. 14 W., southeastern Custer County. View, looking eastward, of typical butte country, termed Caddo County Buttes farther east.

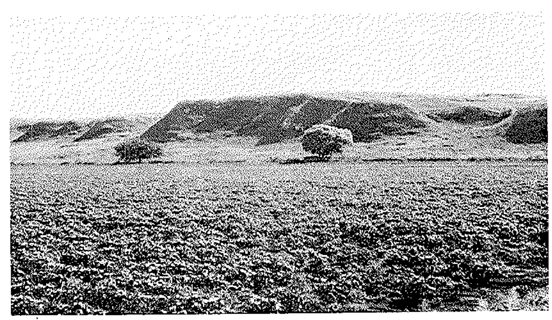


Figure 15. Escarpment capped by Weatherford Bed (gypsum) of Rush Springs Formation. View, looking southwest, on East Barnitz Creek, in W½NW¼ sec. 1, T. 13 N., R. 18 W., central Custer County. This is typical escarpment in western two-thirds of County, and almost everywhere it is slumped.

red-brown shale. In the Weatherford area, the interval is about 25 feet, with a stray gypsum near the middle (fig. 17). In many places it is possible to distinguish the Weatherford from the overlying Moccasin Creek, even where both are gypsums, such as the area west of State Highway 54 in the SE¼ sec. 13, T. 12 N., R. 15 W., where about 40 feet of sandstone occurs between the two beds (fig. 18). Where the Moccasin Creek is thinner the bed consists typically of multiple gypsum units, whereas the Weatherford is a single gypsum bed. And the Moccasin Creek is a double dolomite at some localities, such as that of the East Clinton core, with 33 feet of sandstone below to a single bed of Weatherford dolomite. On the outcrop, the Weatherford at some localities is a single dolomite and the Moccasin Creek a single dolomite, with as much as 42 feet of sandstone in between, as seen in the buttes north of Thomas (figs. 19, 20). At Sugar Loaf Mound, south of Thomas, the interval is 24 feet, being mostly siltstone with some sandstone, but the Moccasin Creek and Weatherford are single dolomite beds eroding into mappable escarpments and correlated into the main outcrop on the basis of elevation and dip (fig. 21). At some places where the gypsum is leached, the Weather-

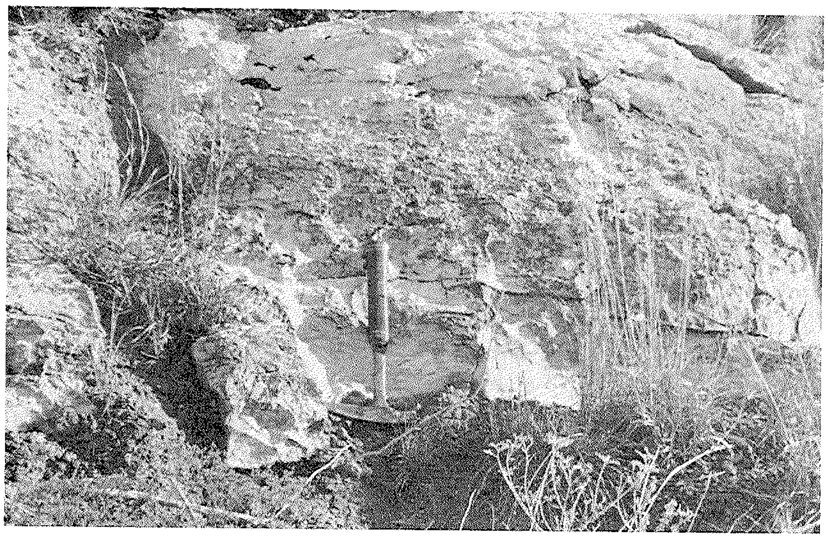


Figure 16. One Horse Bed (now Weatherford) of Rush Springs Formation (gypsum). View at type locality. Closeup, looking east, in SW¼SE¼SE¼ sec. 22, T. 16 N., R. 15 W., southeastern Dewey County. This bed caps buttes and knobs in this area (measured section 16).

Figure 17. Interval between Weatherford Bed (gypsum, *W*) of Rush Springs Formation (at base) and Moccasin Creek Bed (gypsum, *M*) at base of Cloud Chief Formation (at top), with stray gypsum (*G*) about 11 feet below Moccasin Creek Bed and 13 feet above Weatherford Bed. View, looking south, of orange-brown gypsiferous siltstone, in NW¼NW¼ sec. 8, T. 12 N., R. 15 W., southeastern Custer County.

Figure 18. Interval of 40 feet of Rush Springs sandstone between Weatherford Bed (gypsum) in middle of picture and Moccasin Creek Bed (gypsum; basal Cloud Chief) at top of hill. View, looking northwest, on west side of State Highway 54, in SE¼ sec. 13, T. 12 N., R. 15 W., southeastern Custer County.

Figure 19. Buttes north of Thomas, capped by Moccasin Creek Bed (dolomite) of basal Cloud Chief Formation. View, looking west, of northern two buttes north of Indian Hill in NE¼ sec. 24, T. 15 N., R. 15 W., northeastern Custer County.

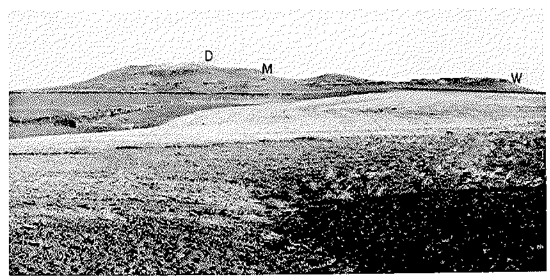


Figure 21. Sugar Loaf Mound, south of Thomas. View looking south, with Weatherford Bed (dolomite, *W*) of Rush Springs Formation at base, Moccasin Creek Bed (dolomite, *M*) of basal Cloud Chief Formation in middle, and Day Creek Bed (dolomite, *D*) of Cloud Chief Formation at top, in NE¼ sec. 7, T. 14 N., R. 14 W., northeastern Custer County (measured section 2).

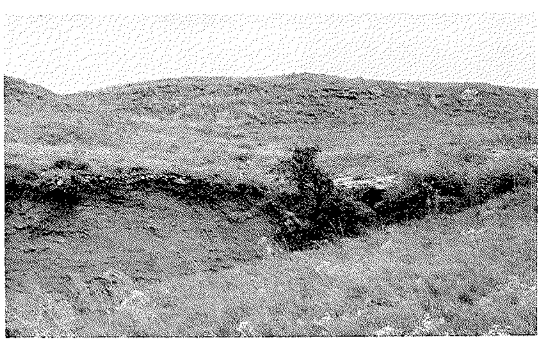


Figure 20. Butte north of Indian Hill, capped by Moccasin Creek Bed (dolomite) of basal Cloud Chief Formation, with Weatherford Bed (dolomite) of Rush Springs Formation in center of photograph. View, looking east, on west side of butte, in SE¼NE¼ sec. 24, T. 15 N., R. 15 W., northeastern Custer County (measured section 3).

ford is missing, and a dashed line is placed on the map to represent this bed. This area is mainly north and just west of Weatherford, where some colluvial wash probably also covers the outcrop. At other places where the gypsum is leached, a greenish-gray zone can be distinguished, especially at the Moccasin Creek boundary. In general, in a region where one dolomite, gypsum, or greenish-gray leached zone occurs, if much shale is present above the zone, the bed is the Moccasin Creek; but if much sandstone is above the zone, the bed is the Weatherford. Sandstone occurs below both beds, so one must look above the bed in order to determine its correct position.

Description in Dewey County.—In Dewey County, the Rush Springs Formation is about 280 feet thick in the southern part and 186 feet in the northern part, the main lithology being orange-brown fine-grained quartzose sandstone. As many as 5 stray gypsum beds are in the upper 188 feet of the Rush Springs.

In southeastern Dewey County, the Old Crow Bed is a gypsum bed about 2.5 feet thick, eroding into a mappable escarpment, about 120 feet below the top of the Rush Springs (figs. 6, 7; measured section 16). In central Dewey County, south of Taloga, the Old Crow is a 3-foot gypsum and occurs about 120 feet below the top of the Rush Springs, with several stray gypsums in the underlying 65 feet of section. In northwestern Dewey County near Camargo, the Old Crow is a 1-foot gypsum and occurs about 103 feet below the top of the Rush Springs. In this region the Old Crow was locally mapped and used as the basis for distinguishing the Marlow from the Rush Springs on the geologic map of Oklahoma (Miser and others, 1954). This interpretation was incorrect, the top of the Marlow being about 90 to 120 feet below the Old Crow, well below the bottom of the Canadian River. North of this region the Old Crow is absent. In the area south of Seiling the Old Crow is absent, the Rush Springs consisting of 186 feet of sandstone without dolomites or gypsums. In northwestern Blaine County, in sec. 6, T. 17 N., R. 13 W., the Rush Springs is about 247 feet thick, and the Old Crow is tentatively identified as a 9-inch dolomite 102 feet below the Moccasin Creek dolomite, with a stray 9-inch dolomite about 67 feet below the Moccasin Creek. The Old Crow is absent north of this area. Thus it is evident that the Old Crow is mostly confined to Dewey and Custer Counties but may extend westward into the subsurface of Texas.

The Weatherford Bed is mainly gypsum, about 24 to 32 feet below the top of the Rush Springs. In southeastern Dewey County, in the SE¼ sec. 22, T. 16 N., R. 15 W., the bed was named the One Horse Gypsum by Cragin (1897, p. 363) and is 4 feet thick, with 32 feet of sandstone above to the Moccasin Creek dolomite (fig. 16; measured section 16). The bed caps many buttes and knobs and is persistent for many miles west of the Canadian River. In northwestern Dewey County near Camargo, the Weatherford is a 2.5-foot gypsum bed, with 25 feet of sandstone above to the Moccasin Creek double gypsum bed. North of this area, the Weatherford is absent. I have been unable to find this bed in the section south of Seiling, the northernmost occurrence being that north of Taloga. Thus the Weatherford is confined to Dewey County and the region southward into Custer and Washita Counties. In the subsurface of southwestern Dewey County, in the West Leedey core, the Weatherford is identified as a 1.1-foot white gypsum bed, with about 24 feet of orange-brown sandstone and siltstone above to the base of the Moccasin Creek gypsum. A few miles south, in the South Leedey core of Custer County, the Weatherford is absent in the subsurface, and I have been unable to find it at the surface of northwestern Custer County. Thus this bed is apparently local to Dewey, Custer, and Washita Counties, with isolated buttes in Caddo County, and one would not expect to be able to correlate this bed into Texas. Its distribution is shown by Fay (1965, pl. 3).

Description in Roger Mills County.—In central Roger Mills County, the Rush Springs Formation is about 250 feet thick (subsurface). In the North Cheyenne core (measured section 15), the upper 54 feet of Rush Springs was cored at the bottom of the well and is a fine-grained orange-brown quartzose sandstone. The Moccasin Creek Bed is 4.5 feet thick, consisting of a triple gypsum sequence at the top of the Rush Springs, and crops out on the north side of the Washita River. The Weatherford Bed is absent. Thus the Rush Springs extends westward along the Washita River valley from Hammon, near the Custer County line, to Strong City and Cheyenne, Roger Mills County, contrary to the geologic map of Oklahoma (Miser and others, 1954), which shows only Cloud Chief in this region.

In northwestern Roger Mills County along the south side of the Canadian River and extending into Hemphill County, Texas, the Rush Springs occurs below a multiple gypsum or dolomite. The exposed sandstone is 10 to 20 feet thick, and the overlying gypsums are here identified as the Moccasin Creek, with red-brown shale of the Cloud Chief above. On the geologic map of Oklahoma (Miser and others, 1954) this region is mapped as alluvium and dune sand next to the Ogallala outcrop.

Many other counties will have to be remapped, using the new boundary at the top of the Rush Springs. For instance, the Rush Springs extends as far west as southeastern Texas County, but only the Cloud Chief is shown on the geologic map of Oklahoma.

Age and correlation.—The Rush Springs is here correlated with the Queen Sandstone of New Mexico, considered to be Guadalupean in age, following DeFord and Lloyd (1940, p. 8), the Roswell Geological Society (Ahlen and others, 1960), and Fay (1965, pl. 3). The Rush Springs is also considered to be the equivalent of the upper part of the Goat Seep Limestone and the Cherry Canyon Formation.

The preceding is based in part on unpublished material, especially from cores and surface work around Sanford Dam, northwest of Borger, Hutchinson County, Texas. Near Sanford, the Whitehorse Group is about 330 feet thick and rests upon red-brown shale of the Dog Creek Shale. The Rush Springs is about 195 feet thick below the Moccasin Creek Bed (previously termed the Saddlehorse Gypsum Lentil by Gould, 1907, p. 16), with a gypsum (Old Crow?) occurring about 70 feet below the top of the Rush Springs. In southeastern Moore County, Texas, along Plum Creek and on the old George Leaverton Ranch, the Rush Springs is about 190 feet thick, consisting of orange-brown sandstone and some red-brown shale with a gypsum (Old Crow?) about 50 feet below the Moccasin Creek. The Old Crow (?) is a persistent gypsum in this region and can be correlated eastward into central Hemphill County, Texas, and southeastern Ellis County, Oklahoma, as shown by Fay (1965, pl. 3). The Emanuel–Relay Creek zone consists mainly of gypsums or one gypsum bed that is correlated throughout the Texas Panhandle at the base of the Rush Springs. In the Plum Creek and Leaverton Ranch areas, a 14-foot massive gypsum crops out at the base of the Rush Springs, and in the Sanford Dam cores this bed is a 4-inch dolomite. This bed is tentatively identified as the Emanuel Bed, and it is 135 feet above the Dog Creek Shale.

The Dozier Lentil of Collingsworth and Hall Counties, Texas, is 3 to 20 feet thick, occurring 140 to 310 feet above the base of the Marlow Formation (thicker section southward), and is here classed in the Rush Springs Formation. In northern Collingsworth County, near Dozier and Shamrock, the lentils are near the base of the Rush Springs. In Hall County, the Rush Springs is 132 feet thick, and the Dozier consists of sandstone and sandy limestone 110 to 130 feet above the Eskota Gypsum and 240 to 260 feet below the Claytonville (Alibates) Dolomite. Thus the Dozier, as recently mapped by Barnes (1967, 1968) on the Lubbock and Plainview sheets, is near the top of the Rush Springs in Hall County. Newell (1940, p. 270) listed the following fossils from the Dozier Lentil of Collingsworth (c), Hall (h), and Motley (m) Counties, Texas: *Edmondia rotunda* (c, h), *Dozierella gouldii* (c, h, m), *Myalina* sp. (c), *Parallelodon* sp. (c), *Gryphellina sellardsi* (c, h), *Schizodus oklahomensis* (c, h), *Aviculopecten vanvleeti* (c, h), *Pernopecten symmetricus* (c, h), *Pseudamusium*? sp. (c), *Allorisma*? *albequus* (c, h), *A. rothi* (c, h), *Permophorus albequus* (c, h, m), *P. a. longus* (c, h), *Spirorbis* sp. (c, h), *Lepetopsis*? *haworthi* (c, h), *Bellerophon* sp. (h), *Baylea capertoni* (c, h), *Worthenia beedei* (h), *Murchisonia gouldii* (c, h), *Taosia dozierensis* (c, h), *Naticopsis transversus* (c, h), *Streptacis permiana* (c, h), *Cyclobathmus haworthi* (c, h), *Plagioglypta girtyi* (c, h), *Pakistania schucherti* (c), *Pseudodielasma perplexa* (c, h), *Composita mexicana* (c, h), *C. subcircularis* (h), and *Lioclema dozierense* (c, h, m). These are compared with the Capitan fauna from Texas and the Kazanian and Bakmuth faunas of Russia.

Origin.—The Rush Springs sandstone grades northward from Custer County into shale and is about four times thinner northward. Westward in Texas, the Rush Springs contains much shale and gypsum and is about half as thick as in Custer County. The source of the sand was probably to the east or southeast of Custer County. It is possible that the Ouachita Mountains and Ozarks were source areas and that several streams supplied the sand. It is possible that the present-day streams in Oklahoma that flow eastward follow old channels of Permian streams that once flowed westward.

During El Reno time the coarse clastics originated from a southeastern land source, with a river flowing northwestward toward

Grady County, Oklahoma, as shown by Fay (1964, p. 68–70). Mostly fine mud and silt were carried. It is possible that with renewed uplift during Whitehorse time the Ouachitas sheared over the Arbuckles south of the Atoka area and supplied much sand to the Whitehorse sea. Also, the Ozarks may have been uplifted. Thus there may be a tectonic reason for separation of the Cimarronian Series from the Custerian Series at the El Reno–Whitehorse boundary, in addition to changes in clay minerals and spores and pollen.

FOSS GROUP

Name.—The Foss Group, here proposed to include the Cloud Chief Formation below and the Doxey Shale above, is named for the town of Foss, northwestern Washita County, Oklahoma.

Type locality.—The type locality for the Foss Group is southwestern Custer County, around the Foss Reservoir between Clinton and Hammon, especially on the south side of the reservoir (frontispiece). In the area northwest of Clinton, the Cloud Chief can be examined, where it is 177 feet thick in the Red Hills area in the SE¼ sec. 11, the NE¼ sec. 14, and the SE¼ sec. 12, T. 12 N., R. 18 W., and the SW¼ sec. 8 and the NE¼ sec. 4, T. 12 N., R. 17 W. (measured section 6). The Doxey portion is about 195 feet thick in the NE¼ sec. 1, T. 12 N., R. 21 W., and the NW¼ sec. 31, T. 13 N., R. 20 W. (measured section 12). The Foss Dam cores contain subsurface information on the Cloud Chief–Rush Springs section (measured sections 9, 10).

Discussion.—The name Quartermaster Group or Formation is here rejected, because the Elk City Sandstone cannot be grouped with the Doxey Shale into a natural tectonic or sedimentologic unit. In fact, it is difficult to distinguish the Doxey from the Cloud Chief except for the orange-brown color of the Cloud Chief and the red-brown color of the Doxey, with a greenish-gray indurated silty, gypsiferous, or carbonate zone at the base of the Doxey. Thus, it is natural to include the Doxey with the Cloud Chief because both units are primarily shale bodies with much siltstone. Also, the rocks exposed along Quartermaster Creek are mostly Rush Springs and Cloud Chief and do not belong to the Quartermaster Formation.

The term Quartermaster division was proposed by Gould (1902, p. 57) for about 300 feet of red-brown shales and orange-brown sandstones above the Greer division. The name was for Quartermaster Creek in Roger Mills and Custer Counties. The terms Quartermaster Formation and Quartermaster Dolomite were used by Evans (1928, p. 708) for 150 feet of beds directly above the massive gypsum of the Cloud Chief Formation, with the dolomite at the base supposedly truncating 150 feet or more of beds below into the top of the Whitehorse. Griley (1933) proposed the terms Bessie, Doxey, and Elk City for members of the Quartermaster Formation, with the Bessie consisting of the shales and siltstones of the Cloud Chief above the massive gypsum, but these terms were never defined. Green (1936, p. 1473) subdivided the Quartermaster Formation into the Cloud Chief, Doxey, and Elk City Members and seems to have been the first person to define lithologies and boundaries for these units, showing the lenticularity of the basal massive Cloud Chief gypsum and possible equivalence of dolomites with the gypsum. Green (1937, p. 1528) classed the Doxey and Elk City as formations of the Quartermaster Group. Miser and others (1954) used the terms Doxey and Elk City as members of the Quartermaster Formation for units above the Cloud Chief Formation. Fay (1965, p. 37) discarded the term Quartermaster, reserving evidence to be presented in the Custer County publication.

The term Bessie is dropped because it was never defined originally and because it is the clastic phase of the Cloud Chief Formation above the massive Cloud Chief gypsum and is in part equivalent to the gypsum. It is obvious that Evans (1928) saw stray dolomites, such as the Weatherford, Moccasin Creek, and Day Creek, in different areas and correlated these dolomites as the same bed. Green (1936) generally used the Weatherford Bed for his base of the Cloud Chief, whereas the Moccasin Creek is used herein, so Green's Cloud Chief thicknesses are slightly greater than those used in this report. The Greer division included the thick Cloud Chief gypsum, and the Quartermaster division included the clastic Cloud Chief above the gypsum to the top of the Permian red-bed sequence. The term Greer was further confused with the Blaine of southwestern Oklahoma, so the name is now dropped.

CLOUD CHIEF FORMATION

Name.—Gould (1924, p. 337) first proposed the name Cloud Chief Formation for beds above a dolomite, now termed the Weatherford but correlated as the Day Creek by Gould, or, where the dolomite was missing, for beds above the Whitehorse sandstone to the base of the Quartermaster Formation. The unit was named for Cloud Chief, Washita County. Sawyer (1929, p. 11) defined the Rush Springs Formation, with the top defined at a gypsum 40 feet above the Weatherford dolomite. Gould (1905, p. 55) named the Whitehorse Group, with the defined top at the Day Creek dolomite. Miser and others (1954) used the names Day Creek and Weatherford dolomites for defining the basal Cloud Chief on the geologic map of Oklahoma, a usage no longer followed because these two beds are stratigraphically at least 60 feet apart. Fay (1965, p. 73) redefined the Whitehorse–Cloud Chief boundary, naming a new unit within the base of the Cloud Chief for mapping purposes and theoretical considerations. This unit is the Moccasin Creek Bed and is between the Day Creek (above) and the Weatherford (below).

The Greer division of Gould (1902, p. 52), named for Greer County, is the same as the massive Cloud Chief gypsum and the Blaine Formation of southwestern Oklahoma. The Quartermaster division of Gould (1902, p. 57) included the clastic part of the Cloud Chief above the massive gypsum, so subsequent references using Gould's terminology include some Cloud Chief. The name Bessie Member, after Bessie, Washita County, was proposed for this clastic phase by Griley (1933, p. 234), but it was never defined. Green (1936, p. 1473) included the Cloud Chief in the Quartermaster Formation but later (1937, p. 1528) excluded it from the Quartermaster Group. Green's defined base and top of the Cloud Chief was the Weatherford Bed and the Doxey Shale, respectively. At present, the upper boundary is the base of a greenish-gray carbonate or gypsiferous siltstone bed, included within the base of the Doxey, where a color change takes place from orange-brown Cloud Chief below to red-brown Doxey above, as mapped in Custer County (pl. 1).

The name Taloga Formation was proposed by Cragin (1897, p. 362) for beds supposedly above the Day Creek dolomite; it was named for Taloga, Dewey County, Oklahoma. Much confusion resulted because of a miscorrelation by Cragin, who was in a hurry, riding horseback from Greenfield, Blaine County, Oklahoma, to Taloga to Kansas. While in the Greenfield area, he thought that the dolomites there were the Day Creek and that all of the beds exposed on his trip were above the Day Creek. The first town of any size at that time was Taloga, so he named the formation after this town, and the name remained in valid use for 65 years by the Kansas Geological Survey. Fay (1962, p. 69–70) abandoned the name Taloga because it included the upper part of the Marlow, all of the Rush Springs, and the Moccasin Creek Bed or lower part of the Cloud Chief (near Taloga), all of which are below the Day Creek Bed.

The Cloud Chief is subdivided into four units: Moccasin Creek Bed, Kiger Member, Day Creek Bed, and Big Basin Member (ascending). Each of these units is discussed separately.

Type locality.—The type locality for the Cloud Chief Formation is the region around Cloud Chief, Washita County.

Type section.—A provisional type section for the Cloud Chief Formation is in southwestern Dewey County, in the SE¼SW¼ sec. 6 to the SE¼ sec. 7, T. 16 N., R. 20 W., in the West Leedey core, where the Cloud Chief is 171 feet thick, with the upper 37 feet exposed below 74 feet of Doxey Shale, as proposed by Fay (1965, p. 71) (measured section 17). The Moccasin Creek Bed is 13.5 feet thick, consisting of three gypsum beds with red-brown shale and siltstone between. The overlying Kiger Member is 28.8 feet thick and consists of red-brown shale and orange-brown siltstone with two thin gypsum beds. The Day Creek Bed is a 3-foot white to light-orange gypsum. The overlying Big Basin Member, 126 feet thick, consists of red-brown shale and siltstone, with orange-brown siltstones, sandstones, and shales near the top. This is also the type section for the Big Basin Member because it is the nearest complete section to Kansas, where the member was first named.

Description in Custer County.—The Cloud Chief Formation is about 175 feet thick in Custer County and consists of red-brown to orange-brown shale, with some sandstones and siltstones. The 0.1- to 10-foot Day Creek dolomite is 28 to 52 feet above the base. The 1- to 9-foot Moccasin Creek Bed at the base, consists of gypsum, dolomite, multiple gypsums or dolomites, or greenish-gray zones where gypsums are leached. In the subsurface of southwestern Custer County, the Cloud Chief is about 310 feet thick.

In the Weatherford–Clinton area of southeastern Custer County, the lower 118 feet of the Cloud Chief is gypsum, grading westward and northward into the Moccasin Creek Bed, the Kiger Member, the Day Creek Bed, and the lower part of the Big Basin Member. The terms Kiger and Big Basin are not used on the geologic map of Custer County (pl. 1) because the Day Creek Bed occurs in spots and is not recognizable in the southwestern part of the County south of the Washita River. Also, in many places the Cloud Chief is covered by Pleistocene terrace deposits, leaving patches whose stratigraphic position within the Cloud Chief is uncertain. In the area of the North Branch of Quartermaster Creek, the Day Creek Bed appears to be absent owing to nondeposition, and in other areas it appears to grade into a greenish-gray siltstone, making positive recognition difficult where many of these beds are present.

Moccasin Creek Bed.—The name Moccasin Creek Bed was proposed by Fay (1965, p. 73) for the dolomite, gypsum, multiple dolomites or gypsums, or greenish-gray zones at the base of the Cloud Chief Formation. The name comes from West Moccasin Creek, Woods County, Oklahoma. This bed was termed the upper Cyril Gypsum by Reeves (1921, p. 48–50) for use in Caddo County, the lower part of the "upper shale member" by Norton (1939, p. 1806) for use in Kansas, the "purple-platy" beds by Evans (1931, p. 424) for use in northwestern Oklahoma, and the double gypsum near Camargo by Evans (1931, p. 420) for use in northwestern Dewey County. Griley (1931) recognized this bed in Dewey and Roger Mills Counties, with sandstone below and shale above, but failed to name it, having mentioned the persistence of this unit over a wide area and its use in important correlations. The new usage of Moccasin Creek for a basal Cloud Chief marker would show greater outcrop area for the Cloud Chief in northwestern Oklahoma north of the Canadian River, and much less area in central western Oklahoma, than is shown on the present State geologic map (Miser and others, 1954).

The type section for the Moccasin Creek Bed is in the SE¼SE¼ sec. 8, T. 28 N., R. 18 W., along the headwaters of West Moccasin Creek, in northwestern Woods County. Here, the Moccasin Creek consists of three parts: (1) an upper 4-inch greenish-gray quartzose limestone or dolomite, (2) a middle 1-foot red-brown shale and siltstone, and (3) a lower 1.5-foot greenish-gray calcitic sandstone. It overlies orange-brown sandstone of the Rush Springs Formation and is overlain by red-brown shale of the Kiger Member.

In Custer County, the Moccasin Creek Bed ranges in thickness from 1 to 9 feet and can be gypsum, dolomite, or greenish-gray leached zones. No particular pattern was found for the distribution of the various lithologies, but the bed is commonly gypsum in the Clinton-Weatherford area (fig. 22). In the area east of Bear Creek, the gypsum is as thick as 118 feet and is termed simply Cloud Chief gypsum. One small quarry was opened in this area (fig. 23), and a detailed economic study of the gypsum was done by Ham and Curtis (1958), which is discussed in a later section.

In the Bear Creek area, on the western and northwestern fringes of the thick gypsum body, the Moccasin Creek is a dolomite, with the gypsum absent. In the NE¼ sec. 5, T. 12 N., R. 15 W., the dolomite is 5 to 8 feet thick and was extensively quarried by the Federal Work Projects Administration (WPA) in 1938. Here, the dolomite overlies an orange-brown sandstone of the Rush Springs Formation and is overlain by about 40 feet of red-brown shale (fig. 24). In some areas the dolomite grades laterally into siltstone as thick as 8 feet, as seen in several buttes and a quarry in the NW¼NW¼ sec. 22, T. 12 N., R. 16 W. (fig. 25). In the East Clinton core, the bed is a double dolomite, the upper one being 2.1 feet thick and the lower 2.5 feet thick, with 3.9 feet of orange-brown shale and siltstone between (measured section 4). In the Thomas area, the Moccasin Creek is a dolomite 1.5

Figure 22. Moccasin Creek Bed (gypsum) of basal Cloud Chief Formation on sandstone of Rush Springs Formation. View, looking south, in NW¼NW¼ sec. 8, T. 12 N., R. 15 W., southeastern Custer County. Locally this bed grades into dolomite.

Figure 23. Quarry in Moccasin Creek Bed (gypsum) of basal Cloud Chief Formation. View, looking south, at 10-foot working face, in SE¼SW¼ sec. 31, T. 13 N., R. 14 W., southeastern Custer County. Gypsum is crushed and used locally for land plaster.

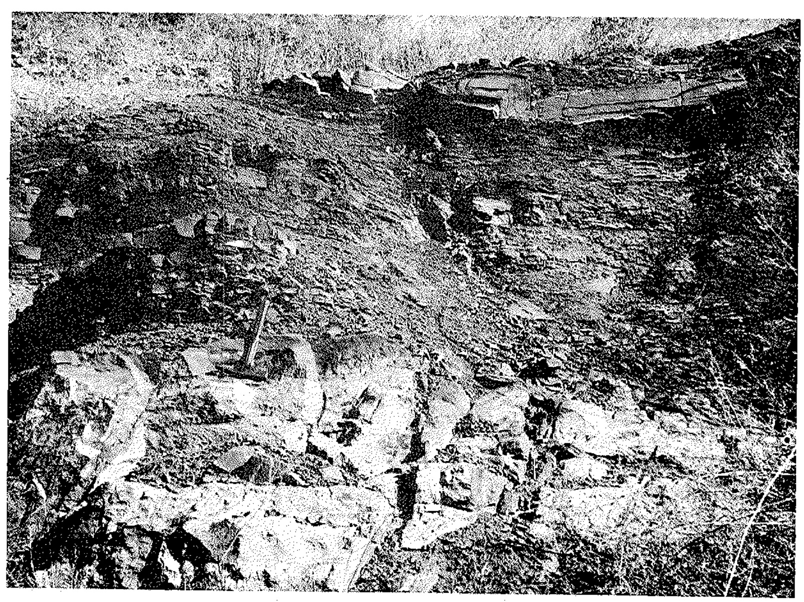


Figure 24. Quarry in Moccasin Creek Bed (dolomite) of basal Cloud Chief Formation, with red-brown shale above, in south quarry face in NW¼NE¼ sec. 5, T. 12 N., R. 15 W., southeastern Custer County.

to 2 feet thick, capping the northernmost two buttes north of Thomas, being about 42 feet above the Weatherford dolomite in the Rush Springs Formation. South of Thomas, the bed is about 50 feet below the Day Creek dolomite of the Cloud Chief, which caps Sugar Loaf Mound, and is about 24 feet above the Weatherford dolomite. In an area just south of Custer County, in the NE¼NE¼ sec. 3, T. 11 N., R. 14 W., about 40 feet of Cloud Chief gypsum is extensively replaced by calcite and aragonite, and farther south much celestite appears in the section down to the Weatherford Bed. On the southwest side of the Washita River in the SE¼SE¼ sec. 32, T. 12 N., R. 16 W., the Moccasin Creek is a gypsum at least 5 feet thick in the road, but just a few yards to the north it is an impure dolomite.

In the western two-thirds of Custer County, the Moccasin Creek is a gypsum or multiple gypsums with an aggregate thickness of less than 9 feet. Just north of Clinton, the bed is a single gypsum about 2 feet thick (measured section 6). In the subsurface at Foss Dam, the bed is a 6- to 7-foot gypsum (measured sections 9, 10). On the south side of Foss Reservoir in the SW¼ sec. 6, T. 13 N., R. 19 W., are isolated areas of the Moccasin Creek gypsum (fig. 26), contrary to the geologic map of Oklahoma (Miser and others, 1954). In northwestern Custer County at the South Leedey site, the bed is a double gypsum, the upper one being 0.4 feet thick and the lower 6.2 feet, with a 2.4-foot orange-brown siltstone between (measured section 8). Three gypsum ledges are present along State Highway 34 in the SE¼SE¼ sec. 30, T. 15 N., R. 20 W., with Rush Springs sandstone below and Cloud Chief siltstone and shale above (fig. 27). In the South Putnam core of central northern Custer County, the Moccasin Creek is composed of several greenish-gray siltstones (measured section 7).

Kiger Member.—The name Kiger division, for Kiger Creek, Clark County, Kansas, was first used by Cragin (1896, p. 39) for the Permian red beds above the Cave Creek (now Blaine) Formation. O'Connor (1963, p. 1877) redefined the Kiger to include only the shale below the Day Creek Bed and above the Whitehorse Formation. Fay (1965, p. 74) followed this usage but separated the Moccasin Creek Bed at the base and designated the overlying beds up to the Day Creek as the Kiger Member of the Cloud Chief Formation.

The type section for the Kiger Member is that proposed by Fay (1965, p. 74) in the SE¼SE¼ sec. 8, T. 28 N., R. 18 W., along the headwaters of West Moccasin Creek, northwestern Woods County, Oklahoma. There, the member is 31 feet thick and consists mostly of red-brown shale, with some interbedded greenish-gray sandstones

Figure 25. Quarry in Moccasin Creek Bed (dolomite) of basal Cloud Chief Formation. Unit grades into siltstone and sandstone on left. View, looking south on east end of quarry, in NW¼NW¼NW¼ sec. 22, T. 12 N., R. 16 W., central southern Custer County.

and siltstones in the upper half, underlain by the type Moccasin Creek Bed and overlain by the type Day Creek Bed.

The southernmost area of exposures of the Day Creek Bed and the underlying Kiger Member is the region east of Clinton, in central southern Custer County. In the NW¼NW¼SE¼ sec. 9, T. 12 N., R. 16 W., in the East Clinton core, the Kiger is 43.1 feet thick and consists of orange-brown siltstone and shale, with some orange-brown sandstone, beneath the Day Creek dolomite (measured section 4).

In northeastern Custer County at Sugar Loaf Mound, in the NE¼ sec. 7, T. 14 N., R. 14 W., the Kiger consists of 39.5 feet of red-brown to orange-brown shale and siltstone, with some orange-brown sandstone, below the Day Creek dolomite (measured section 2).

In northwestern Custer County, in the SW¼NW¼ sec. 5, T. 15 N., R. 20 W., the Kiger is 32 feet thick and is made up of red-brown to orange-brown shale and siltstone, with some orange-brown sandstone, beneath a thin Day Creek dolomite (measured section 8).

Elsewhere in Custer County, the Day Creek is represented by a greenish-gray calcitic siltstone zone, with greenish-gray

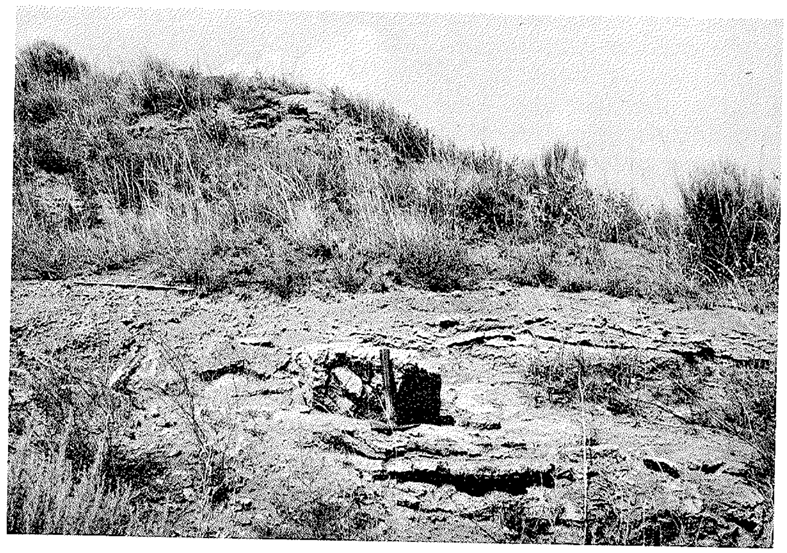


Figure 26. Hill of Moccasin Creek Bed (gypsum) of basal Cloud Chief Formation, with orange-brown siltstone above. View on west side of Foss Reservoir, looking east, in SW¼SW¼ sec. 6, T. 13 N., R. 19 W., western Custer County. This is one of the few outcrops of basal Cloud Chief gypsum that occurs on west side of Washita River in this region.

Figure 27. Moccasin Creek Bed (gypsum) of basal Cloud Chief Formation, dipping northward, with sandstone of Rush Springs Formation below and siltstone and shale of Cloud Chief above. View on east side of State Highway 34, in SE¼SE¼SE¼ sec. 30, T. 15 N., R. 20 W., northwestern Custer County. In this region, Moccasin Creek is composed of several gypsum layers.

zones above, and the Kiger averages about 40 feet thick, ranging up to 53 feet northwest of Clinton in the SE¼SW¼ sec. 8, T. 12 N., R. 17 W. (measured section 6). South of the Washita River, the Day Creek is apparently absent in Custer County. In this region it is difficult to distinguish the Kiger from the Big Basin Member of the Cloud Chief because the lithologies are similar, but more orange-brown sandstone is present higher in the section at places (measured section 6) (fig. 28).

Day Creek Bed.—The name Day Creek Dolomite was first used by Cragin (1896, p. 3) for a massive white dolomite, 1 to 2 feet thick, capping buttes north of Ashland and Sitka, Clark County, Kansas. The dolomite was named for Day Creek. It was the defined top of the Red Bluff beds of Cragin or the top of the Whitehorse beds of Gould. Fay (1965, p. 76–77) included the Day Creek Bed in the Cloud Chief Formation, where it occurs 25 feet or more above the base, and this usage is followed for Custer County. In parts of Harper, Woods, and Woodward Counties, Evans (1931, p. 425) recognized a 3-inch dolomitic zone about 3 feet above the Day Creek and subdivided the Day Creek into upper and lower members, but these two units are here combined into the Day Creek Bed, as proposed by Fay (1965, p. 77). Cragin (1896, p. 45) named the Centennial Mound Dolomite from the mound of the same name (formerly Sentinel Mound) in old Woodward County, Oklahoma, and correlated it with the Day Creek Dolomite. The mound is possibly the one in the SE¼ sec. 6, T. 28 N., R. 19 W., northwestern Woods County, and the cap rock is the Day Creek Dolomite.

The type section for the Day Creek Bed is that proposed by Fay (1965, p. 77) at the headwaters of West Moccasin Creek in the SE¼SE¼ sec. 8, T. 28 N., R. 18 W., northwestern Woods County, Oklahoma. The Day Creek is a 2-foot white to light-gray compact thin-bedded well-indurated dolomite, eroding into a prominent escarpment. It is overlain directly by 2 feet of greenish-gray shale, with about 15 feet of red-brown shale and siltstone above, and is about 34 feet above the base of the Cloud Chief. About 2 feet of greenish-gray siltstone occurs directly below the bed.

In central southern Custer County, the Day Creek is a triple dolomite sequence, separated by orange-brown sandstone, with a total thickness of 10.1 feet in the NW¼NW¼SE¼ sec. 9, T. 12 N., R. 16 W. (measured section 4). The basal dolomite is pink to white, compact, and well indurated, being 0.3 foot thick. It is surmounted by 2.4 feet of sandstone, 0.9 feet of dolomite, 2.8 feet of sandstone, and 3.7 feet of dolomite. At some exposures the bed weathers greenish gray and erodes into a prominent escarpment (fig. 29). The base of this bed is 51.6 feet above the base of the Cloud Chief. This is the southernmost exposure of the Day Creek dolomite in Custer County, the bed being

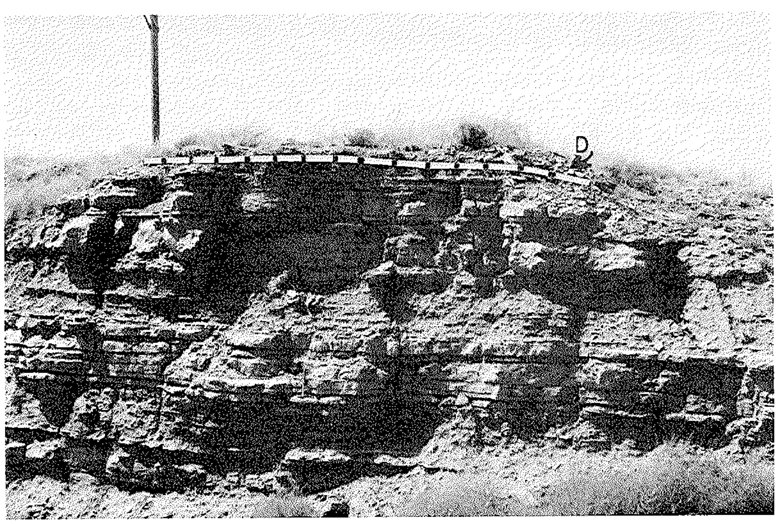


Figure 28. Siltstone and shale of Cloud Chief Formation on north side of road in SE¼SW¼ sec. 23, T. 13 N., R. 19 W., southwestern Custer County. Greenish-gray dolomitic siltstone (*D*) is about 75 feet above Day Creek Bed.

Figure 29. Day Creek Bed (dolomite) of Cloud Chief Formation. View, looking north, west of old country clubhouse, in SE¼NE¼ sec. 17, T. 12 N., R. 16 W., central southern Custer County.

apparently absent south of the Washita River.

In northeastern Custer County, south of Thomas at Sugar Loaf Mound, in the NE¼ sec. 7, T. 14 N., R. 14 W., the Day Creek is 10.25 feet thick, where it caps the mound and is 41 feet above the base of the Cloud Chief. The bed is a double dolomite, being composed of a 2.5-foot pink to white compact dolomite at the base, surmounted by 6.26 feet of orange-brown siltstone with dolomitic lenses and a 1.5-foot pink to white dolomite at the top (fig. 30) (measured section 2).

In northwestern Custer County, in the SW¼NW¼ sec. 5, T. 15 N., R. 20 W., the Day Creek is a 1-inch white to tan dolomite, with 41 feet of beds below to the Rush Springs Formation (measured section 8) (fig. 31). Elsewhere in Custer County, the Day Creek is a greenish-gray calcitic siltstone, occurring 40 to 50 feet above the base of the Cloud Chief. In the Red Hills area northwest of Clinton, in the SE¼SW¼ sec. 8, T. 12 N., R. 17 W., the Day Creek is a greenish-gray calcitic sandstone about 53 to 54 feet above the base of the Cloud Chief (measured section 6).

Big Basin Member.—The name Big Basin Sandstone was first used by Cragin (1896, p. 46) for the 2- to 12-foot greenish-gray sandstone and mudstone conglomerate about 40 feet above the Day Creek Bed. The sandstone was named for the depression of the same name in western Clark County, Kansas. The shales below were termed Hackberry by Cragin, but because the name was preoccupied the term Big Basin Formation was proposed for all of the red beds above the Day Creek in Kansas, according to Norton (1939, p. 1813), O'Connor (1963, p. 1877), and Jewett and others (1964). Fay (1965, p. 79) changed the rank to Big Basin

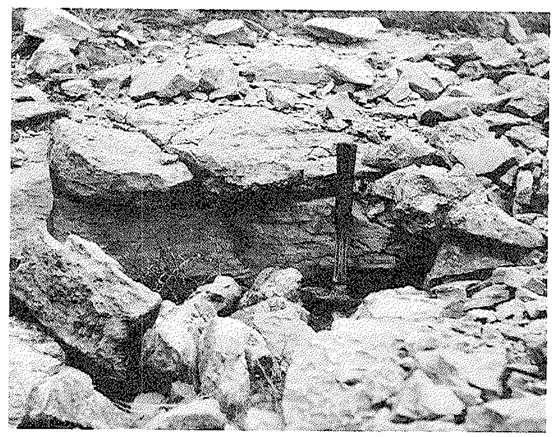


Figure 30. Day Creek Bed (dolomite) of Cloud Chief Formation, where it caps Sugar Loaf Mound. View, looking south, at lower bed, about 8 feet below top, in SE¼NE¼NE¼ sec. 7, T. 14 N., R. 14 W., northeastern Custer County (measured section 2).

Figure 31. Day Creek Bed (dolomite) of Cloud Chief Formation (at hammer head) in sandstone. East side of State Highway 34, in NW¼NW¼SW¼ sec. 5, T. 15 N., R. 20 W., northwestern Custer County (measured section 8).

Member of the Cloud Chief Formation, with the lower limit placed at the top of the Day Creek Bed and the upper limit placed at the base of the Doxey Shale or the base of the Alibates Bed.

The top is eroded at the surface in Kansas and in Harper, Woods, and Woodward Counties, Oklahoma. In Ellis, Dewey, Roger Mills, and Custer Counties, the entire Cloud Chief is preserved, and the nearest complete section to Kansas would be that found at the West Leedey core site in southwestern Dewey County (measured section 17).

The provisional type section for the Big Basin Member is that proposed by Fay (1965, p. 80) at the West Leedey core site in the SE¼ sec. 7, T. 16 N., R. 20 W., and adjoining region to the west and northwest, in southwestern Dewey County (measured section 17). This is also the type section for the Cloud Chief Formation, which is 171 feet thick, the Big Basin Member being 126 feet thick. The Big Basin is mainly red-brown to orange-brown shale and orange-brown siltstone, with some orange-brown sandstone.

In Custer County, in the East Clinton core, in the SE¼ sec. 9, T. 12 N., R. 16 W., the lower 158 feet of Cloud Chief is preserved, with the upper 96 feet belonging to the Big Basin Member (measured section 4). The Big Basin is mostly orange-brown shale and siltstone, with a 12-foot orange-brown sandstone near the top and with some interbedded red-brown shale in this area (fig. 32). The sandstone near the top caps many of the hills in the region, and these have been locally mapped as the Doxey Shale on the geologic map of Oklahoma (Miser and others, 1954), but measured sections farther west show the Cloud Chief to be thicker and this sandstone belongs to the Cloud Chief.

In central southern Custer County west of Clinton, the Cloud Chief is 177 feet thick and the Big Basin Member is 122 feet thick (measured section 6). The Big Basin is mostly orange-brown siltstone and shale, with much sandstone in the lower 30 feet, and greenish-gray siltstones in the upper 10 feet (fig. 33).

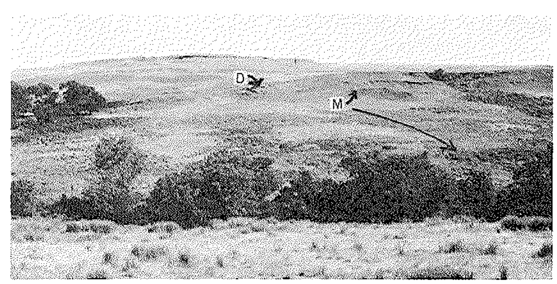


Figure 32. Cloud Chief topography. Moccasin Creek Bed (dolomite, *M*) is at base, Day Creek Bed (dolomite escarpment, *D*) is in middle, and a prominent 13-foot sandstone caps hill 140 feet above base. View, looking southeast, in NE¼ sec. 9, T. 12 N., R. 16 W., central southern Custer County (measured section 4).

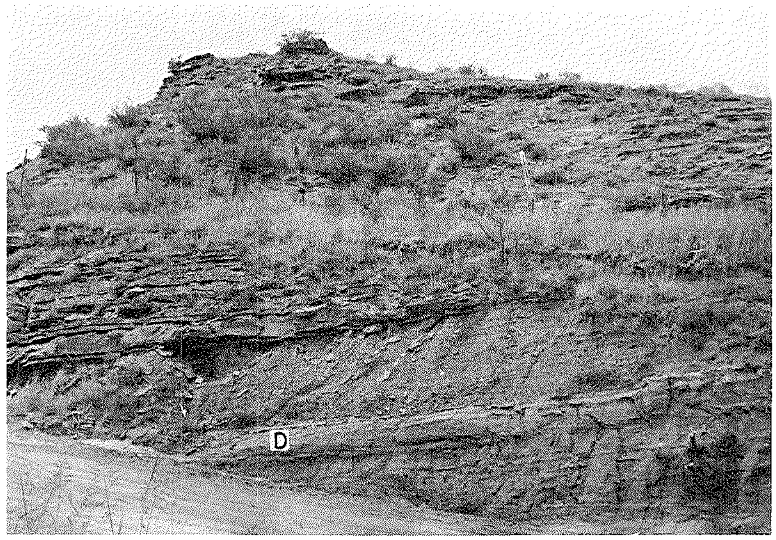


Figure 33. Cloud Chief Formation in Red Hills northwest of Clinton, in SW¼SE¼SW¼ sec. 8, T. 12 N., R. 17 W., central southern Custer County (measured section 6). Day Creek Bed (dolomitic siltstone, *D*) is at bottom of photograph, surmounted by red-brown shale and siltstone, with orange-brown to greenish-gray sandstone capping hill, on north side of road.

In southeastern Custer County the lower 118 feet of the Cloud Chief is gypsum, the upper 70 feet of which would be basal Big Basin Member.

The upper part of the Big Basin is mainly orange-brown shale and sandstone, with some greenish-gray siltstones. A local pink shale occurs about 25 feet below the top, west of Foss Reservoir (fig. 34), and many satin-spar beds are present in the upper 10 to 20 feet in central southern Custer County (fig. 35). A greenish-gray sandstone several feet thick occurs about 37 feet below the top and is best seen along U.S. Highway 66 (Interstate 40), south of Alfalfa railroad station (measured section 11).

Figure 34. Pink shale in orange-brown sandstone, both Cloud Chief Formation, about 25 feet below Doxey Shale, on west side of road in SE¼SE¼NE¼ sec. 22, T. 13 N., R. 20 W., central western Custer County. This bed appears to be unique to region here and a few miles farther south.

In central northern Custer County at the South Putnam core site, the preserved lower 91 feet of the Cloud Chief is present, but the Day Creek is unrecognizable (measured section 7). The rocks are mostly orange-brown siltstone and sandstone, with some orange-brown to red-brown shale and greenish-gray siltstone. The upper 50 to 60 feet is probably equivalent to the Big Basin Member.

Description of Cloud Chief Formation in Dewey County.—The only complete section of Cloud Chief with all named members is in southwestern Dewey County, at the type section (measured section 17). Here, the Cloud Chief is 171 feet thick, the basal Moccasin Creek being 13.5 feet thick and composed of 3 gypsums, surmounted by 28.8 feet of Kiger red-brown shale and orange-brown siltstone, overlain by a 3-foot white to orange gypsum of the Day Creek, and 126 feet of red-brown to orange-brown shales, siltstones, and sandstones of the Big Basin member. Elsewhere, only the basal Big Basin and lower beds are exposed.

One of the most controversial areas for correlations within the Cloud Chief Formation in Oklahoma is near Camargo in northwestern Dewey County. In the bluff about 1 mile northeast of Camargo, in the SW¼SW¼ sec. 18, T. 18 N., R. 19 W., at an elevation of approximately 2,132 feet, a 9-foot double gypsum caps the bluff. The upper bed is white to greenish gray and about 3 feet thick, with 1 foot of red-brown to orange-brown siltstone below, resting on 5 feet of gypsum, white to greenish gray in the upper 3 feet and orange-brown and arenaceous in the lower 2 feet. This is here correlated as the Moccasin Creek Bed, at the base of the Cloud Chief Formation. A 2.5-foot white to greenish-gray gypsum occurs about 25 feet below, and this bed is correlated as the Weatherford Bed of the Rush Springs Formation, with sandstone above and below the Weatherford. About 74 feet below the Weatherford is a 1-foot white to red-brown massive gypsum, here correlated as the Old Crow Bed of the Rush Springs. About 10 feet of sandstone occurs below the Old Crow to the base of the bluff. About 3 miles to the east, in the NE¼ sec. 20, T. 18 N., R. 19 W., about 72 feet of red-brown shales and greenish-gray siltstones was measured above the Moccasin Creek double gypsum, and the Day Creek was absent. Along Trail Creek northwest of Camargo and south of Vici, in the SW¼SW¼ sec. 24, T. 19 N., R. 20 W., about 16 feet of red-brown shale occurs at the top of the section, with a 2.5-foot greenish-gray calcitic siltstone below that might correlate with the Day Creek Bed. About 26 feet of red-brown shale and greenish-gray siltstones occur below the 2.5-foot bed, down to a double dolomite. The upper dolomite is a 2-inch maroon to light-pink bed, with 3 feet of red-brown shale below, and the lower bed is a 0.5-inch greenish-gray dolomitic band. In the NW¼NW¼NW¼ sec. 36, T. 19 N., R. 20 W., on the south side of the road east of the creek, the dolomitic zones grade into gypsum, with about 25 feet of sandstone below to a 2-foot bed of white to greenish-gray gypsum. The double dolomite and double gypsum zone is here correlated with the Moccasin Creek Bed, and the underlying 2-foot gypsum, with the Weatherford Bed. The Day Creek is probably unrecognizable.

The only place in Dewey County that the Day Creek and Moccasin Creek occur together as dolomites, similar to the typical sections in Woodward, Harper, and Woods Counties, is south of Seiling, in the SE¼ sec. 23, T. 19 N., R. 16 W., described by Fay (1965, p. 176). Here, the Day Creek dolomite is about 1 foot thick and caps the hill, with 27.8 feet of Kiger shale, siltstone, and sandstone below; the Moccasin Creek is a double dolomite 2.4 feet thick, with a split shale 2 feet thick in the middle. Farther east near Eagle City (Blaine County), in the SE¼ sec. 1 and the NE¼ sec. 12, T. 17

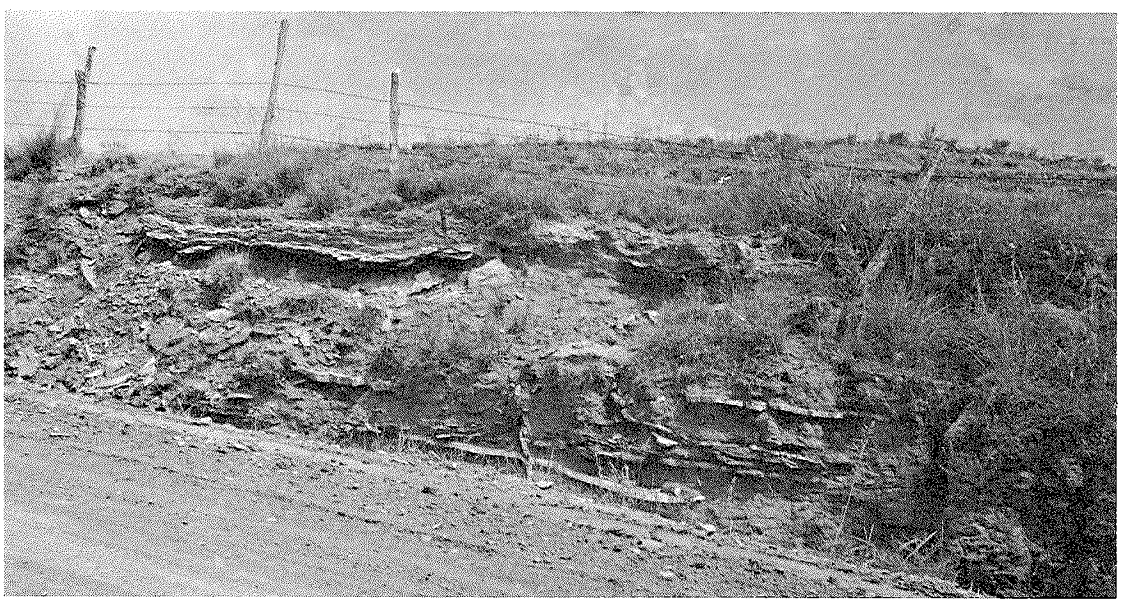


Figure 35. Siltstone of Doxey Shale (at hammer) resting on orange-brown shale, sandstone, and satin spar of Cloud Chief Formation. South side of road, in NW¼NW¼NE¼ sec. 14, T. 12 N., R. 18 W., central southern Custer County.

N., R. 14 W., northeastern Dewey County, the Day Creek dolomite is about 4 feet thick, capping the hill, with 26 feet of Kiger sandstone below to a 3-foot dolomite correlated as the Moccasin Creek Bed. The Seiling area needs to be remapped to include the Cloud Chief in the region.

In north-central Dewey County, north of Taloga, in the NW1/4NW1/4 sec. 30, T. 19 N., R. 16 W., east of U.S. Highway 183, the Cloud Chief is mostly eroded away, with the lower 20 feet of the Kiger red-brown shale and greenish-gray siltstone preserved above 2.7 feet of the Moccasin Creek. The Moccasin Creek is a double dolomite, the upper part being maroon and impure and about 2 inches thick, with 1 foot of red-brown shale below, and the lower part being white to pink and 1.5 feet thick. The underlying 29 feet of orange-brown siltstone and sandstone of the Rush Springs Formation down to the 6-foot Weatherford gypsum can be measured in the SE1/4 sec. 25, T. 19 N., R. 17 W. It is obvious that this entire area needs to be remapped as Rush Springs in place of Cloud Chief, because the Weatherford Bed was the unit used for separation of these formations in this area by Miser and others (1954).

In the area south of Taloga, in the NE1/4 sec. 34, T. 18 N., R. 17 W., about 39 feet of Cloud Chief is exposed, with the Big Basin Member consisting of 4.5 feet of red-brown shale and greenish-gray siltstone; the underlying Day Creek Bed a double zone 4.35 feet thick of a 0.5-inch greenish-gray dolomitic shale at the top and a 2- to 3-inch maroon dolomitic shale at the base, with 4 feet of greenish-gray siltstone and red-brown shale between; overlying 27.75 feet of red-brown shale, greenish-gray siltstone, and orange-brown sandstone of the Kiger Member; with 2.25 feet of the Moccasin Creek Bed at the base. The Moccasin Creek has a 0.5-inch greenish-gray calcitic shale at top, with 2 feet of red-brown shale below, and a 2-inch maroon to light-pink dolomite at the base, about 16 feet above a 0.5-foot pink to greenish-gray dolomite or 4-foot gypsum, here correlated as the Weatherford Bed. The Weatherford gypsum was used by Miser and others (1954) as the basis for separation of the Rush Springs from Cloud Chief in this region, but almost no Cloud Chief exists here except in high areas.

In the region north of Putnam in south-central Dewey County, in the NW1/4SW1/4 sec. 25, T. 17 N., R. 17 W., the Cloud Chief is about 39 feet thick, with the preserved thickness of the Big Basin Member being about 8 feet, consisting of red-brown shale and greenish-gray siltstone. The Day Creek Bed is a 3-inch maroon to greenish-gray dolomite ledge, and the underlying Kiger Member is 28.3 feet thick, consisting of red-brown shale, greenish-gray siltstone, and orange-brown sandstone. The Moccasin Creek Bed is a double dolomite ledge 3.4 feet thick, the upper dolomite being maroon to dark gray and about 10 inches thick, with 2.5 feet of orange-brown shale below, and the basal dolomite being 1 inch thick and maroon to gray. The underlying Rush Springs sandstone is 26 feet thick down to the Weatherford gypsum, which is 9 feet thick. Again, in this region the Weatherford was used for mapping the base of the Cloud Chief, and a new map will show the Cloud Chief to be restricted to the Putnam area.

In southeastern Dewey County, in the NW1/4 sec. 27, T. 16 N., R. 15 W., the Moccasin Creek Bed is a dolomite capping a few high areas, and the basal Cloud Chief needs to be mapped in this region. The Weatherford gypsum occurs about 30 feet lower in the section and covers many square miles, having been used by Miser and others (1954) as the base of the Cloud Chief (measured section 16).

Description of Cloud Chief Formation in central Roger Mills County.—In the region northwest of Cheyenne, in the SW1/4 sec. 31 and the SW1/4 sec. 32, T. 14 N., R. 23 W., the entire Cloud Chief Formation is exposed. It is 190 feet thick, with the Big Basin Member being 127 feet thick and composed of orange-brown shale and siltstone, with some greenish-gray siltstone, red-brown shale, and orange-brown sandstone. The Day Creek Bed is a double gypsum 6.3 feet thick, with a 5.3-foot orange-brown siltstone and sandstone in the middle and a 0.5-foot white gypsum at the top and base. The underlying Kiger Member is 51.3 feet thick, being mostly red-brown shale and orange-brown siltstone and sandstone. The Moccasin Creek Bed at the base is 4.5 feet thick and is a triple gypsum, the sequence from top to bottom being 0.7 foot of white gypsum, 0.9 foot of orange-brown shale and siltstone, 0.5 foot of white gypsum, 0.5 foot of red-brown shale, and 1.9 foot of white to gray gypsum. The Weatherford Bed of the Rush Springs Formation is apparently absent in the region (measured section 15).

The Day Creek Bed seems to occur as sporadic gypsums or dolomites in the area from Clinton to Leedey to Cheyenne and may have been deposited in isolated places instead of as a continuous sheet. The Weatherford Bed of the Rush Springs apparently was not deposited in the Leedey-Cheyenne area, and perhaps this region marks the southwesternmost occurrence of this bed. The Moccasin Creek Bed appears to be continuous over large areas, but it occurs as both a gypsum and a dolomite, with gypsum being more prevalent in western areas, such as Roger Mills County, and dolomite more prevalent northward in areas like Woods County.

Age and correlation of Cloud Chief.—The Cloud Chief Formation of Oklahoma is here considered to be the equivalent of the Seven Rivers Formation and overlying Yates Sand of southeastern New Mexico and adjacent parts of Texas, following DeFord and Lloyd (1940, p. 8), Ahlen and others (1960), DeFord and Riggs (1941, p. 1715), and Fay (1965, p. 69, 79, pl. 3). The Moccasin Creek Bed is correlated as the Saddlehorse Gypsum Lentil of Gould (1907, p. 16), at the base of the Cloud Chief Formation in the Borger-Amarillo region of the Texas Panhandle, the name Saddlehorse being abandoned.

In the Sanford Dam cores and on adjacent outcrops in Hutchinson County, Texas, along the Canadian River, the Cloud Chief is 70 to 105 feet thick, consisting mostly of red-brown shale, with an 8-foot orange-brown sandstone at the top. The Day Creek Bed is absent in this area, and the Cloud Chief is not subdivided. The basal Moccasin Creek Bed is a 21-foot triple-gypsum sequence, and the upper 8-foot sandstone is here correlated as the Yates, because Ahlen and others (1960) recognized the Yates as being just below the Alibates. Directly above the Yates is 4.5 feet of red-brown shale that may be Doxey, but the overlying Alibates is such a good regional marker that it would probably be best to include the base of the Doxey at the base of the Alibates. Near Sanford, and farther southwest in Moore and Potter Counties, Texas, the Cloud Chief is 60 to 70 feet thick, and the Moccasin Creek occurs as a single or a double dolomite or gypsum bed at the base.

In Palo Duro Canyon of eastern Randall County, Texas, the double gypsum at the bottom of the canyon is here correlated with the Alibates Dolomite Bed, and the overlying 68 feet of Permian red beds are here classed as Doxey. According to Gus Eifler (Austin, Texas, personal communication, 1967), this gypsum corresponds closely to the Claytonville Dolomite farther south in the area of the Lubbock sheet. The Cloud Chief is about 240 feet thick in the Palo Duro Canyon region, with many gypsum units. The contact with the underlying Rush Springs is best seen along Little Red River in western Hall County, Texas. Farther north, the Alibates extends for a great distance in the subsurface of the western part of the Oklahoma and Texas Panhandle areas, being 100 feet thick or more, consisting of many gypsums and dolomites. The Roswell Geological Society has correlated much of the Ochoan rocks above the Alibates Bed, and after reading their discussions I would correlate the lower part of the Alibates with the Tansill Formation, which grades into the top of the Capitan Limestone (Guadalupean), according to DeFord and Riggs (1941, p. 1715). The Castile-Salado gypsum and salt sequence almost pinches out before reaching this region, and it probably correlates with the middle part of the Alibates. The Rustler Limestone would be the equivalent of the upper part of the Alibates. Thus the entire Cloud Chief would be Guadalupean in age, and if the lower Alibates is the same as the lower Doxey, the basal Doxey would also be Guadalupean in age.

Direct correlation of units higher than the Moccasin Creek Bed from the Borger-Amarillo region to the Cheyenne area of Roger Mills County is almost impossible, owing to post-Permian erosion and cover by the Ogallala Formation of Tertiary age. Fortunately, several outcrops of the Moccasin Creek occur in northwestern Roger Mills County, on the south side of the Canadian River, and these can be traced almost continuously into Hemphill County, Texas. In the NE¼ sec. 7, T. 16 N., R. 26 W., the Moccasin Creek is a single or a double dolomite, each about 2 inches thick, with a 1-foot red-brown shale between. The Cloud Chief is about 124 feet thick in this region, with 10 to 25 feet of shale and siltstone exposed, and about an equal amount of underlying Rush Springs sandstone. Farther west, in central Hemphill County, Texas, on the Oscar Forgey ranch in sec. 128, Block 41, H. and T.C. RR. Co. Survey, about 5 miles northwest of Gem, the Moccasin Creek is 14.5 feet thick, where it consists of an upper 1-foot white to pink gypsum, 5 feet of red-brown shale below, 3.5 feet of white gypsum grading into dolomite, 1.5 feet of red-brown shale, and 3.5 feet of white gypsum grading into dolomite; it rests upon 10 feet or more of Rush Springs sandstone and is overlain by 25 feet or more of orange-brown shale. A local stratigraphic test confirms a total thickness of 236 feet for the underlying Whitehorse Group. From this area westward to the region east of Borger, Hutchinson County, Texas, the red beds are covered by Ogallala deposits of Tertiary age and are eroded so that one must rely upon subsurface information. Many tests were drilled in the Pampa-Plemons region in the Texas Panhandle and in central and southern Ellis County, Oklahoma, by an oil company, and the results are herein used as a basis for subsurface correlations. The base of the Whitehorse was traced in this region, using this information (Fay, 1965, pl. 3). The Moccasin Creek Bed could be traced westward into the Saddlehorse Gypsum, and the Alibates Bed could be traced only eastward to southwestern Roberts County, Texas. The interval and lithology of beds between the Alibates and Moccasin Creek is commensurate with those of the Cloud Chief farther east in Oklahoma, and thus the Cloud Chief-Doxey contact is placed at the base of the Alibates Bed.

Origin of sand in Cloud Chief.—When the lower part of the Cloud Chief Formation is studied in detail, it is obvious that the Kiger Member is entirely sandstone only in the region northwest of Eagle City, Blaine County, extending into Dewey County. To the northwest, in Woodward, Harper, and Woods Counties, the Kiger contains much shale. In southeastern Custer County, the Kiger is entirely gypsum. Farther west, in Texas, the Kiger is mostly shale, and the entire Cloud Chief is only 60 to 105 feet thick. Thus the source of the Cloud Chief sand was probably somewhere east of Blaine County; the sand may have been derived from the Ozark uplift or the Ouachita Mountains.

The Yates Sandstone at the top of the Cloud Chief in the Texas Panhandle is a thin unit that is apparently absent in Oklahoma. The unit is much thicker in New Mexico, and it is obvious that the source of this sand is somewhere west of Amarillo, Texas.

In Hall County, Texas, along the Red and Little Red Rivers, the Cloud Chief is about 240 feet thick, containing much sandstone and gypsum. The sandstones appear to be more numerous and thicker eastward, suggesting an eastern or southeastern source, such as the Ouachita Mountains of Texas. Thus the coarse clastics of the Cloud Chief in Oklahoma and the Texas Panhandle probably were derived from several source areas.

Doxey Shale

Name.—The name Doxey Shale, for Doxey in central Beckham County, Oklahoma, was first proposed by Griley (1933, p. 234) for a member of the Quartermaster Formation, with the Bessie Member below and the Elk City Member above. The Bessie Member was never defined but probably was proposed for the shales and siltstones of what is now the Cloud Chief Formation, above the massive Cloud Chief gypsum. Griley attributed the name Bessie to Schweer and Buckstaff, but Buckstaff (1931) did not mention the term. The Doxey and Elk City were not defined by Griley. Green (1936, p. 1473) subdivided the Quartermaster Formation into the Cloud Chief, Doxey, and Elk City Members and was the first person to define lithologies and boundaries for these units. Green (1937, p. 1528) classed the Doxey and Elk City as formations of the Quartermaster Group, and Miser and others (1954) classed them as members of the Quartermaster Formation. In this report, the Doxey is classed as a formation of the Foss Group, together with the underlying Cloud Chief Formation.

Type section.—The section north and northeast of Carpenter in the NW¼ sec. 31, T. 13 N., R. 20 W., Custer County, is here designated as the type section, including outcrops along the road to the east (measured section 12).

Description in Custer County.—The base of the Doxey is marked as a greenish-gray calcitic siltstone, with red-brown shale above and orange-brown siltstone and shale of the Cloud Chief below (figs. 35, 36). At the type section the Doxey is about 195 feet thick and is mostly red-brown shale and orange-brown to greenish-gray siltstones, with a 4-inch tan dolomite about 70 feet above the base. The siltstones are moderately to well indurated and erode into resistant ledges, capping rugged hills about 40 feet or more above the base (fig. 37). In the middle of the Doxey, several distinct ledges of indurated siltstones erode into prominent escarpments, and these may be traced for several miles. The dolomite about 120 feet below the top is tan to greenish gray, argillaceous to silty, thinly laminated and moderately indurated, and erodes into an escarpment. This bed can be traced over a wide area and is best seen along State Highway 34, just northwest of the Carpenter core site.

The upper 10 feet or more of the Doxey is red-brown shale, and the contact with the overlying orange-brown sandstone of the Elk City Sandstone is sharp. A light-greenish-gray shale or siltstone several inches thick occurs at the base of the Elk City (fig. 38).

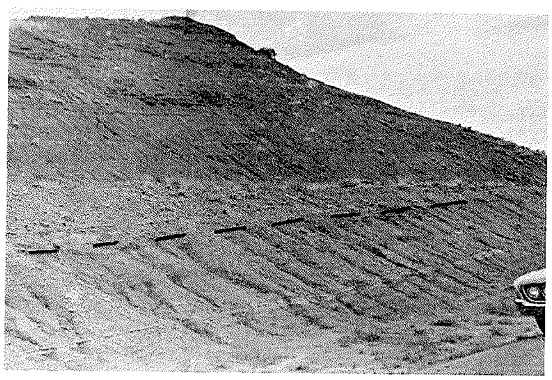


Figure 36. Doxey-Cloud Chief contact (dashed line) on south side of U.S. Highway 66 (Interstate 40) in NW¼NE¼NW¼ sec. 33, T. 12 N., R. 18 W., southwestern Custer County (measured section 11). Cap rock is red-brown siltstone, and slopes are red-brown Doxey shales. Cloud Chief is orange-brown shale with thin greenish-gray siltstones. Basal Doxey bed is greenish-gray siltstone interbedded with red-brown shale and siltstone.

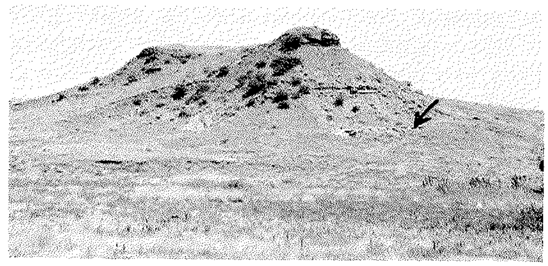


Figure 37. Doxey topography. Butte of Doxey Shale capped by red-brown siltstone, with resistant siltstone in middle and greenish-gray dolomitic siltstone at base (arrow). View, looking southeast, in NW¼NE¼ sec. 23, T. 12 N., R. 18 W., central southern Custer County.

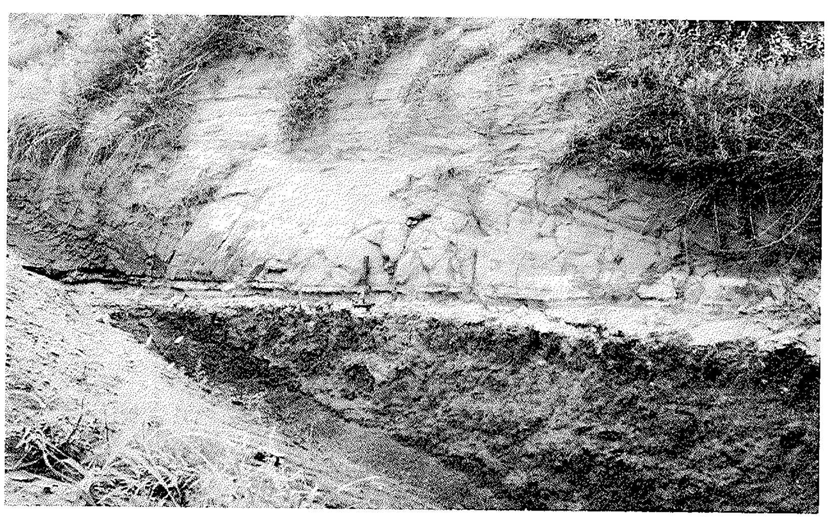


Figure 38. Elk City Sandstone on Doxey Shale. View, looking northwest, on north side of road, showing cross-bedded Elk City in SE¼SE¼SE¼ sec. 34, T. 12 N., R. 20 W., southwestern Custer County (measured section 13).

In places, this zone weathers a maroon color, but it is traceable on the ground and on aerial photographs by its light color. The Elk City erodes into rounded hills, and the Doxey erodes into slopes below the hills, so the mapped contact is slightly below the Elk City escarpment.

Age and correlation.—The Doxey is mainly Ochoan in age, with the lower part probably Guadalupean, as discussed in the description of the Cloud Chief Formation. In the northern Texas Panhandle the lower 50 feet or less of the Doxey is exposed at the surface.

In the Borger region of Hutchinson County, Texas, the change from orange-brown sandstone of the Cloud Chief to overlying red-brown shale of the Doxey is about 4.5 feet below the base of the Alibates Dolomite. Here, the Alibates is about 14 feet thick, consisting of a lower white to pink dolomite 7 feet thick, a middle shale and siltstone 5 feet thick, and an upper pink to white dolomite 2 feet thick. The overlying beds are about 21 feet thick, consisting of red-brown shale and orange-brown siltstone with the top eroded away. The base of the Doxey is placed at the base of the Alibates Bed because the color change is so close to this contact and because the thickness and lithology of the interval from the Saddlehorse to the Alibates Bed in the subsurface farther east in Roberts County, Texas, are commensurate with those of the Cloud Chief from the Moccasin Creek Bed to the base of the Doxey in western Oklahoma, taking into consideration the progressive westward thinning of the Cloud Chief.

Gould (1907, p. 17) named the Alibates Dolomite Lentil for the cap rock along the Canadian River in Hutchinson, Moore, and Potter Counties, Texas, about 180 to 250 feet above the river; the unit was named for Alibates Creek in northeastern Potter County. Local stories indicate that a man named Al Bates or A. L. Bates or Aly Bates lived in the area and that the term is corrupted from his name. In this region the Alibates is a double dolomite ledge, the lower being as thick as 9 feet and the upper 5 feet, with 5 feet of red-brown shale and orange-brown to maroon siltstone between. In southeastern Moore County, much red and gray flint occurs in the Alibates; this flint was used locally by ancient Indians for tools. The underlying Cloud Chief is 60 to 105 feet thick, with an orange-brown sandstone at the top, here correlated with the Yates Sandstone. In the subsurface north of the type area and farther westward, the Cloud Chief is 150 to 200 feet thick, and the Alibates ranges from 35 to 100 feet thick, apparently increasing in thickness at the base. At places, four beds are present instead of two, and some occurrences are gypsum or anhydrite instead of dolomite, with thicker sections to the west of Amarillo. At several places, red beds 100 to 200 feet thick are present above the Alibates and below the Triassic, with some interbedded gypsums toward the top. It is possible that most of the Doxey is present in these areas, and the shale appears to correlate with the Dewey Lake Formation at the top of the Ochoan Series farther southwestward. The Alibates has not been identified east of the southwestern corner of Roberts County, Texas. In Palo Duro Canyon, the Doxey is at least 68 feet thick, above the double gypsum (Alibates) at the bottom of the canyon.

In Union County, New Mexico, the Alibates grades westward into red-bed conglomerates and granite wash. The interval down to the base of the Blaine is thinner than normal, and this interval also grades into red-bed conglomerates and granite wash.

As mentioned under the discussion of the Cloud Chief Formation, the lower Alibates is correlated with the Tansill Formation (Guadalupean), the middle Alibates with Castile-Salado (basal Ochoan) rocks, the upper Alibates with the Rustler Formation (middle Ochoan), and the remainder of the overlying Doxey with the Dewey Lake Formation (upper Ochoan).

Roth and others (1941, p. 315) described *Myalina acutirostris, Schizodus oklahomensis,* and *Naticopsis transversus* from a 2-foot dolomite 228 feet below Dockum Triassic beds in Briscoe County, Texas, in comparing the fossils with those of the Whitehorse Group. This dolomite correlates with the Alibates or Claytonville, at the base of the Doxey.

Origin.—The Doxey is mostly a shale or siltstone unit in Custer County and surrounding regions in Oklahoma. In western Texas, the Dewey Lake contains much sandstone, and these coarse clastics were probably derived from an area in eastern New Mexico. The buried Amarillo Mountains must have had a slight influence on the Doxey and underlying beds, with the Cloud Chief being thinner over the crest of the uplift and more sandstone being present in the Doxey west of the uplift. As the Marlow, Rush Springs, Cloud Chief, and Doxey grade into conglomerates and granite wash of Union County, New Mexico, but contain much shale in the Texas Panhandle and are much thinner than in Oklahoma, the fine clastics must have had a dual origin—from the east and west.

POST-FOSS ROCKS

Elk City Sandstone

Name.—The name Elk City Sandstone Member of the Quartermaster Formation was proposed by Griley (1933) for beds above the Doxey Member to the top of the Permian red beds. The sandstone was named for Elk City, Beckham County, Oklahoma. The term Quartermaster is no longer used, and its nomenclature is discussed under sections on the Foss Group, including the Cloud Chief Formation and the Doxey Shale. The Elk City is here raised to formation rank, with the base including a greenish-gray zone at the top of the Doxey Shale; the top is eroded in Oklahoma.

Type section.—The provisional type section for the Elk City Sandstone is along the road in the SE¼ sec. 34, T. 12 N., R. 20 W., Custer County, about 7 miles northeast of Elk City, where the lower 34 feet is exposed (measured section 13).

Description in Custer County.—The Elk City Sandstone crops out in the southwestern corner of Custer County and is less than 50 feet thick, with the top eroded. At the type section the Elk City is 34 feet thick and is a fine-grained orange-brown sandstone, with a 1-inch greenish-gray siltstone and shale at the base. The next overlying 13 feet is orange-brown sandstone that is highly cross-bedded (fig. 38). A 4-inch maroon to greenish-gray shale occurs about 14 feet above the base and weathers into a prominent purple and white marker bed in Custer County, ranging down to 10 feet above the base (fig. 39). The next overlying 20 feet contains in places some thin red-brown shale beds and in places a coarse-grained sandstone. This coarse sand may have been derived from weathering and reworking of previous beds by Pleistocene rivers, but comparison with beds farther west in the Sandstone Creek area of Beckham and Roger Mills Counties indicates that this sand is a lentil or facies within the Elk City similar to the Doe Creek Lentil of the Marlow Formation in Woods and Woodward Counties. The Elk City erodes into rounded hills above the Doxey Shale slope, and the contact zone weathers white to light greenish gray, making mapping of this contact easy

Figure 39. Purple and greenish-gray shale in Elk City Sandstone, about 10 feet above base, on east side of road, in SW¼NW¼ sec. 19, T. 12 N., R. 20 W., southwestern Custer County.

to trace on the ground and on aerial photographs.

Description in Beckham County.—In Beckham County, the Elk City may be subdivided into two distinct types of rocks. The normal Elk City is fine-grained orange-brown sandstone, moderately to weakly indurated and even-bedded to cross-bedded, similar to that described in adjacent Custer County. Another type of rock is along Sandstone Creek east of Berlin, Roger Mills County, extending in an east-southeast direction to a high hill just north of Elk City. It is a fine- to coarse-grained calcitic to dolomitic sandstone, highly cross-bedded and well indurated. It erodes into prominent buttes and isolated hills, similar to the Verden and Doe Creek Lentils of the Marlow Formation, and thus is easily mapped in the field. At many places the rock is brecciated and contains vertical cylindrical structures. These were described first by Griley (1937, p. 1569) as probably *Calamites* on the authority of "Reed of the U.S. Geological Survey." The name Sandstone Creek Lentil is here given to this facies; the name comes from Sandstone Creek in northeastern Beckham and southern Roger Mills Counties. The best exposure is at Indian Hill in the NW¼SW¼ sec. 30, T. 12 N., R. 22 W., Beckham County, where approximately 80 feet or more of the Elk City is exposed above the Doxey Shale. The Sandstone Creek Lentil is interbedded with the normal fine-grained Elk City sandstone and with some red-brown shale at Indian Hill. At the top is a bed of the Sandstone Creek Lentil, 10 to 15 feet thick, containing many cylindrical tubes. On the southwest side of the hill, a partial jaw of a reptile with an outline of four teeth was found by E. C. Olson of the University of California at Los Angles in the summer of 1963. The jaw was pronounced to be Permian. The cylindrical structures perhaps were caused by some type of burrowing clam or soft-bodied animal that dug into the sea bottom, according to Ralph Johnson of the University of Chicago. The cross-bedding and coarse grains might have been caused by submarine currents trending in an east-southeast direction, sweeping away finer material and causing brecciated material to form on the sea bottom. Local admixture of sea water was probably favorable for the deposition of calcium carbonate.

In the area a few miles northwest of Berlin, along the north side of the road in the SW¼SW¼ sec. 31, T. 12 N., R. 23 W., Roger Mills County, a Pliocene skull was found in red-brown sandstone similar to the Sandstone Creek Lentil. The contact between the Elk City and the Tertiary in this area is obscure, and it is possible that some beds mapped as Elk City are actually Tertiary.

Description in Washita County.—Ham and Jordan (1961, p. 5) reported a maximum thickness of 185 feet of the Elk City Sandstone in the Burns Flat area in T. 10 N., R. 19 W., based upon well studies by Bill Stacey of the U.S. Geological Survey, Ground Water Branch (Oklahoma City). The sandstone is coarse grained at the base and fine to medium grained above, with some moderate reddish-brown siltstone beds.

In the area south of Canute, along the road, the Elk City is a fine- to coarse-grained sandstone, containing many lentils and concretions of red-brown shale. In the summer of 1963, E. C. Olson of the University of California at Los Angeles found some fossil bones in the Elk City in this area but was unable to identify the fragments. They were associated with plant fragments and casts. Green (1936, p. 1474) stated that the Elk City was about 170 feet thick in this region, with the top eroded, the best exposure being in the SE¼ of T. 11 N., R. 19 W.

Age and correlation.—As discussed in the sections on the Cloud Chief and Doxey, the Elk City is probably post-Ochoan in age. Ahlen and others (1960) stated that near the crest of the Amarillo uplift the Rustler Formation of Ochoan age comes in contact with the Tansill Formation (Guadalupean) and that this upper anhydrite interval is termed the Alibates. Thus the Dewey Lake above the Rustler-upper Alibates would be the same as the Doxey, with the Alibates considered at the base of the Doxey Shale. If this interpretation is correct, the Elk City is younger than the known Ochoan of New Mexico and may be the youngest Permian formation in North America. No named series is mentioned above the Ochoan, so the name Custerian was proposed to include this unit. Thus the Custerian Series includes Upper Guadalupean, Ochoan, and post-Ochoan rocks in Oklahoma.

The highest Permian rocks in the Oklahoma and Texas Panhandles belong to the Foss Group. The Elk City is apparently absent, but it is possible that some Elk City could occur where post-Permian erosion was shallow. The red beds in this area are overlain by Triassic Dockum rocks, Cretaceous Kiowa and Dakota rocks, Tertiary Ogallala deposits, and Pleistocene deposits. Some occurences of basal Dockum (Tecovas Formation) rocks are orange-brown micaceous sandstone similar to the Elk City Sandstone, and the two could be confused if not directly compared with surface samples. The remainder of the Dockum and higher units are different from each other and radically different from the Doxey and Elk City; it is here doubted that these rocks can be misidentified from one place to another if they are compared directly with known surface samples. For instance, the Tecovas Formation of Palo Duro Canyon, Randall County, Texas, is mainly greenish-gray, chocolate-brown, yellow-brown, and red-brown shale and siltstone, with about 50 feet of white sandstone in the middle, and some orange-brown micaceous sandstone and siltstone at the base. The overlying Trujillo Formation contains many greenish-gray pebble conglomerates. In Texas and Beaver Counties, Oklahoma, the Tecovas and Trujillo are similar to their occurrence in Palo Duro Canyon, and the Dakota is a pink coarse-grained quartzose sandstone and quartzite. The Dockum of Beaver County is now classed as Dakota, and the Tecovas and Trujillo occur only in Texas County and possibly in eastern Cimarron County, Oklahoma. The Kiowa is dark-gray shale, white sandstone, and tan limestone. The Morrison Formation (Jurassic) contains varicolored shales and speckled brown and white sandstones. The Ogallala and Pleistocene beds are mainly gravels, coarse to fine sands, and light-colored silts, with some volcanic ash and limestones. Hence, it would be difficult to confuse most of these formations with red-brown gypsiferous shales, orange-brown fine-grained quartzose sandstones, and red-brown siltstones of the Permian.

Origin of the sand.—At present, the only evidence of landward areas is in the region south of Canute, Washita County, where fragmentary plant material was found. The Sandstone Creek Lentil strikes in a southeasterly direction, and it is possible that land was southeast of Cordell, Washita County. Much of the sand might have been derived from erosion of the Whitehorse Group farther east and southeast, possibly along the flanks of the Arbuckle and Ouachita Mountains.

CRETACEOUS SYSTEM

Comanchean Series

The Cretaceous System is classically divided into an upper and a lower series, and in the United States the lower part was termed the Comanchean Series by Hill (1887, p. 298). According to Stephenson and others (1942, p. 442), the upper part of the Comanchean is probably the equivalent of units higher than the Lower Cretaceous of Europe. The Comanchean is subdivided into the Trinity, Fredericksburg, and Washita Groups (ascending).

WASHITA GROUP

The Washita Division was first defined by Hill (1887, p. 298) for a group of formations at the top of the Lower Cretaceous or Comanchean Series in the Gulf Coast region. According to traditional usage, the Kiamichi Formation of Hill (1891, p. 515) was included with the underlying Fredericksburg Group, but Stephenson and others (1942, p. 444) included the Kiamichi with the Washita Group.

Kiowa Formation

Name.—The name Kiowa Shale, for Kiowa County, Kansas, was first proposed by Cragin (1894, p. 49) for a fossiliferous shale above the Cheyenne Sandstone, with the top eroded. Hill (1895, p. 208) used the name Belvidere Shales for the same interval as the Kiowa, which were named for the area near Belvidere, Kiowa County, Kansas. In the same paper, Hill used the terms Camp Supply Beds (p. 227) and Comet Creek Bed (p. 228) for the outliers near Fort Supply, Ellis and Harper Counties, Oklahoma, and those near Comet Creek (Barnitz Creek), Custer County, Oklahoma, respectively. Cope (1894, p. 64) first reported on the Fort Supply area, and Marcou (1854) first reported on the Comet Creek area. Cragin (1895,

p. 361) used the term Belvidere Beds to include the Cheyenne Sandstone, the Champion Shell Bed, and the Kiowa Shales, the Champion being a 1.5-foot fossiliferous gypsiferous shell bed at the base of the Kiowa. The Kiowa was subdivided into the Tucumcari Shales above and the Fullington Shales below, and the Fullington was subdivided into the Blue Cut Shales above and the Black Hill Shale below. The Tucumcari and the Fullington were not differentiated, except that *Texigryphaea tucumcarii* (Marcou) was found in the former and *Texigryphaea navia* (Hall) in the latter. The Blue Cut included some tan limestones and gray shales, and the Black Hill was principally black shale. The underlying Champion contained abundant specimens of *Texigryphaea hilli* (Cragin). Twenhofel (1924, p. 20–23) discarded the previous subdivisions and used the term Kiowa for all of the beds above the Cheyenne Sandstone as originally defined.

South of Kiowa County, Kansas, the Cheyenne Sandstone and the Champion Shell Bed pinch out, and the Kiowa rests upon Upper Permian red beds in Oklahoma.

Type section.—The type section for the Kiowa is that proposed by Fay (1965, p. 82) on the northwest side of Avilla Hill (previously termed Black Hills) in the SW¼ sec. 36, T. 34 S., R. 19 W., southern Comanche County, Kansas. Here, the Kiowa is 140 feet thick, with the top eroded. The lower 70 feet is mostly dark-gray shale with a 15-foot white sandstone at the base, and the upper 70 feet is yellow-brown shale with thin limestone beds. This is the maximum recorded thickness for the Kiowa in Kansas and Oklahoma, as shown by Bullard (1928, pl. 10). A common clam of the Kiowa, which acts as a marker, is *Texigryphaea.*

After a tentative study of the Lower Cretaceous oyster *Gryphaea (Texigryphaea)* Stenzel, I believe that the subgeneric name *Texigryphaea* should be raised to generic rank (see Fay, 1975). As pointed out by Sylvester-Bradley (1959, p. 36), the genus *Gryphaea* is probably polyphyletic, the Lower Jurassic forms of Europe probably having come from *Ostrea liassica* or related species, the Upper Jurassic forms of Europe from *Ostrea knorri,* and the Lower Cretaceous *Texigryphaea* of the United States probably form *Ostrea wardi.* I disagree that *O. wardi* is the ancestor of *Texigryphaea,* because Imlay (1940, p. 147–148, pl. 8, figs. 1–6) described an older *Texigryphaea* from the Carbonera Formation of Durango, Mexico. Stenzel (1959, p. 21) thought that *Texigryphaea* probably came from Jurassic forms of *Gryphaea* of the United States or nearby areas, but the common Jurassic *Gryphaea* of Wyoming has radiate umbonal striae not seen in *Gryphaea* or *Texigryphaea,* and this form should probably be transferred to some new genus. As pointed out by Stenzel (1959, p. 20), *Gryphaea arcuata* Lamarck, 1801, is the type of the genus *Gryphaea* and occurs in the Lower Jurassic of Europe. The type of *Texigryphaea* is *Gryphaea roemeri* Marcou, 1862, as designated by Stenzel (1959, p. 22), which occurs in the Lower Cretaceous of North America. *Texigryphaea* can be distinguished from *Gryphaea* by having an umbonal sulcus on the left valve; also, the beak is incurved to one side rather than normal to the plane of valve commissure. In addition, the left valve has a keel adjacent to the umbonal sulcus in *Texigryphaea,* which is lacking in *Gryphaea.* Thus the name *Gryphaea* as used in the literature for the Lower Cretaceous of Oklahoma, Texas, Arkansas, Kansas, New Mexico, and Mexico, is now replaced by *Texigryphaea,* and many of the species as commonly used will have to be restudied (see Fay, 1975). The common marker for the Kiowa has been designated *Gryphaea corrugata* Say, but after investigation of the history behind the collection of the types (now lost) it is necessary to discard this name from the literature (Fay, 1975). The original types collected by Thomas Nuttall in 1819 were said to be "on the Red River," and from close examination of Nuttall's map it is evident that he crossed the Kiamichi River about 3 miles west of the mouth and then proceeded southward toward the Red River. It is possible that he collected some specimens of *Texigryphaea* from the Fort Worth Limestone immediately after crossing the Kiamichi in secs. 14, 15, 16, 21, and 22, T. 7 S., R. 19 E., Choctaw County, Oklahoma. Hill and Vaughan (1898, p. 57) thought that Nuttall collected near Goodland from the Kiamichi Formation, about 14 miles northwest of the mouth of the Kiamichi, but Nuttall (1821, p. 152–157) was not near this area, being on the Red River instead. The original description of

Gryphaea corrugata by Say (1823, p. 410–411) is inadequate and lacks a figure. No one has been able to locate the types, so the name *Texigryphaea corrugata* Say is here suppressed. Further discussion is given in Fay (1975).

If mature specimens from the type localities are compared, the following 10 spe cies of *Texigryphaea* can be tentatively distinguished: *T. belviderensis* (Hill and Vaughan), 1898, upper Kiowa Shale, from Black Hills about 4 miles west of Sun City, northeastern Comanche County, Kansas; *T. gibberosa* (Cragin), 1892, Georgetown Limestone (Duck Creek), near Austin, Texas; *T. hilli* (Cragin), 1891, Champion Shell Bed, 0.5 to 1 mile south of Belvidere, Kiowa County, Kansas; *T. marcoui* (Hill and Vaughan), 1898, Walnut Clay, on Bee Caves road 9 miles west of Austin, Texas; *T. mucronata* (Gabb), 1869, Potrero Formation, top and west base of Cerro de las Conchas, about 6 miles east of Arivechi, Sonora, Mexico; *T. navia* (Hall), 1856, middle Kiowa Formation, NE¼SE¼ sec. 34, T. 13 N., R. 18 W., Custer County, Oklahoma; *T. pitcheri* (Morton), 1834, probably upper Duck Creek Formation to lower Fort Worth Formation, near Fort Towson, in an area along the old military road to Red River, Choctaw County, Oklahoma; *T. roemeri* (Marcou), 1862, Grayson Formation, near Hueco Springs on Guadalupe River, about 5.5 miles north-northwest of New Braunfels, Comal County, Texas; *T. tucumcarii* (Marcou), 1855b, about 20 feet above the base of the Tucumcari Shale, Mount Tucumcari, about 3.5 miles south-southeast of Tucumcari, Quay County, New Mexico; *T. washitaensis* (Hill and Vaughan), 1898, Duck Creek Formation, 2 miles north of Denison, Texas. Of these, *T. hilli, T. marcoui,* and *T. mucronata* may be identical, being almost identical in age and differing only in the degree of lobing of the posterior flange. Viewed with the left valve down, *T. hilli* has a low rounded lobe, *T. marcoui* has a long medial lobe, and *T. mucronata* is almost unlobed. *T. pitcheri* appears to be the young form of *T. tucumcarii*, and the latter name probably should be suppressed.

In the Kiowa Formation of Kansas, *T. hilli* occurs in the Champion Shell Bed at the base of the Kiowa, *T. navia* occurs about 50 feet higher, and *T. belviderensis* occurs near the top, with intermingling of the latter two species in the upper half of the Kiowa. The report of *T. tucumcarii* near the top may be incorrect. *T. navia* is triangular in outline, *T. belviderensis* is more rounded along the lower margin and has a shallow sulcus on the left valve, and *T. tucumcarii* is similarly rounded but has a deep sulcus on the left valve. Please refer to Fay (1975) for a review and discussion of the type material.

Description in Custer County.—In Custer County, the Kiowa is mostly a dark-gray shale, with a *Texigryphaea navia* limestone bed about 2 feet thick and some yellow-brown shale. This occurrence represents the lower part of the Kiowa. Bullard (1928) showed about 90 separate outcrops in Custer County, and the map in this report shows about 275 outcrops, all west of R. 16 W., or roughly west of U.S. Highway 183. The exposures are slumped and less than 50 yards wide, and it is impossible to reconstruct an accurate stratigraphic sequence. One of the best exposures was discovered by Marcou in 1853 while going from camp 31 to camp 32 on September 1, about 3 miles southwest of camp 31, in the SW¼SE¼NE¼SE¼ sec. 34, T. 13 N., R. 18 W. A 1-foot tan to white coarse-grained sandstone (now Dakota) occurs here, along with several feet of gray to tan shale with some blocks of *Texigryphaea navia* limestone (fig. 40). It was in this area that Marcou (1854, p. 157, map; 1855a, p. 43; 1856, p. 131) first recognized Lower Cretaceous rocks in North America, comparing the fossils with Neocomian fossils of Europe. This is also the type locality for *Texigryphaea navia* (Hall), 1856 (p. 100, pl. 1, figs. 7–10).

The Kiowa Formation occurs in association with Pleistocene gravels and is easily seen on aerial photographs, because the limestone and gravel erode into resistant mounds (Fig. 41). Some deposits are 20 feet thick or more; perhaps the Cretaceous beds collapsed into sinkholes beneath Pleistocene rivers in the area (fig. 42).

In order to aid historians, the itineraries of Whipple (1856), Marcou (1856), and Blake (1856) were followed, using the astronomical coordinates given in separate appendixes by Whipple (appendix D), Whipple's original penciled notes in Wright and Shirk (1950), and Möllhausen's (1858, p. 158–163) account

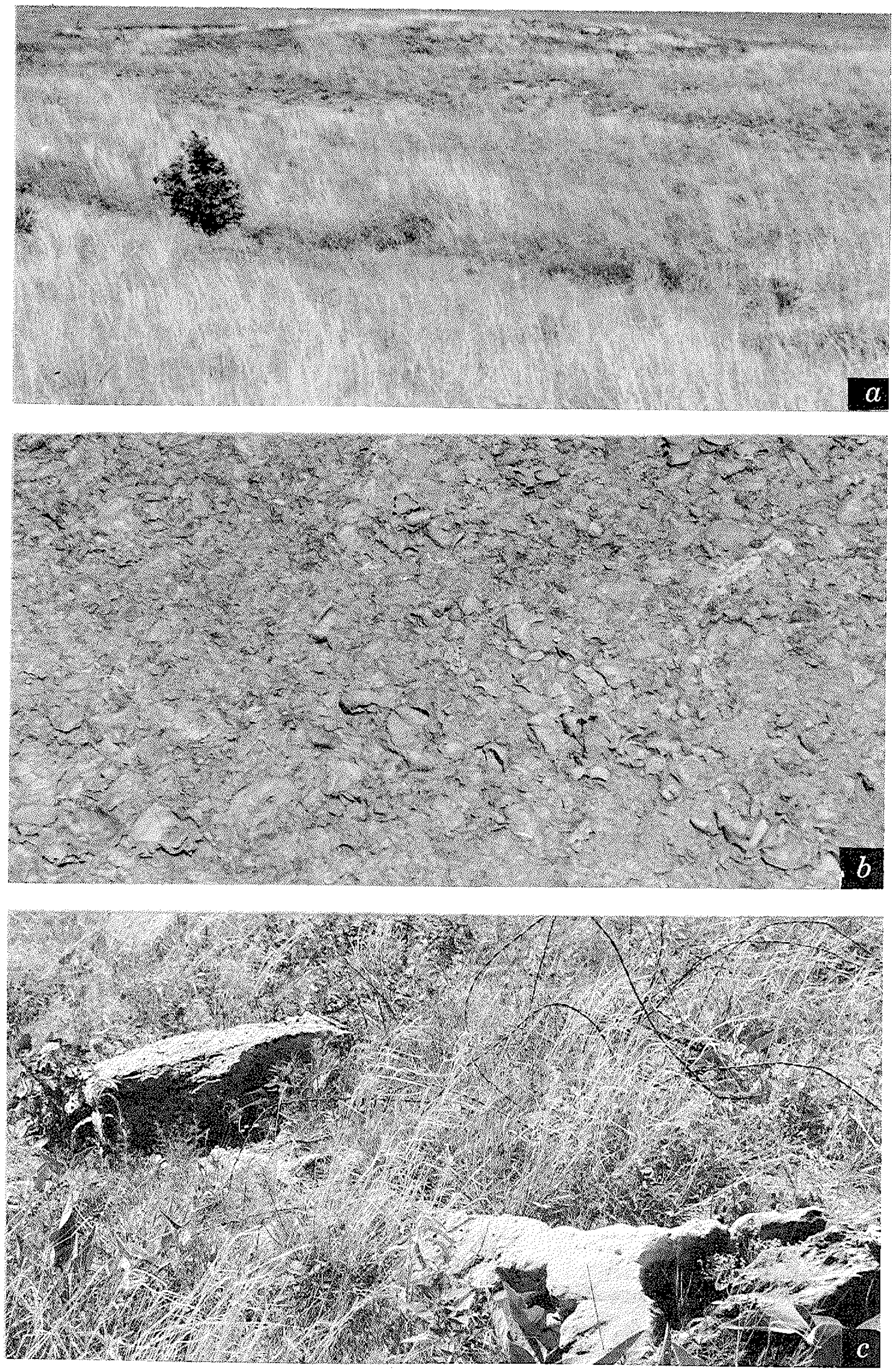


Figure 40. *a*, Type Neocomian locality of Marcou (1854), near camp 31, Comet Creek or False Washita; in SW¼SE¼NE¼SE¼ sec. 34, T. 13 N., R. 18 W., looking northeast at shale of Kiowa Formation on upper Cloud Chief Formation. *b*, closeup of *Texigryphaea navia* limestone. *c*, basal sandstone of Dakota Group at east end of hill.

(see pl. 1). The distances traveled are measured along the route and not along a beeline. The latitude given in the itineraries was off 1 to 2 miles from the actual camp sites, and the longitude, 10 or more miles.

Beginning with Camp 28 in the NW¼ sec. 15, T. 11 N., R. 10 W., Canadian County, the expedition traveled about 19 miles westward, passing Rock Mary in the NW¼ sec. 1, T. 11 N., R. 12 W., Caddo County, and camping on a stream that flowed northward toward the Canadian River, after passing through the Caddo County Buttes. Camp 29 was probably in the SW¼ sec. 3, T. 11 N., R. 13 W., Caddo County. The next day, August 30, 1853, the expedition probably entered Custer County in the east part of sec. 36, T. 12 N., R. 14 W., and passed by some deep caves in the Cloud Chief gypsum in the NE¼NE¼ sec. 25, T. 12 N., R. 15 W., described by Möllhausen (1858, p. 159–161). They moved about 16 miles northwest of camp 29 and came to their first major stream, named Gypsum Creek (now Bear Creek), with camp 30 being in the NE¼ sec. 33, T. 13 N., R. 15 W., about 1 mile east of the main stream, on the south side of a tributary creek. On August 31, the party crossed Bear Creek in sec. 32 and moved slightly north of west about 4 miles, getting their first view of the Washita valley from the high mounds in sec. 26, T. 13 N., R. 16 W. They then turned southwestward and crossed Bear Creek (now Turtle Creek) near the center of sec. 33, T. 13 N., R. 16 W., and 3 miles farther they crossed Elm Creek (now Beaver Creek). Turning slightly north of west, they entered the Washita valley within a mile and went westward several miles along the north bank of the Washita. The expedition then traveled northward about 4 miles and came back southwestward about 1 mile, making camp probably in a

Figure 41. Kiowa Formation (Cretaceous). Limestone blocks with many *Texigryphaea navia* Hall are common in this area and are more resistant to erosion than surrounding Pleistocene sediments, leaving many hills. View in SE¼SW¼ sec. 23, T. 13 N., R. 19 W., southwestern Custer County.

Figure 42. Gravel pit of probable Pleistocene sediments, with collapsed blocks of limestone and shale of Kiowa Formation (Cretaceous) in the sand and gravel, resting upon Permian red beds, in NE¼NE¼ sec. 17, T. 13 N., R. 18 W., west-central Custer County.

small wooded valley near the center of the NE¼ sec. 19, T. 13 N., R. 17 W. Camp 31 was probably at this locality, on the east side of Barnitz Creek, because Marcou (1856, p. 131) mentioned that a bed of gypsum dips to the north at an angle of 15° *near* camp 31; about half a mile north of here the beds have this inclination but are flat or slumped in many directions elsewhere. Also, Marcou mentioned that the gypsum is more abundant here than in the area between camps 30 and 31, and this is only locally true for a small area in sec. 19, because farther south along Barnitz Creek there is almost no gypsum. Whipple (1856, p. 26) named the main stream Comet Creek for a bright comet seen in the western sky, and this creek is now Barnitz Creek, contrary to the opinion of the U.S. Board on Geographic Names (1967, p. 24), who list Comet Creek as the stream south of Butler. Next, the expedition crossed Comet Creek below the place where East Barnitz Creek and West Barnitz Creek join and moved southwestward about 3 miles to the SE¼ sec. 34, T. 13 N., R. 18 W., where Marcou collected *Texigryphaea navia* and became the first person to recognize Lower Cretaceous rocks in North America. Blake (1856, p. 119) gave the locality as Camp No. 31, False Witchita, repeated by Hall (1856, p. 100) as False Washita, as taken from Marcou's labels. From Marcou's account (p. 131) it is obvious that he did not understand that Comet Creek was the main stream; his False Washita is no doubt the same as Barnitz Creek, as he probably thought that Whipple named a small tributary Comet Creek. The party traveled about 15 miles from camp 31, following the ridge northwestward from sec. 34, and probably made camp 32 in the SE¼ sec. 20, T. 14 N., R. 19 W., on September 1, 1853, at what they named Silver Creek. The next day they moved about 4 miles northwestward to Marcou Creek (now Wild Horse Creek). Five miles beyond, following the ridge, they crossed Wood Creek (now the North Branch of Quartermaster Creek), moving westward and southwestward about 2.5 miles to Oak Creek (now Quartermaster Creek), and camped about 4 miles northwestward on the west side of the creek in the SW¼NW¼ sec. 27, T. 15 N., R. 21 W., Roger Mills County (camp 33). Vaughan (1897, p. 49) first recognized Comet Creek as Barnitz Creek.

Age and correlation.—Based upon studies of *Texigryphaea,* the Champion Shell Bed of Kansas, at the base of the Kiowa, correlates with the Goodland Limestone or Walnut Clay of southern Oklahoma and northern Texas. The lower Kiowa correlates with the Kiamichi Formation, and the upper Kiowa correlates with the lower Duck Creek Formation. The outliers in Custer County correlate with the lower Kiowa and part of the upper Kiowa, or with the Kiamichi and the lower Duck Creek.

Miser and others (1954) correlated the Kiowa with the upper part of the Purgatoire Formation in Cimarron County, Oklahoma, and with the Kiamichi Formation of southern Oklahoma. Dobrovolny and others (1946, sheet 1) subdivided the Purgatoire Formation of Quay County, New Mexico, into the Tucumcari Shale, Mesa Rica Sandstone, and Pajarito Shale Members (ascending). They show Mount Tucumcari in the SW¼ sec. 31, T. 11 N., R. 31 E., with Ogallala (Tertiary) beds on top, resting upon the Mesa Rica Sandstone, and about 50 feet of the Tucumcari Shale below, resting upon the Morrison Formation of Jurassic age, with much sand in the upper half of the Tucumcari. On sheet 2, they mention that most of the fossils collected by previous authors came from the Tucumcari Shale. Griggs and Read (1959, p. 2007) rejected the name Purgatoire, elevating the members to formations for a much larger area of northeastern New Mexico and using the name Mesa Rica in place of Dakota. *Texigryphaea belviderensis* in the upper Kiowa is similar to *T. tucumcarii* from the Tucumcari Shale, and it is possible that the Tucumcari Shale is equivalent to the Kiowa Formation, except that fossils as high stratigraphically as the Fort Worth Limestone have been reported from the Tucumcari but not from the Kiowa. Therefore, the upper part of the Tucumcari must be higher than the Kiowa of Cimarron County, Oklahoma, and only the lower part of the Tucumcari Shale of New Mexico is the same as the Kiowa of Cimarron County, as shown by Bullard (1928, p. 96).

It would probably be best to reject the name Purgatoire, replacing it with Kiowa. Stovall (1943, p. 71–81) showed that the Purgatoire Formation has a basal white sandstone and conglomerate up to 70 feet thick, overlain by a dark-gray to buff shale about 49 feet thick in Cimarron County, and that the basal sandstone thins out eastward, being absent northeast of Boise City. The overlying shale was termed Kiowa, and the underlying sandstone, Cheyenne. Some sandstone occurs in the upper part of the shale, and a thin limestone and *Texigryphaea* occur below this sandstone. But the term Cheyenne Sandstone should not be used in Oklahoma. The type Cheyenne, in Kiowa County, Kansas, is nonmarine, contains fossil leaves, and pinches out southward and westward, being absent south of Comanche County, Kansas, and west of Meade County, Kansas. The 70-foot sandstone in Cimarron County contains fossil logs, pinches out northeastward, and is probably marine. In Texas County, this basal sandstone is marine, contains marine fossils, and is about 5 feet thick. In Woods County, the sandstone is about 15 feet thick and is also marine, being interbedded with lower shale of the Kiowa. This sandstone and overlying shales, limestones, and sandstones should be classed as parts of the Kiowa Formation in Oklahoma.

DAKOTA GROUP

Name.—The name Dakota Group was first used by Meek and Hayden (1861, p. 419) for exposures along the Missouri River near Dakota City, Dakota County, northeastern Nebraska. Tester (1931) studied the type region and showed that the Dakota is a series of sandstones and shales about 100 feet thick at the surface, overlain by about 25 feet of Graneros Shale, with about 15 feet of Greenhorn Limestone above the Graneros. The basal Dakota is not exposed here.

Type section.—A type section was proposed by Condra and Reed (1943, p. 19) about 1 mile southeast of Homer, Dakota County, Nebraska, in the NE¼ sec. 13, T. 27 N., R. 4 E. The Dakota was found to be about 147 feet thick, with about 75 feet of Fuson Shale below and about 170 feet of Lakota Sandstone below the Fuson, resting upon probable Pennsylvanian beds. The upper 147-foot sandstone and shale was named the Omadi Sandstone, and the Dakota Group was redefined to include the Omadi, the Fuson, and the Lakota. Only the upper 100 feet of the Omadi is exposed at the surface near Homer, Nebraska, with the remainder of the section being extrapolated from a well northwest of Homer and from distant outcrops. Subsequent work has shown that the Omadi is Lower Cretaceous. The overlying Graneros Shale is Upper Cretaceous. The subsequent correlation of the Dakota and usage of names and groupings of differing rank have resulted in considerable confusion as to identification of the Dakota outside of the type area.

Description in Custer County.—In southwestern Custer County, in secs. 27 and 28, T. 12 N., R. 19 W., and the S¼ sec. 33, T. 12 N., R. 20 W., the Dakota is a pinkish-brown to gray fine- to coarse-grained cross-bedded to even-bedded well-indurated quartzitic sandstone, about 8 feet thick (fig. 43). Permian pebbles are common, and pebbles of quartzite and fossil wood are associated with loose cobbles of Kiowa limestone containing *Texigryphaea navia* around the margins of the blocks. The blocks are slumped on the Doxey Shale and the Elk City Sandstone and appear to be associated with gravels of probable Pleistocene age. A similar sandstone was noted by Marcou in sec. 34, T. 13 N., R. 18 W. (fig. 40c).

Age and correlation.—The Dakota Group of Custer County can be correlated with rocks of similar lithology in Cimarron County, Oklahoma, where the Dakota Group is divided into three units: (1) a lower tan to pink sandstone and quartzite 115 feet thick, (2) a middle gray shale with coal 47 feet thick, and (3) an upper sandstone like the lower unit, but not quartzitic, 53 feet thick, according to Stovall (1943, p. 86). The lower sandstone is widespread; it is Early Cretaceous in age and rests upon gray shale of the Kiowa Formation. The middle shale is restricted to southwestern Cimarron County and is Early Cretaceous, according to Potter (1963, p. 227). The upper sandstone is also restricted to southwestern Cimarron County. In Kansas, the upper sandstone was determined to be Late Cretaceous by Hattin (1962). In Cimarron County, the upper sandstone was correlated as Upper Cretaceous by Kauffman and others (1977, p. 31–32). The overlying Graneros Shale is about 66 feet thick in Cimarron County and lies unconformable upon the different units of the Dakota. In Baca County, Colorado, the Graneros rests upon the lower unit; thus

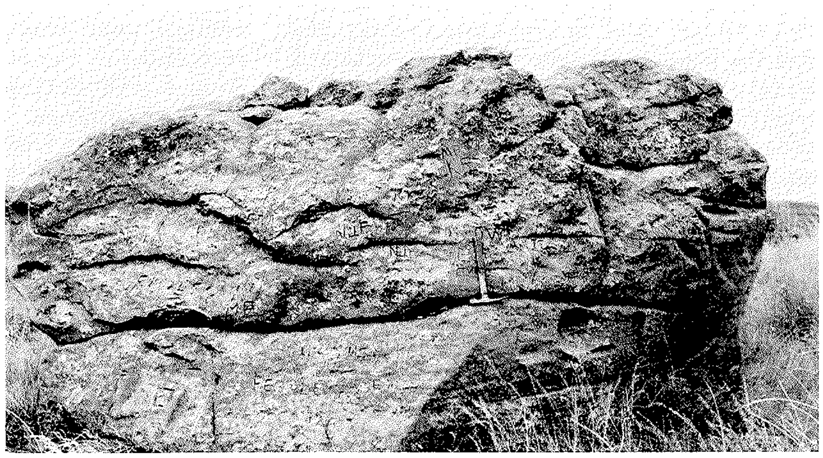


Figure 43. Sandstone block of Dakota Group resting upon covered outcrop of Elk City Sandstone, in $SW^1/_4SE^1/_4SE^1/_4$ sec. 33, T. 12 N., R. 20 W., southwestern Custer County. Sandstone is yellow brown, well indurated, medium grained, cross-bedded, and quartzitic in places, with some reworked fossil wood and quartzite pebbles.

the Dakota of Baca County is Lower Cretaceous, as reported by McLaughlin (1954, p. 108).

The Custer County quartzites and sandstones are here correlated with the lower unit of Cimarron County and are designated the lower unnamed sandstone of the Dakota Group. Bullard (1928) showed areas of Cretaceous sandstone in Washita County and showed this sandstone below the Kiowa Formation. After checking these areas of slumped structures, I was unable to determine the correct position of the sandstone but have concluded that the sandstone is correlative with the lower unit of the Dakota Group and is therefore above the Kiowa Formation.

QUATERNARY SYSTEM

Pleistocene Series

In Custer County, the Pleistocene deposits can be subdivided into three regions: (1) Canadian River, (2) Deer Creek, and (3) Washita River. These deposits consist of 100 feet or less of sand, gravel, silt, and clay, with the Pearlette volcanic ash in the Deer Creek and Washita River areas. Several distinct terrace levels can be seen in each river system. The Canadian River and Deer Creek systems were discussed by Fay (1962, p. 85–93, pl. 4), who showed that Deer Creek was the old Canadian River during Nebraskan-Kansan time. This left Deer Creek as an underfit stream in the old Canadian River valley.

The Canadian River deposits are separated from the Deer Creek deposits by a sandstone ridge of the Rush Springs Formation, with high mounds such as Sugar Loaf and Indian Hill on top in the Thomas area. East of these mounds is a veneer of silt and clay with some sand, in several terrace levels, on the west side of the Canadian River. On the east side of the Canadian are 100 feet or more of gravels and finer clastics, with comparable terrace levels, but no volcanic ash.

The Deer Creek deposits occur west of the mounds and may be as thick as 40 feet, consisting of gravel and finer clastics, with much volcanic ash (figs. 44, 45). The ash was identified as the Pearlette ash (late Kansan) by Ham (1949, p. 48–57), and 16 areas have been mapped in Custer County north of Custer City in secs. 12–15, T. 14 N., R. 16 W., and secs. 21, 27, 28, 34, T. 15 N., R. 16 W. The ash is white and about 3 to 15 feet thick. It is overlain by red-brown siltstone, sandstone, and gravel, with a red-brown soil on top, showing that the soil is transported and not residual from red beds (fig. 45).

Many fossil snails were found in the $NE^1/_4NE^1/_4SE^1/_4$ sec. 14, T. 14 N., R. 16 W., and in the $SW^1/_4SW^1/_4SW^1/_4$ sec. 27, T. 15 N., R. 16 W. Fossil bones and snails were found in a gray silt above the gravel in a pit in the $NW^1/_4$ sec. 12, T. 14 N., R. 15 W. (fig. 44).

In certain selected areas where gypsum has been leached or reworked by ground water, caliche deposits occur with Pleisto-

Figure 44. Pleistocene gravel pit, with gravel and reworked red beds in lower part, surmounted by sand and silt (light colored) in upper part. View on west side of creek, looking west at 30-foot face, in SW¼NW¼ sec. 12, T. 14 N., R. 15 W., northeastern Custer County. Many bones and snails occur in upper silt.

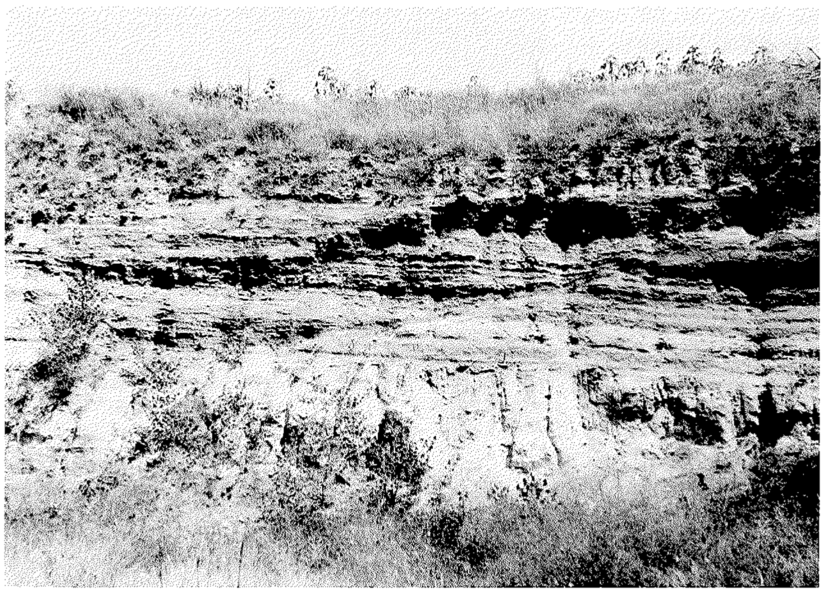


Figure 45. Pearlette (late Kansan) volcanic ash, in lower part of picture, with tan to red-brown sandstone and gravel above, grading into red-brown soil. View, looking south, in SE¼SE¼NE¼ sec. 15, T. 14 N., R. 16 W., central Custer County. The 11-foot ash deposit was worked in this abandoned pit.

cene pebbles in the matrix of calcium carbonate (fig. 46). In almost every instance, a local gypsum nearby can be traced to about the same level of the caliche, and where the gypsum is missing the caliche bed is present. It is possible to find Pleistocene quartzite pebbles resting directly upon gypsum, and in some cases it is possible to find the pebbles surrounded by the gypsum (fig. 47). With advanced weathering, the sulphate has been replaced by carbonate, resulting in a conglomerate with a caliche matrix.

The Washita River Pleistocene deposits are less than 30 feet thick, consisting of gravels and finer clastics, with some volcanic ash. They occur mostly on the north side of the Washita River, in several terrace levels, and generally west of the Custer City–Weatherford area. In three places, a volcanic ash (probably Pearlette) is present (NE¼NE¼ sec. 21, T. 14 N., R. 16 W.; SW¼SW¼ sec. 31, T. 13 N., R. 15 W.; NW¼NE¼ sec. 1, T. 12 N., R. 16 W.). In the section 31 locality, the ash is probably mixed with gypsite and clay about 4 feet thick, and it contains fossil snails and some elephant remains. In the SE¼SE¼ sec. 16, T. 13 N., R. 19 W., a tan well-indurated

Figure 46. Pleistocene caliche with quartzite pebbles, resting upon sandstone of Rush Springs Formation. View on north side of road, in SW¼SE¼ sec. 5, T. 12 N., R. 16 W., central southern Custer County. This ledge is traceable laterally into Weatherford gypsum and appears to have been formed by let-down of gravel into gypsum, with replacement of sulfate by carbonate.

cross-bedded sandstone is present, containing quartzite pebbles, and is about 15 feet thick (fig. 48). The Pleistocene elsewhere is not well indurated in this manner (except where replaced by caliche), and it is possible that this sandstone is older than Pleistocene. Gravels almost 20 feet thick occur in the Barnitz Creek valley, suggesting that the channel of the ancient Washita River once flowed in this area. As previously mentioned, Barnitz Creek appears to be an underfit stream. At Foss Dam the low terrace material and alluvium are as thick as 132 feet, as shown in drilling by the U.S. Bureau of Reclamation from 1946 to 1957 (measured sections 9, 10).

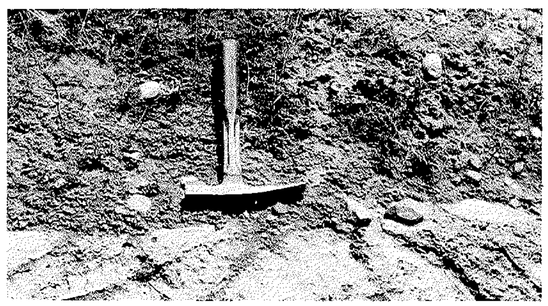


Figure 47. Pleistocene pebbles on weathered gypsum of Moccasin Creek Bed of Cloud Chief Formation, in NE¼NE¼NE¼ sec. 1, T. 12 N., R. 17 W., central southern Custer County. As weathering proceeds, quartzite pebbles are incorporated into gypsum, making it possible to find such pebbles almost completely surrounded by gypsum.

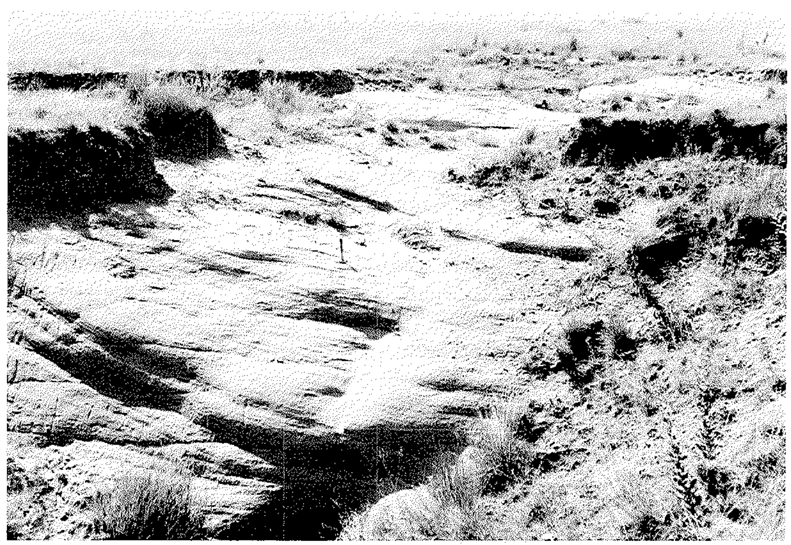


Figure 48. Tan Pleistocene(?) sandstone, with interbedded quartzite gravel and conglomerate at top. View, looking northwest, in SE¼SE¼ sec. 16, T. 13 N., R. 19 W., southwestern Custer County. This deposit is about 15 feet thick. It is coarse grained, cross-bedded, and well indurated and may be older than Pleistocene.

PART II.—ECONOMIC GEOLOGY OF CUSTER COUNTY

ROBERT O. FAY[1]

INTRODUCTION

The main geologic products of Custer County are oil and gas, water, clay, dolomite, gypsum, sandstone, sand and gravel, volcanic ash, uranium, and salt. The treatment of oil and gas is beyond the scope of this report. Ground-water resources are discussed in Part III. Salt occurs only in the subsurface and would require mining or drilling for recovery.

Clay

One company, Acme Brick Co., presently produces brick in Custer County from clay and shale in the Cloud Chief Formation. The plant is at the southwest edge of Clinton in the NE¼ sec. 21, T. 12 N., R. 17 W. It covers approximately 50 acres, including the pit (fig. 49). The company owns approximately 120 acres and has an ample supply of shale for many years. The company produces about 20 million bricks per year, of which about 19 million are pink and the remainder are gray or white to gray with burnt-on coatings. Approximately 95 percent of these bricks are shipped out of Clinton. The company employs about 50 persons. Mr. Jim Laminack is the present superintendent of the plant, and appreciation is here acknowledged for his time and assistance in preparing this section, which describes in some detail how the brick is produced.

The enterprise began in 1929 as Western Brick and Tile Co. At that time the company advertised production of face brick, common brick, fire brick, face tile, hollow tile, drain tile, sewer pipe, flue lining, mortar color, fire clay, and wall coping. The plant was purchased by Acme Brick Co. in 1944 and is now producing face brick only.

The pit is south of the plant, and the Cloud Chief Formation, which has possibly been reworked, is quarried. Here, the Cloud Chief consists of red-brown to orange-brown shale, siltstone, and some sandstone. A shale planer was used in previous quarry operations, where vertical faces were cut about 30 feet high, but now a scraper is used to transport the clay to a mixing bin, seen in the upper left corner of figure 49. Approximately 40,000 tons per year is mined from the pit.

The mixed clay is then transported westward over a conveyor belt and dropped to another conveyor belt that moves northward to a rotary dryer, where the moisture is driven out of the clay at about 400°F. The dried clay is then transported northward to the top of a crushing plant, where the material is crushed by a hammer mill and screened to 8-mesh size through vibrating screens. Oversized pieces that do not pass the screens are returned by a link belt to the top of the crusher.

The screened portion is then dropped by feeder to a pug mill, where a rotary screw slowly moves the pulverized clay forward to a vacuum chamber while water is added in small streams on either side. A side elevator is present near the end of the pug mill, where rejected molded clay or broken predried bricks are returned. The vacuum chamber operates at about 26 pounds per square inch and removes excess air and some moisture, giving a tighter body to the clay. This type of clay preparation is termed the stiff-mud process.

The clay is then fed into an extruder, which has large augers near the vacuum chamber and smaller augers farther away, with a mold at the far end in the shape of a brick, the length horizontal and the width vertical. Small porcelain rods are present in the center of the mold to form holes in the brick. A continuous column of clay

[1]Geologist, Oklahoma Geological Survey.

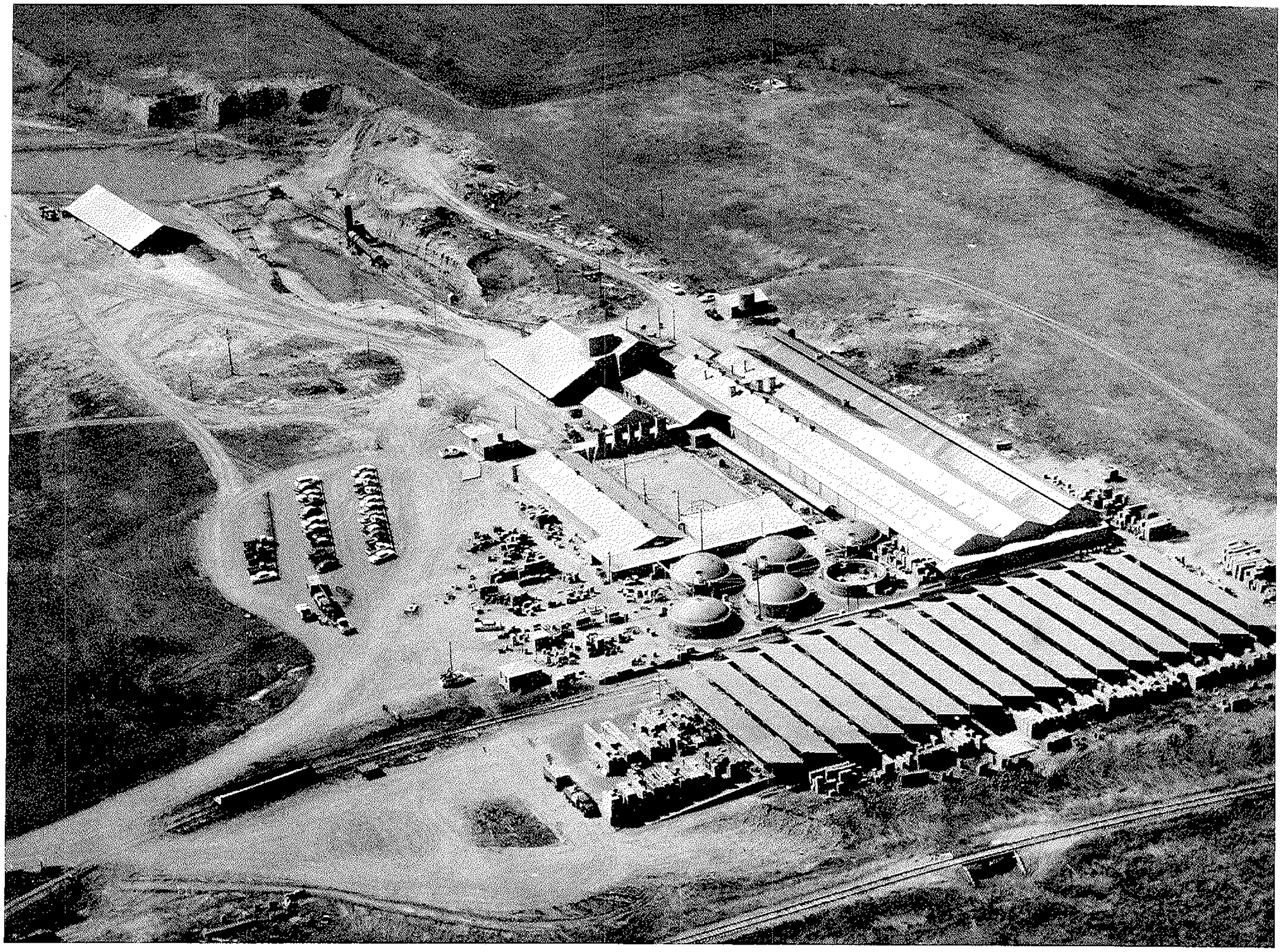


Figure 49. Acme Brick Co. plant and pit at southwest edge of Clinton, Custer County. Shale from Cloud Chief Formation, possibly reworked, is being quarried. View, looking southwest, in NE¼ sec. 21, T. 12 N., R. 17 W. Photograph courtesy of Acme Brick Co.

is then extruded in the shape of a brick, with holes inside, onto a conveyor belt that passes below a cutting machine. Different types of molds are used to produce different types of textures.

The cutting machine consists of a rotary drum with steel wires spaced apart by the distance of the face height of the brick. The machine then is lowered to the continuous column of extruded clay, and approximately 16 clay cuts are made. Two offbearing belts move the cut bricks either northward to be placed in beehive kilns or westward to be placed in a continuous or tunnel kiln.

The first kilns were updraft kilns, but these were dismantled many years ago. Then the beehive kilns were constructed, employing the downdraft process, whereby 12 gas burners on the sides supply the heat and the hot air is pulled from the ceiling down through the floor, thus creating an even heat flow. The bricks are taken off the northward-moving belt and placed by hand into packages, where they are transported to the kilns and stacked by lift truck. Each kiln holds about 50 thousand bricks, and after the packages are stacked, the 3-foot-thick walls of fire brick are closed off by hand. The kilns are slowly heated from 90°F to 450°F to allow water to escape, then gradually raised to 1,950°F for firing, and then slowly cooled. The bricks are removed by lift truck to the strapping station, where they are strapped in bundles and then removed to the warehouse on the north side. The Atchison, Topeka & Santa Fe Railway Co. has a spur line the length of the warehouse, and the final bundles are shipped out by rail as well as by truck.

The latest and most-used kiln is the Harrop continuous kiln. The westward-moving belt carries the bricks to small cars on rails, where 2,000 bricks are loaded on each car. The cars are then moved slowly through several long drying ovens, where the temperature is gradually raised from 90°F to

450°F. Then the cars are removed to the kiln at the west end of the plant, where the temperature is raised to 750°F at the south end, gradually raised to 1,950°F in the middle, and lowered to about 90°F at the north end after firing. About 26 working cars with a total of 52,000 bricks pass through the kiln in 24 hours.

It is well known that the Cloud Chief Formation in Oklahoma contains montmorillonite and that this clay mineral absorbs much water. This causes an abnormally slow drying process. Upon firing, the Cloud Chief has a high porosity or absorption of 14 to 16 percent at 1,950°F. In order to reduce the drying time and the absorption to 12 percent or less, other clay shales containing kaolinite, illite, and chlorite are added for bulk. The exact proportions of each clay to be mixed with the Cloud Chief cannot be revealed. Quartz, dolomite, and calcite are also present in the Cloud Chief Formation, along with some sulfate in the form of gypsum. If these minerals are present in high quantities, they can cause porosity troubles, but fortunately they are present in small enough quantities to be negligible. About 5-percent iron is present, which may be responsible for the color in the brick. Manganese is added to produce gray brick. Sodium, potassium, and titanium are present in small quantities, being related to the fluxing action during firing.

The best brick is produced at 1,950°F, with the color light pink. At 2,000°F it is light buff, at 2,050°F dark buff, and at 2,100°F brown. The plant stores other types of bricks and tile for local consumption, but these are imported from other plants.

Gypsum

The Cloud Chief gypsum is of economic importance. It occurs in the Weatherford area, having been studied by Ham and Curtis (1958) and Ham (1961). The area is principally in T. 12 N., R. 15 W., with a maximum reported thickness of 118 feet in the SW¼ sec. 15 and the NW¼ sec. 22, T. 12 N., R. 15 W.; the basal 41 feet is anhydrite. The mineral probertite ($NaCaB_5O_9 \cdot 5H_2O$) was reported from seven cores along a north-trending area in the central part of T. 12 N., R. 15 W. It generally occurs in the basal 10 feet of the gypsum as white compact nodules. The average weighted composition of the rock gypsum was found to be 91.28 percent gypsum ($CaSO_4 \cdot 2H_2O$), 1.38 percent anhydrite ($CaSO_4$), 5.34 percent calcium and magnesium carbonate, and 1.55 percent silica. The overburden is almost nil. The estimated gypsum reserves are calculated to be 1.3 billion short tons, and the anhydrite reserves, 523 million short tons. The gypsum is slightly pink to orange, contains some iron, and ranges from fine-grained alabaster to coarsely selenitic gypsum. The Southwestern Gypsum Co. opened a small plant in August 1961 in the SW¼ sec. 31, T. 13 N., R. 14 W. (fig. 23), producing a 200-mesh product for use in horticulture. The gypsum is a medium- to fine-grained alabaster, about 44 feet thick, and is composed of about 95.92 percent pure gypsum, 0.77 percent anhydrite, 1.43 percent $CaCO_3$, 1.02 percent $MgCO_3$, 1.11 percent SiO_2, and less than 0.1 percent iron oxide (Fe_2O_3). Only the upper 10 feet was worked, and the estimated reserves in the area are about 3 million tons. The company operated for a short while and closed because of poor management. This gypsum is suitable for making wallboard, plaster, retarder for portland cement, horticultural products, and art products for sculpturing.

Volcanic Ash

The volcanic-ash deposits of Custer County are made up mostly of glassy shards ranging from 0.01 to 0.25 mm in size and constituting 59 to 97 percent of the ash, the remainder being clay, silt, quartz, orthoclase, biotite, diatoms, and fossils snails and bones. The general geology, petrography, and chemistry were given by Buttram (1914) and Ham (1949). The deposits are the Pearlette ash of Pleistocene (late Kansan) age, believed to have been deposited in low areas or lakes along ancient rivers. The source of the ash may have been volcanoes in the Valle Grande region of the Jemez Mountains, about 30 miles west of Santa Fe, in Sandoval County, New Mexico, according to Swineford (1949, p. 308). Recent studies (Powers and Wilcox, 1964; Wilcox, 1965; Izett and others, 1970; Wilcox and others, 1970; Naeser and others, 1973; Wilcox and Izett,

1973) indicate that the Pearlette ash deposits range in age from 0.6 to 2 million years and that the ash may have originated, in addition to the Valle Grande region, in the Yellowstone National Park region and in the Crater Lake region of Oregon. The westerly winds carried the dust as far as Iowa, South Dakota, and north Texas.

In Custer County, the ash occurs in three areas along the ancient Deer Creek and Washita River systems: (1) the Custer City area in secs. 12, 13, 14, 15, and 21, T. 14 N., R. 16 W.; (2) the Independence area in secs. 21, 27, 28, and 34, T. 15 N., R. 16 W.; and (3) the Indianapolis area in sec. 31, T. 13 N., R. 15 W., and sec. 1, T. 12 N., R. 16 W. Approximately 230,000 cubic yards of reserves are present, about 80,000 of which are in the Indianapolis area and contain much gypsite and clay (table 1).

A small pit was opened and operated by the Finnell System from 1916 to 1959 in the SW¼NE¼ sec. 15, T. 14 N., R. 16 W., just north of Custer City (fig. 45). About 20 boxcar loads were removed by truck to Custer City, where the material was shipped by railway. Mr. E. L. Henderson (deceased) directed local operations for many years, and now Mr. Marvin Janzen, owner of the leased property, maintains the equipment. The Finnel System merged with the Kent Co. of Rome, New York, into Keltec, Inc., 500 East Street, Elkhart, Indiana. Subsequently the chemical operations were sold to the Alberto-Culver Co. of Chicago, Melrose Park, Illinois. Keltec still owns the pit but dropped interest because of high silicate content. The ash was being used as an ingredient in a cleanser for the floor-cleaning operation of the Finnell System.

Another company, Fran-O-Lite Minerals, Inc., of Oklahoma City, began operation in November 1965 on the Nellie Everitt place in the SW¼SW¼ sec. 27, T. 15 N., R. 16 W. The ash was hauled to a small plant on a railroad spur in Custer City, where it was crushed and sieved into 25- and 50-pound bags and sold for many uses, such as insulation, crop dusting, water softening, oil absorption, in rubber products, fire-clay applications, manufactured stone, oil-well-drilling muds, fire-proofing and water-proofing materials, in the paint industry, scouring soaps, polishing materials, soil conditioning, swimming-pool filters, and absorption of grease and wastes. The operation was suspended a few years later.

Dolomite

Dolomite ($CaMg(CO_3)$) occurs mostly in the southeastern part of the County and in a few prominent knobs in the northeastern part, being of minor economic importance. At many places the magnesium content is low, and the rock is an impure limestone (table 2). The estimated reserves are about 1.4 million cubic yards, being concentrated mostly in four areas (fig. 50). These reserves are spread over three rock units, the Weatherford Bed of the Rush Springs Formation and the Moccasin Creek and Day Creek Beds of the Cloud Chief Formation. The dolomite occurs in 13 different areas, each bed ranging from 1–3 feet to 12 feet in thickness. The rock has been used for building stone, crushed stone for baffles to prevent soil erosion, and dam- and bridge-construction work. In the 1930's the Civilian Conservation Corps (CCC) and the Work Projects Administration (WPA) opened quarries in sec. 5, T. 12 N., R. 15 W., the NW¼ sec. 10, T. 12 N., R. 16 W., the NE¼ sec. 34, T. 13 N., R. 16 W., and the SW¼ sec. 35, T. 14 N., R. 15 W. Other quarries were in the NW¼ sec. 22, T. 12 N., R. 16 W., the NW¼ sec. 26, T. 13 N., R. 16 W., and the NE¼ sec. 7, T. 14 N., R. 14 W.

Sandstone

Sandstone was quarried at two places. In the 1930's a quarry in the upper Cloud Chief was opened in the NW¼ sec. 16, T. 12 N., R. 16 W., just south of the old country club, and the stone was used for the clubhouse, local houses, the Clinton High School stadium, and CCC baffles. Another quarry in the lower Rush Springs, in the NE¼ sec. 8, T. 15 N., R. 14 W., was opened by the Atchison, Topeka & Santa Fe Railway Co., and the rock was used for ballast and baffles along the tracks. The sandstone is cemented by calcite, gypsum, and other minerals and is well indurated, resembling an impure dolomite at many places.

Sand and Gravel

Extensive sand and gravel deposits cover much of Custer County north of the

TABLE 1.—ESTIMATED RESERVES AND CHEMICAL ANALYSES OF VOLCANIC ASH IN CUSTER COUNTY

Area	Thickness (feet)	Overburden (feet)	Reserves (cu yds)	Analyses													X-ray no.	Lab sample no.
				SiO_2	Al_2O_3	Fe_2O_3	Na_2O	MgO	K_2O	CaO	TiO_2	P_2O_5	S	Cl	MmO	LOI		
T. 12 N., R. 16 W.																		
NW¼NE¼ sec. 1	4	0.5	80,000	33.26	4.58	0.67	0.22	1.00	0.79	27.66	0.18	0.16	15.40	0.01	0.02	8.94	L-1284	10,815
T. 13 N., R. 15 W.																		
SW¼SW¼ sec. 31	4	0-5	3,500	27.50	3.26	0.00	0.00	0.33	0.26	28.76	0.09	0.11	18.50	0.01	0.00	10.18	L-1285	10,816
T. 14 N., R. 16 W.																		
SE¼SE¼ sec. 12	1	0-2	trace															
NW¼SW¼ sec. 13	1	0-5	trace															
NE¼ sec. 14	3-15	0-5	15,000															
NW¼SW¼ sec. 14	2	0-5	3,000															
SE¼NE¼ sec. 15	11	8-10	30,000	70.12	--15.80--		4.42	0.23	3.20	0.53						6.43	(old analysis)	
NE¼SW¼ sec. 15	1	0-5	trace															
NE¼NE¼ sec. 21	1	0-5	trace															
T. 15 N., R. 16 W.																		
C NE¼ sec. 21	1	0-1	trace															
SW¼SW¼ sec. 27	3-8	0-5	100,000	71.86	12.62	3.53	2.48	0.18	5.14	0.91	0.17	0.03	0.12	0.13	0.06	3.53	L-1283	10,814
C NE¼ sec. 28	1-2	0-10	trace															
NE¼NW¼ sec. 34	4	0-5	2,000															

Table 2.—Reserves and Analyses of Dolomites in Custer County

Area	Unit	Thickness (feet)	Overburden (feet)	Estimated reserves (cubic yards)	Analyses					
					SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	H_2O
T. 12 N., R. 14 W.										
SW¼ sec. 36	Weatherford	3	0-2	21,000						
S½ of Tp.	Weatherford	1	0-20	200,000	8.60	0.54	0.36	86.39	--	4.06
T. 12 N., R. 15 W.										
sec. 5	Moccasin Creek	12	0-20	200,000	2.20	1.86	0.14	94.96	--	1.00
T. 12 N., R. 16 W.										
secs. 9, 10, 16, 17	Day Creek	10	0-10	600,000						
NW¼NW¼ sec. 22	Moccasin Creek	8	0-5	35,000						
T. 13 N., R. 15 W.										
sec. 8	Moccasin Creek	2	0-10	700	2.80	0.09	0.60	85.66	11.29	--
SW¼ sec. 33	Moccasin Creek	8	0-20	700						
T. 13 N., R. 16 W.										
NW¼ sec. 26	Moccasin Creek	3	0-10	2,000						
secs. 27, 28, 33, 34	Weatherford	3	0-10	250,000						
NE¼ sec. 34	Moccasin Creek	3	0-2	3,000						
T. 14 N., R. 14 W.										
NE¼ sec. 7	Day Creek Moccasin Creek Weatherford	3 (avg.)	0-40	5,000						
T. 14 N., R. 15 W.										
SW¼ sec. 35	Moccasin Creek	10	0-5	50,000						
T. 15 N., R. 15 W.										
NE¼ sec. 24	Moccasin Creek Weatherford	1.5 (avg.)	0-20	30,000						

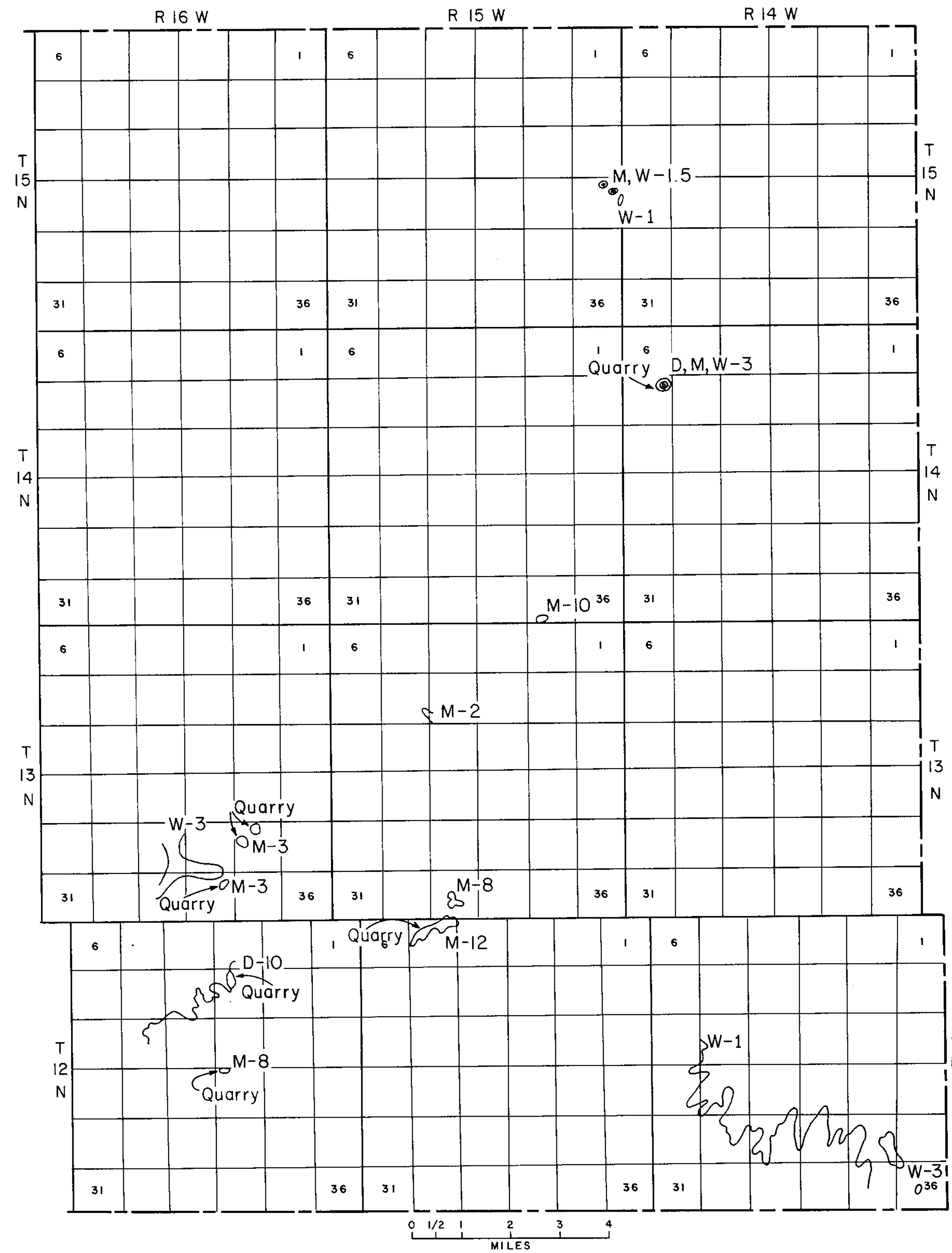


Figure 50. Distribution of prominent dolomites in Custer County. *D,* Day Creek Bed of Cloud Chief Formation; *M,* Moccasin Creek Bed of Cloud Chief Formation; *W,* Weatherford Bed of Rush Springs Formation.

Washita River, and many small pits have been opened. Some tests were run by the Oklahoma Geological Survey, and the results are shown in table 3. The material has been used for road metal and concrete and as ballast for railroad tracks. In some areas, such as T. 12 N., R. 15 W., and T. 12 N., R. 20 W., sand and gravel are almost absent except along stream channels and perhaps in isolated pockets. In other areas, such as T. 13 N., R. 18 W., T. 14 N., Rs. 17 and 19 W., and T. 15 N., Rs. 18 and 19 W., the deposits have not been worked. The terrace deposits are up to 30 feet thick or more, and some areas smaller than 10 acres contain many thousands of cubic yards. Some local drift sand is present in the eastern part of the County along Deer Creek and the surrounding area.

Salt

Salt (NaCl) occurs in two formations in the subsurface of Custer County. The upper salt is termed the Flowerpot, with a thickness of 625 feet having been reported in the Gulf 1 Burgtorf well in sec. 6, T. 13 N., R. 15 W.; the top of the salt is 950 feet below the surface, according to Jordan and Vosburg (1963, p. 62, pl. 3C). The salt is apparently local, judging from wells 4 to 10 miles southwest, west, and north of the area, where the salt is either absent or occurs as perhaps 60 feet or more of mixed shale and brine. If a total thickness of 600 feet of pure rock salt is present in sec. 6, and 1.88 million tons per square mile-foot of salt is estimated, with the salt considered to weigh 135 pounds per cubic foot, the estimated reserves in this area would be about 1.128 billion short tons. If about 80 percent of the section is pure salt, and the other 20 percent is shale, and the section remains about the same for 1 square mile in all directions around sec. 6, the estimated reserves for a salt section 500 feet thick would be about 8.5 billion tons. Jordan and Vosburg (1963, p. 40, fig. 12) showed 175 feet of pure rock salt directly below the anhydrites of the Blaine Formation, with the remaining 450 feet being salt and shale. Based on this figure, and using the 9-square-mile area around sec. 6, a more realistic estimate of obtainable rock salt would be 2.9 billion tons. Of this amount, if mining is considered, only certain selected beds perhaps 8 to 10 feet thick could be used, and about one-half of this amount would be left as pillars. Thus, if one pure bed of salt 8 feet thick could be mined over 9 square miles, the estimated recoverable reserves would be about 67 million short tons.

The second salt zone is the lower Cimarron or Garber salt (Lower Permian), about 150 feet thick, the top of which occurs at a minimum of 1,600 to 1,700 feet below the surface. It is present in Tps. 12–15 N., Rs. 19–20 W., and Tps. 14–15 N., Rs. 14–15 W. The estimated reserves are about 90 billion tons, with no consideration given to possible shale or anhydrite contamination. This bed will have to be studied further before reliable estimates can be made on reserves.

Uranium and Vanadium

The uranium and vanadium minerals carnotite ($K(UO_2)_2(VO_4)_2 \cdot 3H_2O$) and tyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot 5\text{–}8H_2O$) occur in the upper Cloud Chief pink shales and in the lower Doxey siltstone. The shales are 0.5 to 1 foot thick and contain much montmorillonite. The siltstone is greenish gray to maroon and calcitic to gypsiferous, ranging up to 5 feet or more in thickness. The uranium content varies from 0 to 0.006 percent, and the vanadium content, from 0.002 to 0.044 percent; the highest concentrations are reported from the lower Doxey north of Foss, Washita County (table 4; fig. 51). The radiometric map (fig. 51) was constructed from geiger-counter readings of counts per minute beyond background, taken at intervals along the Doxey–Cloud Chief contact. The analyses were completed by William H. Bellis of the Oklahoma Geological Survey, using X-ray fluorescence and artificial standards. The Foss occurrences were first noted in 1955 on the Thorpe farm, east of the road and south of the creek, in the SW¼NW¼NW¼ sec. 29, T. 12 N., R. 18 W., by members of the Red Rock Uranium Co. of Foss. The company consisted of Oscar ("Pod") Gunter of Hammon (president); his son, Edward K. ("Happy") Gunter of Elk City; H. T. ("Red") Johnson of Hobart; Harold Irwin and H. A. Fritzmeyer of Hammon; W. C. ("Wimpey") Lister of Oklahoma City; Ed Berrong, Art Schotts, and a Mr. Roof of Weatherford; and Rex Hoover of Foss.

TABLE 3.—MECHANICAL ANALYSES OF SAND AND GRAVEL DEPOSITS IN CUSTER COUNTY

Location	Approximate screen analysis (percent retained on) inches			mesh				Wash loss	Remarks
	1	½	¼	20	50	100	200±		
T. 12 N., R. 16 W.	11.1	13.3	9.4	47.2	7.5	1.9	1.9	8.5	2-5 ft thick; 2-5-ft overburden;
NW NW sec. 6	13.2	27.2	10.3	16.2	11.0	5.2	2.2	14.7	est. reserves, 10,000 cu yds
C SW sec. 7		0.2	0.3	1.6	48.7	19.3	1.9	15.9	20-30 ft thick; 4-6-ft overburden; est. reserves, 4,500 cu yds
SW SW sec. 8				4.0	58.0	22.0	10.0	6.0	0-2 ft thick; est. reserves
				8.0	70.0	10.0	4.0	8.0	1,000 cu yds
NW NW sec. 18	1.9	13.2	10.5	45.5	9.7	1.9	0.6	16.5	1-9 ft thick; 1-5-ft overburden;
		2.6	2.6	41.7	25.0	1.9	1.3	25.0	est. reserves, 800 cu yds
SE NW sec. 33			0.8	4.9	61.5	9.0	1.6	22.1	4-6 ft thick; 2-ft overburden;
T. 12 N., R. 17 W.									
E½ NE sec. 5		3.0	5.0	27.0	15.0	4.0	1.0	45.0	2 ft thick; est. reserves, 150 cu yds
	15.0	4.0	6.0	26.0	32.0	4.0	1.0	12.0	
T. 12 N., R. 18 W.									
NE NE sec. 2	7.0	6.0	7.0	23.0	22.0	5.0	5.0	25.0	3-4 ft thick; 1-2-ft overburden;
	4.0	6.0	5.0	34.0	28.0	5.0	1.0	17.0	est. reserves, 1,100 cu yds
T. 13 N., R. 14 W.									
SE SE sec. 5	3.0	3.0	6.0	37.0	36.0	3.0	6.0	6.0	3-9 ft thick; 4-9-ft overburden; est. reserves, 300 cu yds
SE SW sec. 6	6.0	14.0	21.0	40.0	10.0	2.0	3.0	4.0	1-8 ft thick; 2-5-ft overburden;
		3.0	3.0	19.0	58.0	6.0	4.0	7.0	est. reserves, 1,000 cu yds
NW NW sec. 8	7.0	9.0	8.0	23.0	38.0	5.0	2.0	8.0	2-5 ft thick; 1-6-ft overburden;
	7.0	16.0	18.0	35.0	13.0	2.0	1.0	8.0	est. reserves, 300 cu yds
NE NW sec. 16	12.0	16.0	16.0	27.0	9.0	5.0	4.0	11.0	1-3 ft thick; est. reserves,
		2.0	4.0	42.0	42.0	4.0	3.0	3.0	1,000 cu yds
NW NE sec. 35	22.0	9.0	8.0	13.0	23.0	6.0	5.0	14.0	3-5 ft thick; 3-ft overburden;
	5.0	4.0	3.0	10.0	39.0	21.0	5.0	13.0	est. reserves, 1,200 cu yds

TABLE 3.—MECHANICAL ANALYSES OF SAND AND GRAVEL DEPOSITS IN CUSTER COUNTY—*Continued*

Location	Approximate screen analysis (percent retained on) inches 1	½	¼	mesh 20	50	100	200±	Wash loss	Remarks
T. 13 N., R. 15 W.									
NE NE sec. 14	8.0	14.0	18.0	60.0				9.0	4-6 ft thick; 1-2-ft overburden; est. reserves, 125 cu yds
T. 13 N., R. 16 W.									
SW NW sec. 31	9.0	25.0	25.0	27.0	5.0	1.0	1.0	2.0	3-12 ft thick; 1-5-ft overburden; est. reserves, 500 cu yds
T. 13 N., R. 17 W.									
SE SW sec. 19		9.0	21.0	50.0	8.0	2.0	2.0	8.0	est. reserves, 2,00 cu yds
NE SW sec. 30	8.0	11.0	10.0	25.0	16.0	5.0	3.0	22.0	2-5 ft thick; 1-3-ft overburden;
				34.0	56.0	5.0		5.0	est. reserves, 2,250 cu yds
NW SW sec. 30	4.0	13.0	22.0	45.0	11.0	2.0	1.0	2.0	3-8 ft thick; 2-ft overburden;
		2.0	5.0	32.0	49.0	7.0	2.0	3.0	est. reserves, 3,580 cu yds
SE SW sec. 30	48.0	26.0	13.0	6.0	1.0	2.0	1.0	3.0	2-5 ft thick; 1-ft overburden;
	5.0	7.0	12.0	26.0	23.0	3.0	3.0	21.0	est. reserves, 31,880 cu yds
T. 14, R. 14 W.									
NW SE sec. 19	2.0	3.0	9.0	54.0	18.0	4.0	3.0	7.0	3-5 ft thick; 0-4-ft overburden;
	8.0	13.0	19.0	23.0	16.0	6.0	1.0	14.0	est. reserves, 400 cu yds
SW NW sec. 31	3.0	4.0	8.0	35.0	34.0	9.0	4.0	3.0	3-5 ft thick; 1-6-ft overburden; est. reserves, 700 cu yds
T. 14 N., R. 15 W.									
NW SW sec. 6		2.0	1.0	33.0	49.0	5.0	5.0	5.0	2-13 ft thick; 2-6-ft overburden;
	8.0	14.0	16.0	32.0	12.0	7.0	2.0	9.0	est. reserves, 5,000 cu yds
SW SE sec. 8	5.0	10.0	14.0	31.0	26.0	3.0	3.0	8.0	1-6 ft thick; 1-3-ft overburden;
	1.0	2.0	5.0	51.0	26.0	4.0	6.0	5.0	est. reserves, 30 cu yds

SW NW sec. 12	2.0	3.0	7.0	41.0	31.0	4.0	3.0	9.0	2-16 ft thick; 0-6-ft overburden;
	4.0	6.0	17.0	19.0	30.0	9.0	8.0	7.0	est. reserves, 15,000 cu yds
SW NE sec. 17	15.0	13.0	21.0	17.0	7.0	3.0	4.0	20.0	2-13 ft thick; 0-4-ft overburden;
	1.0	9.0	23.0	43.0	7.0	8.0	4.0	5.0	est. reserves, 20,000 cu yds
T. 14 N., R. 16 W.									
E½ NE sec. 1	2.0	8.0	9.0	32.0	30.0	4.0	4.0	11.0	2-12 ft thick; 2-6-ft overburden;
		3.0	4.0	37.0	40.0	4.0	4.0	8.0	est. reserves, 8,000 cu yds
SE NE NW sec. 14	1.6	4.8	4.1	52.2	12.1	1.5	1.5	22.6	4-8 ft thick; 0-3-ft overburden;
									est. reserves, 350 cu yds
NE NE NW sec. 4	3.1	3.7	8.8	46.7	20.0	5.0	0.6	11.8	6-8 ft thick; 1-3-ft overburden;
		3.2	3.9	41.6	24.7	5.2	1.3	20.1	est. reserves, 1,550 cu yds
NE SW sec. 13	6.0	11.0	16.0	34.0	18.0	2.0	2.0	11.0	3-8 ft thick; 1-3-ft overburden;
	22.0	22.0	15.0	14.0	6.0	1.0	1.0	19.0	est. reserves, 1,500 cu yds
SE NE sec. 14	1.0	6.0	10.0	27.0	29.0	3.0	3.0	19.0	3-6 ft thick; 1-3-ft overburden;
	2.0	10.0	17.0	22.0	18.0	2.0	2.0	27.0	est. reserves, 1,200 cu yds
T. 15 N., R. 16 W.									
SE SW sec. 33	8.5	14.1	11.9	40.7	8.5	1.7	0.0	29.7	1-7 ft thick; 0-3-ft overburden;
	1.5	2.2	2.9	33.1	25.0	7.4	2.2	25.7	est. reserves, 225 cu yds

TABLE 4.—URANIUM AND VANADIUM ANALYSES IN CUSTER COUNTY

Unit	Location	Sample no. (see fig. 51)	Analyses %U	Analyses %V	X-ray lab no.	Lab sample no.	Field cpm[1] beyond background
Upper Cloud Chief (pink shale)	T. 12 N., R. 17 W. SE¼SE¼SE¼ sec. 34	1	none	0.03	L-1002	10,822	16
Upper Cloud Chief (pink shale)	T. 12 N., R. 17 W. SE¼SE¼SE¼ sec. 34	2	0.002	0.002	L-1004	10,824	24
Upper Cloud Chief (pink shale 25 ft below top)	T. 13 N., R. 20 W. SE¼NE¼ sec. 22	3	none	0.006	L-1005	10,825	23
Basal Doxey	T. 12 N., R. 18 W. NW¼SE¼ sec. 20	4	none	0.02	L-1009	10,811	70
Basal Doxey	T. 12 N., R. 18 W. NE¼NW¼ sec. 29	5	none	0.044	L-1008	10,810	56
Basal Doxey	T. 12 N., R. 18 W. SE¼NE¼NE¼ sec. 30	6	none	0.01	L-1003	10,823	90
Basal Doxey	T. 12 N., R. 19 W. SE¼SE¼SE¼ sec. 8	7	none	0.01	L-1010	10,812	68
Basal Doxey	T. 12 N., R. 19 W. C S½NW¼ sec. 24	8	0.006	0.016	L-1006	10,826	110
Basal Doxey (waste pile)	T. 12 N., R. 19 W. C S½NW¼ sec. 24	9	0.004	0.01	L-1007	10,809	110
Basal Doxey	T. 12 N., R. 19 W. NW¼NE¼NE¼ sec. 27	10	none	0.016	L-1011	10,813	80

[1]Counts per minute.

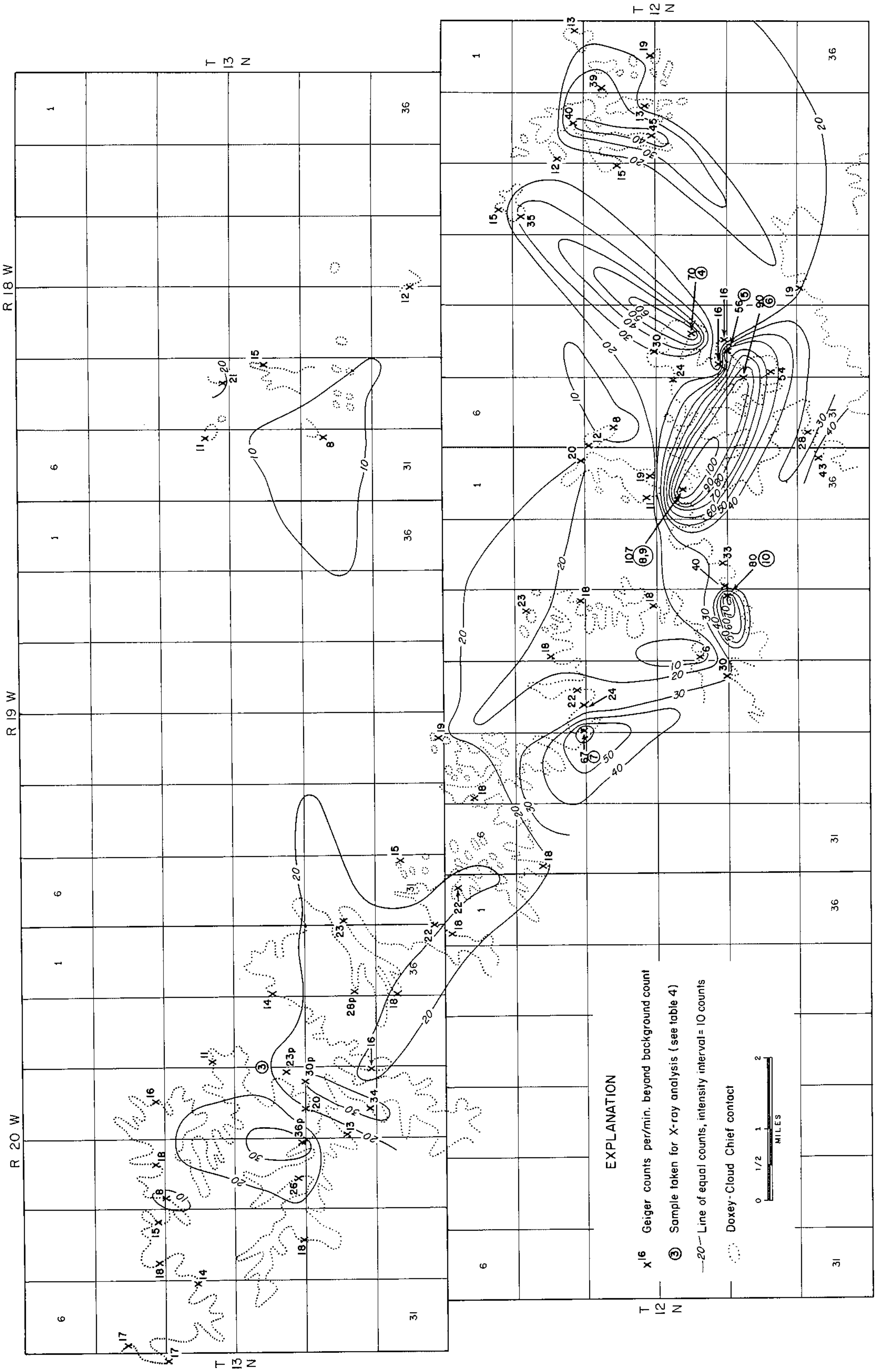


Figure 51. Radiometric map of basal Doxey Shale in Custer County. Numbers refer to counts beyond background of geiger counter.

The group looked over much of the area north of Foss, leased some land, and in May 1956 excavated about 13 tons of lower Doxey siltstone on the Ernest E. ("Bill") Dippel farm near the C S½NW¼ sec. 24, T. 12 N., R. 19 W. They shipped the rock to Grants, New Mexico, where it was ascertained to be noncommercial. This put an end to the operation. The deposits were mentioned previously by Curtis (1956, p. 110) and Finch (1967, p. 20). According to Finch, the uranium and vanadium were probably derived by erosion of preexisting rocks in an uplifted area and transported to a shallow sea where marine and nonmarine beds interfingered. The drainage must have been poor, and the tectonics minor; the metals are thought to have been dissolved by connate solutions high in alkaline bicarbonate while the sediments were being consolidated. With diagenesis or formation of the rock, the liquids were squeezed out to more permeable parts laterally, and where oxidation took place the uranium was dissolved and where reduction took place the uranium was deposited from solution. Reduction could have been caused by carbon (plants), H_2S from anaerobic bacteria acting on organic matter, or by iron sulfide in the rock. This is termed a penesyngenetic and lateral-secretion hypothesis.

PART III.—GROUND WATER IN CUSTER COUNTY

D. L. HART, JR.[1]

INTRODUCTION

The information included in this chapter is a brief summary of the ground-water data that have been compiled by the U.S. Geological Survey during its routine collection of basic water data. There have been no formal studies of ground water in Custer County. Because of the lack of published water data, this generalized summary may be useful to the water users in the County.

Custer County is, however, included in a recently published regional reconnaissance study of the water resources of the Clinton 1° by 2° quadrangle (Carr and Bergman, 1976). This study was issued as Hydrologic Atlas 5 by the Oklahoma Geological Survey in cooperation with the U.S. Geological Survey and covers, in four sheets, the region's geology, ground-water availability, ground-water quality, and surface-water data.

SOURCE, OCCURRENCE AND MOVEMENT

Most of the ground water in Custer County is derived from precipitation falling directly on the area. Mean annual precipitation is about 25 inches; hence approximately 1,300 acre-feet of water falls on each square mile each year. Of this amount, part is evaporated directly from the land surface, part is surface runoff to the Washita and Canadian Rivers, and part seeps into the soil. Some of the water that seeps into the soil is retained near the surface and is evaporated, some is used by vegetation and returned to the atmosphere by transpiration, and some moves slowly downward to become ground water.

Ground water in Custer County accumulates in several water-bearing formations or aquifers. The major aquifers are alluvium along the Washita River, consisting of sand and gravel, and sandstone of the Rush Springs Formation. Pore spaces between the gravel or sand particles that form the skeletons of these aquifers are the containers in which ground water is stored and through which it moves. Below a certain level—the water table—all pores are saturated with water. Once the downward-seeping precipitation has reached the saturated zone it moves slowly through the spaces from areas where the table is high in the uplands to areas where it is low along streams. The rate of movement depends upon the slope of the water table and the permeability of the aquifer. The volume of ground water moving through the aquifer depends upon the rate and cross-sectional area through which the water moves.

Where an aquifer is overlain by a fine-grained, less permeable rock, such as shale, the water is artesian; that is, it is confined and under pressure. Consequently, water in wells drilled into an artesian aquifer will rise above the top of the aquifer. In Custer County, artesian conditions are likely to exist in those localities where the Rush Springs aquifer is overlain by the Cloud Chief Formation. In alluvium the water is not confined but occurs under water-table conditions, thus allowing the water surface to fluctuate freely.

STORAGE

Water levels rise and fall in response to variations in recharge to and discharge from the aquifer. During wet periods, recharge to the aquifer exceeds the natural discharge, and the water level normally is relatively high. During dry periods, natural discharge from the aquifer exceeds the re-

[1] Hydrologist, U.S. Geological Survey, Albuquerque, New Mexico. Publication authorized by the director, U.S. Geological Survey.

charge, and the water table normally is lowered. Pumping from wells retards the rise in water levels during wet periods and accelerates the decline during dry periods.

Because precipitation is the only significant source of recharge in Custer County, changes in the amount of precipitation over a period of time are reflected in a generally rising or declining water-level trend, as shown in figure 52. From 1951 through 1954 when precipitation was below average, the water level declined; from 1954 through 1958 during alternate periods of above- and below-average precipitation, the water level remained more or less stable; and from 1960 through 1961 when precipitation was above average, water levels rose. The effect of precipitation on the water table is not immediate, however. Above-average rainfall during 1959 did not cause a major change in water level until the following year, owing to the time required for moisture to infiltrate the soil and percolate downward into the saturated zone. The time may range from hours to a few days in areas where rocks are very permeable and the water table is near the surface, as in the alluvium along the Washita River, or it may take months where the rocks are tight and water levels are deep.

Smaller peaks and lows shown by the well hydrograph also reflect the effects of both recharge and discharge and primarily show the effects of pumping. Yearly lows usually occur during the late summer and fall after heavy summer irrigation.

AVAILABILITY

The El Reno Group of Permian age includes the Duncan Sandstone, the Flowerpot Shale, the Blaine Formation, and the Dog Creek Shale. Although the Duncan and the Blaine supply water to some wells in adjacent counties, they probably will yield only highly mineralized water in Custer County. The hydrologic significance of the group, primarily the Dog Creek Shale, is its ability to impede the downward movement of fresh water, thus preventing displacement of the highly mineralized water.

The Whitehorse Group of Permian age consists of strata above the El Reno Group and below the Cloud Chief Formation and

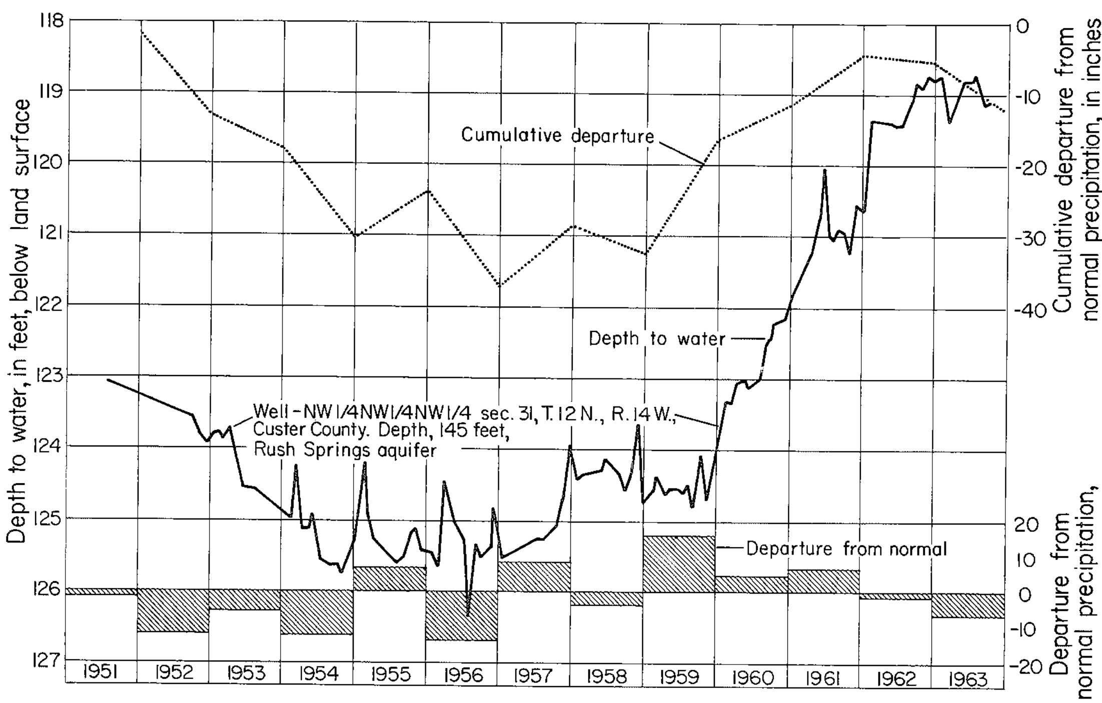


Figure 52. Hydrograph and precipitation data near Weatherford, Custer County.

includes the Marlow and Rush Springs Formations. Sandstones in these formations are the main source of ground water in the County.

In the eastern part of Custer County the Marlow is lithologically similar to the overlying Rush Springs and probably has similar hydrologic characteristics. The quantity of water available to wells from the Marlow is not known because wells drilled into the Marlow first penetrate the overlying Rush Springs and thus receive water from both formations. The only exception is in the extreme northeastern corner of the County adjacent to the Canadian River, where the Rush Springs has been removed by erosion. Although the Marlow Formation is relatively uniform in lithology and thickness throughout the County and may yield adequate quantities of water, the quality of the water deteriorates westward, owing primarily to the solution of gypsum by waters percolating downward through the overlying rocks.

The outcrop area of the Marlow Formation is small compared with the outcrop area of the overlying Rush Springs Formation, and the Marlow therefore receives most of its recharge by downward percolation of water from the Rush Springs. Because most of the recharge comes from the Rush Springs, and because the Rush Springs and the Marlow are hydrologically connected, water pumped from the Marlow causes water-level changes in the Rush Springs.

The upper formation of the Whitehorse Group, the Rush Springs, provides water to wells throughout most of the County except where it has been removed by erosion in a narrow area adjacent to the Canadian River.

The quantity of water available to irrigation wells 250 to 400 feet deep in the eastern part of the County reportedly ranges from 200 to 700 gpm (gallons per minute). Some of the wells in this area, however, receive water from both the Rush Springs and Marlow Formations.

In the western half of Custer County, yields from the Rush Springs may be less than 50 gpm. The smaller yields are due to a reduced saturated thickness caused by thinning of sandstones in the Rush Springs. The depth to water in the Rush Springs is generally less than 100 feet except in T. 12 N., Rs. 14 and 15 W., where the depth is as much as 200 feet.

Recharge to the Rush Springs Formation is by precipitation on the outcrop and by downward percolation of water from overlying rocks. Discharge may occur through pumpage, transpiration, evaporation, seepage into streams, and by water moving downward into the Marlow Formation.

Water in the Rush Springs is generally of suitable quality for municipal use and irrigation in the eastern part of the County but may require treatment for some industrial purposes. In the western part of the County the water is of poorer quality owing to the percolation of water through soluble gypsum in the overlying Cloud Chief Formation and in the Rush Springs, which causes higher concentrations of calcium sulfate. Use of water from the Rush Springs in the southwestern corner of the County is limited, because the water is highly mineralized.

The Foss Group of Permian age consists of the Cloud Chief Formation and the overlying Doxey Shale.

The Cloud Chief Formation overlies the Rush Springs Formation in the western two-thirds of the County, except where erosion by the Washita and Canadian Rivers and their tributaries has exposed the Rush Springs. The tight-grained rocks of the Cloud Chief do not yield more than a few gallons of water a day to wells. The water from the Cloud Chief reportedly is hard and has a high sulfate content.

The Doxey Shale occurs only in the southwestern part of the County and is not a significant aquifer. The Doxey is too fine grained to yield more than meager supplies of water to domestic wells.

The overlying Elk City Sandstone supplies up to 200 gpm to wells south of Custer County but is too thin to supply more than normal domestic needs within the County.

The Kiowa Formation of Early Cretaceous age occurs as small scattered outliers in the southwestern part of the County; the saturated zone, where present, is too thin to provide water to wells.

High terrace deposits of Pleistocene age in Custer County generally are too thin to supply large quantities of water to wells. However, where the saturated thickness is great enough, such as in Ts. 13 and 14 N.,

R. 14 W., they may be good local aquifers. More important than their function as an aquifer is their ability to absorb precipitation, allowing the water to percolate downward to the principal aquifers rather than letting it escape as runoff to streams and rivers. The quality of water in the terrace deposits should be good.

Alluvium and low terrace deposits of Holocene and Pleistocene age provide water to irrigation wells along the Washita River in Custer County. The thickness of the alluvial deposits ranges from a very thin veneer at their surface contact with the Permian rocks to a maximum thickness of 130 feet in localities where they fill depressions in the buried Permian surface. The maximum thickness of the alluvium at the western edge of the County is about 90 feet. The sediments thicken to about 130 feet between Foss Reservoir and Clinton but thin slightly to about 120 feet at the Washita County line. Nowhere along the Washita River's course is the alluvium known to be thicker or coarser than in Custer County. Yields of wells in the alluvium in Custer County may be large because of the high percentage of coarse-grained material. Yields of 1,000 gpm have been reported, although the average yield probably is between 200 and 400 gpm. Large differences in yields may occur within short distances in this aquifer, owing to the lenticular nature of alluvial deposits. The coarsest material generally is in the lower part of the alluvium (fig. 53).

The low terrace deposits and the alluvium probably form a single hydrologic unit with water passing freely from one to the other. These deposits derive their water from precipitation, seepage, and runoff from adjacent high terrace deposits and bedrock and from percolation of flood water from the Washita River. Replenishment during flooding may provide a large increase in stored ground water. Conversely, when the stream is at a low stage, ground water in

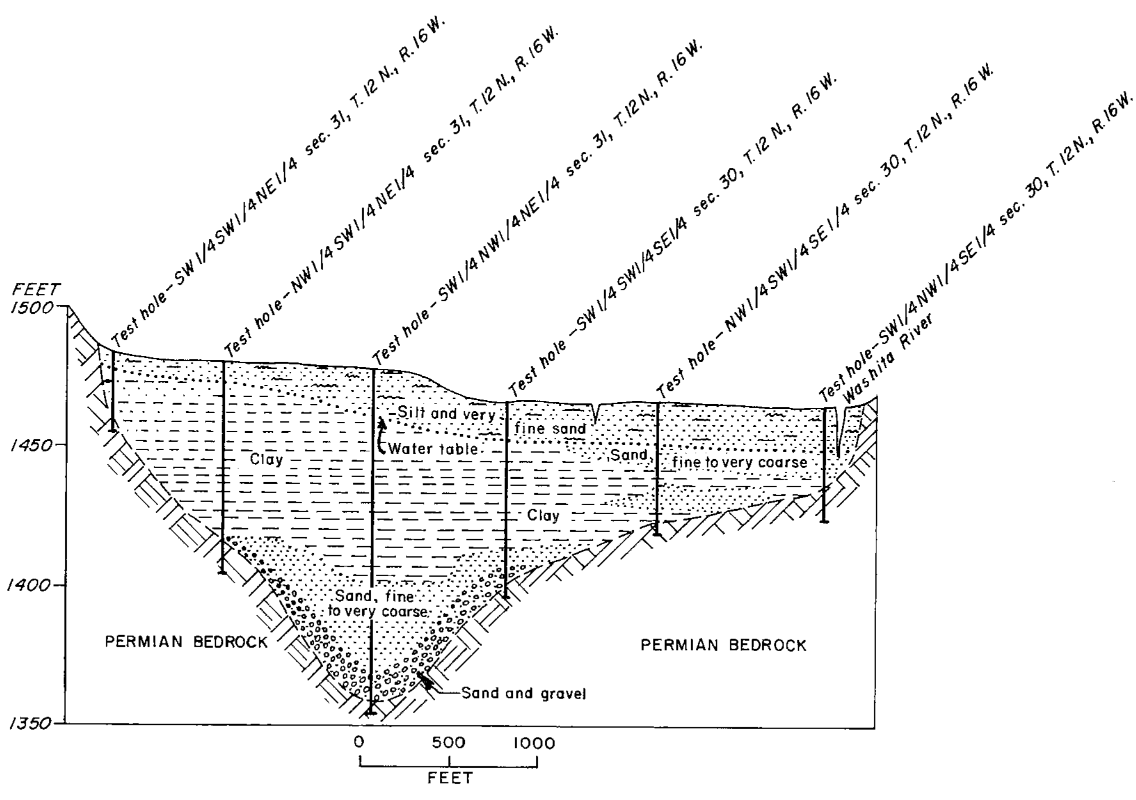


Figure 53. Geologic section across Washita River valley, secs. 30 and 31, T. 12 N., R. 16 W., Custer County.

the alluvium and low terrace deposits moves toward the stream and seeps into the channel to become surface flow. This seepage continues until the stream rises after a rain or until the water table declines to or below the bottom of the stream channel. Ground water also is continuously moving downstream through the alluvial deposits below the stream channel.

Yields from alluvium and low terrace deposits along the Canadian River and the tributaries of the Canadian and Washita Rivers probably are insufficient for more than domestic needs, owing to the abundance of silt and very fine-grained sand.

USE

Ground water is the principal source of supply for municipal, industrial, irrigation, and domestic use in Custer County. The cities of Clinton and Weatherford are the largest users of ground water for municipal supply. The development of large wells for irrigation has been primarily in the eastern third of the County and along the bottom lands of the Washita River. This pattern of development does not reflect greater need for irrigation water in the eastern part of the County but the greater availability of ground water in this area.

Municipal Use

Six communities in Custer County use wells to provide water for municipal needs. The wells are pumped by either turbines or submersible pumping units, using electricity for power.

Arapaho owns 4 wells, but only 2 are presently used to provide water for its 350 residents. The wells are 150 and 215 feet deep and supply approximately 40,000 to 75,000 gpd of water from the Rush Springs Formation.

Butler has 1 well reported to be 190 feet deep that supplies the 350 residents with water from the Rush Springs. The water is not metered, and the quantity pumped is not known. The water reportedly contains high concentrations of dissolved sulfate.

Clinton utilizes a city lake and a well field in adjacent Washita County that serve about 10,000 people. The 20 wells operated by the city range from 105 to 280 feet deep and tap the Elk City Sandstone. The wells are presently used from May through October to supplement the lake supply. During 1966, the total monthly pumpage ranged from 15.7 million gallons during May to 44.5 million gallons during July. In 1977, however, the wells were not used at all, as the lake was able to supply sufficient water to meet the city's needs. Yields of individual wells are from 35 to 200 gpm, and the well field is reported to be capable of supplying 1.5 million gallons per day.

Custer City supplies about 450 customers from 2 wells. Both wells are reported to be 286 feet deep and tap the Rush Springs Formation. The quantity of water pumped is not metered at the pumps.

Thomas has 6 wells that obtain water for approximately 1,200 residents from the Rush Springs. Three wells, 220 feet deep, are used on a regular basis, and 3 standby wells about 125 feet deep are used during periods of heavy consumption. The water is not metered at the wells, but the well field reportedly yields up to 250,000 gpd.

Weatherford obtains its water supply, which serves about 4,000 people, from 19 wells tapping the Rush Springs Formation. The wells range in depth from about 130 to 275 feet. The 14 shallow wells each yield about 35 gpm, whereas the 5 deeper wells yield up to 240 gpm. Pumpage during 1966 varied from a low in January of 14.95 million gallons to a high in July of 36.74 million gallons. In 1977, January pumpage was more than 40 million gallons, and the high, in August, was more than 71 million gallons.

Irrigation Use[2]

In 1975 there were 15,630 acres of land irrigated in Custer County. Of these 15,630 acres, 9,170 were irrigated by ground water from 70 wells. Because of the rolling terrain, virtually 100 percent of the irrigation systems are sprinklers.

The principal irrigated crops are: alfalfa, 4,700 acres; cotton, 1,500 acres; corn forage, 1,500 acres; sorghum forage, 4,700 acres; sorghum grain, 700 acres; peanuts, 700 acres; and wheat, 700 acres.

[2]Data obtained from Schwab (1975).

Rural Use

Most water for domestic and stock use in the County is obtained from small-diameter wells equipped with pumps operated by electricity, by windmill, or by hand. The yield of these wells generally is less than 5 gpm. Water-quality problems, mainly excessive concentrations of sulfate, occur throughout much of Custer County. The water affected is mainly from wells tapping the Cloud Chief Formation or the Rush Springs Formation where gypsum is present in or near the recharge areas.

POTENTIAL DEVELOPMENT

Aquifers in Custer County capable of supplying moderate to large quantities of water to wells are sandstones of the Marlow and Rush Springs Formations in the eastern part of the County and alluvium along the Washita River. Although records are not adequate for evaluation of the hydrology in detail, no areas of serious overdevelopment are known to exist. The area most likely to be affected by overdevelopment is east of Weatherford in the vicinity of that city's well field (T. 12 N., R. 14 W.). With the exception of this area, the Whitehorse aquifer should have the potential to supply water to a great many more wells in eastern Custer County.

Wells tapping bedrock aquifers in the western part of the County generally produce sufficient water for domestic and stock needs. Because the wells are widely scattered and yields are generally small, this area is not likely to be overdeveloped, but extended dry periods may reduce well yields. The water quality is generally poorer than in eastern Custer County because of higher concentrations of dissolved solids, mainly sulfates.

REFERENCES CITED

Ahlen, J. H., and others, 1960 [1961], North-south stratigraphic cross section, Matador Arch to Central Basin Platform, *in* Sweeney, H. N. (chairman), The oil and gas fields of southeastern New Mexico, 1960 supplement, a symposium: Roswell Geological Society, *facing* p. xxxi.

Barnes, V. E., (project director), 1967, Geologic atlas of Texas, Lubbock sheet: University of Texas Bureau of Economic Geology, scale 1:250,000.

———1968, Geologic atlas of Texas, Plainview sheet: University of Texas Bureau of Economic Geology, scale 1:250,000.

Beede, J. W., 1907, Invertebrate paleontology of the upper Permian Red Beds of Oklahoma and the Panhandle of Texas: University of Kansas Science Bulletin, v. 4, p. 113–171, pls. 5–8.

Beroni, E. P., 1956, Recent uranium discoveries in western Oklahoma: Mines Magazine, v. 46, no. 3, p. 68–71.

Blake, W. P., 1856, General report upon the geological collections, with a geologic map, section, etc., *in* Whipple, A. W., Report of explorations for a railway route, near the thirty-fifth parallel of north latitude, from the Mississippi River to the Pacific Ocean, 1853–1854: U.S. 33d Congress, 2d Session, House Executive Document 91, v. 11, pt. 3 (Whipple expedition in 19 vols.: v. 3, pt. 4, p. 1–119, pls. 1–3, 2 maps; call no. 793).

Buckstaff, Sherwood, 1931, Discussion, *in* Evans, Noel, Stratigraphy of Permian beds of northwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 15, p. 434–437.

Bullard, F. M., 1928, Lower Cretaceous of western Oklahoma: Oklahoma Geological Survey Bulletin 47, 116 p., 11 pls.

Buttram, Frank, 1914, Volcanic dust in Oklahoma: Oklahoma Geological Survey Bulletin 13, 49 p.

Carr, J. E., and **Bergman, D. L.**, 1976, Reconnaissance of the water resources of the Clinton quadrangle, west-central Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 5, 4 sheets, scale 1:250,000.

Clapp, F. G., 1920, Geology of Cement oil field [abstract]: Mining and Metallurgy, no. 158, p. 34–35.

Condra, G. E., and **Reed, E. C.**, 1943, The geological section of Nebraska: Nebraska Geological Survey Bulletin 14, 82 p.

Cope, E. D., 1894, Observations on the geology of adjacent parts of Oklahoma and northwest Texas: Philadelphia Academy of Natural Science Proceedings, p. 63–68.

Cragin, F. W., 1891, Further notes on the Cheyenne sandstone and Neocomian shales [Kansas]: American Geologist, v. 7, p. 179–181.

———1892 [1893], A contribution to the invertebrate paleontology of the Texas Cretaceous: Texas Geological Survey Annual Report, v. 4, pt. 2, p. 139–295, pls. 24–46.

———1894, Description of invertebrate fossils from the Comanche series in Texas, Kansas, and Indian Territory: Colorado College Studies, v. 5, p. 49–68.

———1895, A study of the Belvidere beds: American Geologist, v. 16, p. 357–385.

———1896, The Permian system in Kansas: Colorado College Studies, v. 6, p. 1–48.

———1897, Observations on the Cimarron series: American Geologist, v. 19, v. 351–363.

Curtis, N. M. (compiler), 1956, Some facts about Oklahoma uranium: Oklahoma Geology Notes, v. 16, p. 106–120 [including reprint of Beroni, 1956].

Davis, L. V., 1955, Geology and ground water resources of Grady and northern Stephens Counties, Oklahoma: Oklahoma Geological Survey Bulletin 73, 184 p., 2 pls.

DeFord, R. K., and **Lloyd, E. R.**, 1940, [Editorial introduction] *in* West Texas-New Mexico symposium, Part I: American Association of Petroleum Geologists Bulletin, v. 24, p. 1–14.

DeFord, R. K., and **Riggs, G. D.**, 1941, Tansill formation, west Texas and southeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 25, p. 1713–1728.

Dobrovolny, Ernest, Summerson, C. H., and **Bates, R. L.**, 1946, Geology of northwestern Quay County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 62, scale approximately 1 inch to 1 mile.

Dunbar, C. O., 1940, The type Permian; its classification and correlation: American Association of Petroleum Geologists Bulletin, v. 24, p. 237–281.

Evans, Noel, 1928, Stratigraphy of Weatherford area, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 12, p. 705–714.

———1931, Stratigraphy of Permian beds of northwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 15, p. 405–439.

Fay, R. O., 1962, Stratigraphy and general geology of Blaine County, *pt. 1 of* Geology and mineral resources of Blaine County, Oklahoma: Oklahoma Geological Survey Bulletin 89, 12–99, 194–247, 9 pls.

———1964, The Blaine and related formations of northwestern Oklahoma and southern Kansas: Oklahoma Geological Survey Bulletin 98, 238 p., 24 pls.

———1965, Geology and mineral resources of Woods County, Oklahoma: Oklahoma Geological Survey Bulletin 106, 189 p., 4 pls.

———1975, The type species of *Mortoniceras* and the holotype specimens of Lower Cretaceous *Texigryphaea* of the southwestern United States: Oklahoma Geology Notes, v. 35, p. 43–57.

Finch, W. I., 1967, Geology of epigenetic uranium deposits in sandstone in the United States: U.S. Geological Survey Professional Paper 538, 121 p.

Gabb, W. M., 1869, Description of Cretaceous fossils, collected by A. Rémond, at Arivechi, Sonora, Mexico: California Geological Survey, Paleontology, v. 2, p. 257–276, pls. 35–36.

Gould, C. N., 1902, General geology of Oklahoma: Oklahoma Department of Geology and Natural History 2d Biennial Report, p. 17–74.

———1905, Geology and water resources of Oklahoma: U.S. Geological Survey Water-Supply and Irrigation Paper 148, 178 p.

———1907, The geology and water resources of the western portion of the Panhandle of Texas: U.S. Geological Survey Water-Supply and Irrigation Paper 191, 70 p.

———1924, A new classification of the Permian red beds of southwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 8, p. 322–341.

Green, D. A., 1936, Permian and Pennsylvanian sediments exposed in central and west-central Oklahoma: American Association of Petroleum Geologists Bulletin, v. 20, p. 1454–1476.

———1937, Major divisions of Permian in Oklahoma and southern Kansas: American Association of Petroleum Geologists Bulletin, v. 21, p. 1515–1533.

Gregg, Josiah, 1844, Commerce of the prairies [1954 edition, edited by M. L. Moorhead]: University of Oklahoma Press, 469 p.

Gregory, J. N., 1958, Foreword, *in* Bivens, W. E., Jr. (chairman), The base of the Permian—a century of controversy: San Angelo Geological Society Field-Trip Guidebook, p. iii–iv.

Griggs, R. L., and **Read, C. B.,** 1959, Revisions in stratigraphic nomenclature in Tucumcari-Sabinoso area, northeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 43, p. 2003–2007.

Griley, H. L., 1931, Discussion, *in* Evans, Noel, Stratigraphy of Permian beds of northwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 15, p. 433–434.

———1933, Subdivision of Quartermaster formation of Oklahoma, and its relationship to known Triassic of Texas Panhandle [abstract]: Pan-American Geologist, v. 59, p. 234–235.

———1937, [Discussions] *in* Dott, R. H. (editor), Discussions at Permian conference, Norman, Oklahoma, May 8, 1937: American Association of Petroleum Geologists Bulletin, v. 21, p. 1559, 1560–1561, 1569, 1570, 1571, 1572.

Hall, James, 1856, Descriptions and notices of the fossils collected upon the route, *in* Whipple, A. W., Report of explorations for a railway route, near the thirty-fifth parallel of north latitude, from the Mississippi River to the Pacific Ocean, 1853–1854: U.S. 33d Congress, 2d Session, House Executive Document 91, v. 11, pt. 3 (Whipple expedition in 19 vols.: v. 3, pt. 4, p. 99–105, pls. 1–2; call no. 793).

Ham, W. E., 1949, Geological and petrographic investigations, *in* Burwell, A. L., Cellular products from Oklahoma volcanic ash: Oklahoma Geological Survey Circular 27, p. 48–84.

———1961, New gypsum plant to open soon: Oklahoma Geology Notes, v. 21, p. 193.

Ham, W. E., and **Curtis, N. M., Jr.,** 1958, Gypsum in the Weatherford-Clinton district, Oklahoma: Oklahoma Geological Survey Mineral Report 35, 32 p.

Ham, W. E., and **Jordan, Louise,** 1961, A Permian stratigraphic section in west-central Oklahoma: Oklahoma Geology Notes, v. 21, p. 4–9.

Hattin, D. E., 1962, Stratigraphic and paleoecologic significance of macroinvertebrate fossils in the Dakota Formation (Upper Cretaceous) of Kansas, *in* Teichert, Curt, and Yochelson, E. L. (editors), Essays in paleontology and stratigraphy: University of Kansas Department of Geology Special Publication 2, p. 570–589.

Hill, R. T., 1887, The topography and geology of the Cross Timbers and surrounding regions in northern Texas: American Journal of Science, 3d series, v. 33, p. 291–303.

———1891, The Comanche series of the Texas-Arkansas region: Geological Society of America Bulletin, v. 2, p. 503–528.

———1895, On outlying areas of the Comanche series in Kansas, Oklahoma, and New Mexico: American Journal of Science, 3d series, v. 50, p. 205–234.

Hill, R. T., and **Vaughan, T. W.,** 1898, The Lower Cretaceous Gryphaeas of the Texas region: U.S. Geological Survey Bulletin 151, 139 p., 35 pls.

Imlay, R. W., 1940, Neocomian faunas of northern Mexico: Geological Society of America Bulletin, v. 51, p. 117–190, pls. 1–21.

Izett, G. A., Wilcox, R. E., Powers, H. A., and **Desborough, G. A.,** 1970, The Bishop ash bed, a Pleistocene marker bed in the Western United States: Quaternary Research, v. 1, p. 121–132.

Jewett, J. M., and others, 1964, Geologic map of Kansas: Kansas Geological Survey Map M-1, scale 1:500,000.

Jordan, Louise, and **Vosburg, D. L.,** 1963, Permian salt and associated evaporites in the Anadarko basin of the western Oklahoma–Texas Panhandle region: Oklahoma Geological Survey Bulletin 102, 76 p., 3 pls.

Kauffman, E. G., Hattin, D. E., and **Powell, J. D.,** 1977, Stratigraphic, paleontologic, and paleoenvironmental analysis of the Upper Cretaceous rocks of Cimarron County, northwestern Oklahoma: Geological Society of America Memoir 149, 150 p., 12 pls.

Lamarck, J. B., 1801, Systême des animaux sans vertèbres, ou tableau gènèral des classes, des ordres et de genres de ces animaux, etc.: Paris, 432 p.

Lewis, F. E., 1938, Stratigraphy of the Upper and Middle Permian of west Texas and southeast New Mexico [abstract]: American Association of Petroleum Geologists Bulletin, v. 22, p. 1710–1711.

McLaughlin, T. G., 1954, Geology and ground-water resources of Baca County, Colorado: U.S. Geological Survey Water-Supply Paper 1256, 232 p.

Marcou, Jules, 1854, Sur le géologie des montagnes Rocheuses, entre le fort Smith (Arkansas) et Albuquerque (Nouveau-Mexique): Société géologique de France Bulletin, series 2, v. 11, p. 156–160.

———1855a, Résumé of a geological reconnaissance extending from Napoleon, at the junction of the Arkansas with the Mississippi to the Pueblo de los Angeles in California: U.S. 33d Congress, 1st Session, House Executive Document 129, v. 18, pt. 2, p. 40–48 [call no. 737].

———1855b, Résumé explicatif d'une carte géologique des États-Unis et des provinces anglaises de l'Amerique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique, et une planche de fossiles: Société géologique de France Bulletin, series 2, v. 12, p. 813–936, pls. 20–21.

———1856, Résumé and field notes, with a geological section, and other illustrations, *in* Whipple, A. W., Report of explorations for a railway route, near the thirty-fifth parallel of north latitude, from the Mississippi River to the Pacific Ocean, 1853–1854: U.S. 33d Congress, 2d Session, House Executive Document 91, v. 11, pt. 3 (Whipple expedition in 19 vols.: v. 3, pt. 4, p. 120–164; call no. 793).

———1858, American geology; letter on some points of the geology of Texas, New Mexico, Kansas, and Nebraska, addressed to Messrs. F. B. Meek and F. V. Hayden: Zurich, Zürcher & Furrer, 16 p.

———1862, Notes on the Cretaceous and Carboniferous rocks of Texas: Boston Society of Natural History Proceedings, v. 8, p. 86–97.

Meek, F. B., and **Hayden, F. V.,** 1861, Descriptions of new Lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils, collected in Nebraska Territory: Philadelphia Academy of Natural Science Proceedings, v. 13, p. 415–447.

Miser, H. D., and others, 1954, Geologic map of Oklahoma: U.S. Geological Survey and Oklahoma Geological Survey, scale 1:500,000.

Möllhausen, Baldwin, 1858, Diary of a journey from the Mississippi to the coasts of the Pacific with a United States Government expedition [translated by Mrs. Percy Sinnett]: London, Longman, Brown, Green, Longman and Roberts, in 2 vols.; v. 1, 352 p. [especially p. 158–163 on Custer County area].

Moore, R. C., 1940, Carboniferous-Permian boundary: American Association of Petroleum Geologists Bulletin, v. 24, p. 282–336.

Moore, R. C., (editor), 1966, [Introductory material] *in v. 1 of* Echinodermata, *pt. U of* Treatise on invertebrate paleontology: Geological Society of America and University of Kansas Press, p. i–xxx.

Morton, S. G., 1834, Synopsis of the organic remains of the Cretaceous group of the United States: Philadelphia, Key and Biddle, 88 p., 19 pls.

Naeser, C. W., Izett, G. A., and **Wilcox, R. E.,** 1973, Zircon fission-track ages of Pearlette family ash beds in Meade County, Kansas: Geology, v. 1, p. 187–189.

Newell, N. D., 1940, Invertebrate fauna of the late Permian Whitehorse sandstone [with descriptions of fossils by J. B. Knight, R. C. Moore, and K. G. Brill, Jr.]: Geological Society of America Bulletin, v. 51, p. 261–336, pls. 1–10.

Norton, G. H., 1939, Permian red beds of Kansas: American Association of Petroleum Geologists Bulletin, v. 23, p. 1751–1819.

Nuttall, Thomas, 1821, A journal of travels into the Arkansas Territory during the year 1819: Philadelphia, Thomas A. Palmer, 296 p., map.

O'Brien, B. E., 1963, Geology of east-central Caddo County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 72 p., 4 pls.

O'Connor, H. G., 1963, Changes in Kansas stratigraphic nomenclature: American Association of Petroleum Geologists Bulletin, v. 47, p. 1873–1877.

Olson, E. C., 1962, Late Permian terrestrial vertebrates, U.S.A. and U.S.S.R.: American Philosophical Society Transactions, new series, v. 52, pt. 2, 224 p., 21 pls.

Potter, D. R., 1963, An emendation of the sporomorph *Arcellites* Miner, 1935: Oklahoma Geology Notes, v. 23, p. 227–230, 1 pl.

Powers, H. A., and **Wilcox, R. E.,** 1964, Volcanic ash from Mount Mazama (Crater Lake) and from Glacier Peak: Science, v. 144, p. 1334–1336.

Reeves, Frank, 1921, Geology of the Cement oil field, Caddo County, Oklahoma: U.S. Geological Survey Bulletin 726-B, p. 41–85, 7 pls.

Roth, Robert, Newell, N. D., and **Burma, B. H.,** 1941, Permian pelecypods in the lower Quartermaster formation, Texas: Journal of Paleontology, v. 15, p. 312–317, pl. 45.

Sawyer, R. W., 1924, Areal geology of a part of southwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 8, p. 312–321.

———1929, Kiowa and Washita Counties, *pt. HH of* Oil and gas in Oklahoma: Oklahoma Geological Survey Bulletin 40-HH, 15 p.

Say, Thomas, 1823, Descriptions of fossils, *in* James, Edwin, Account of an expedition from Pittsburg to the Rocky Mountains, performed in the years 1819-1820, under the command of Maj. Stephen H. Long: Philadelphia, Carey and Lea, v. 2, 442 p., map.

Schwab, Delbert (compiler) [1975?], 1975 irrigation survey, Oklahoma: Oklahoma State University, 19 p.

Stenzel, H. B., 1956 [1959], Cretaceous oysters of southwestern North America, *in* Kellum, L. B. (chairman), El Sistema Cretácico, un symposium sobre el Cretácico en el Hemisferio Occidental y su correlación mundial: Mexico, 20th International Geological Congress, v. 1, p. 15–36.

Stephenson, C. D., 1925, Observations on the Verden sandstone of southwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 9, p. 626–631.

Stephenson, L. W., and others, 1942, Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and trans-Pecos Texas: Geological Society of America Bulletin, v. 53, p. 435–448.

Stovall, J. W., 1943, Stratigraphy of the Cimarron valley (Mesozoic rocks), *in* Schoff, S. L., Geology and ground water resources of Cimarron County, Oklahoma: Oklahoma Geological Survey Bulletin 64, p. 43–100, pls. 4–11.

Swineford, Ada, 1949, Source area of Great Plains Pleistocene volcanic ash: Journal of Geology, v. 57, p. 307–311.

Sylvester-Bradley, P. C., 1956 [1959], [Discussion of] Cretaceous oysters of southwestern North America by H. B. Stenzel, *in* Kellum, L. B. (chairman), El Sistema Cretácico, un symposium sobre el Cretácico en el Hemisferio Occidental y su correlación mundial: Mexico, 20th International Geological Congress, v. 1, p. 36–37.

Tester, A. C., 1931, The Dakota stage of the type locality: Iowa Geological Survey Annual Report, v. 35, p. 195–332, 2 pls.

Tomlinson, C. W. (chairman), and others, 1940, Classification of Permian rocks: American Association of Petroleum Geologists Bulletin, v. 24, p. 337–358.

Twenhofel, W. H., 1924, The geology and invertebrate paleontology of the Comanchean and "Dakota" formations of Kansas: Kansas Geological Survey Bulletin 9, 135 p., 23 pls.

U.S. Board on Geographic Names, 1967, Decisions on geographic names in the United States, July through September 1966: Decision List 6603, 38 p.

Vaughan, T. W., 1897, Additional notes on the outlying areas of the Comanche series in Oklahoma and Kansas: American Journal of Science, 4th series, v. 4, p. 43–50.

Whipple, A. W., 1856, Report on explorations for a railway route, near the thirty-fifth parallel of north latitude, from the Mississippi River to the Pacific Ocean, 1853–1854: U.S. 33d Congress, 2d Session, House Executive Document 91, v. 11, pt. 3 (Whipple expedition in 19 vols.: v. 3, pt. 4, p. 1–136, map; call no. 793). [Also appendixes A–N in v. 11, pt. 4, v. 4; call no. 794.]

Wilcox, R. E., 1965, Volcanic-ash chronology, *in* The Quaternary of the United States: Princeton University Press, p. 807–816.

Wilcox, R. E., and **Izett, G. A.,** 1973, Criteria for the use of volcanic ash beds as time-stratigraphic markers [abstract]: Geological Society of America Abstracts with Programs, v. 5, p. 863.

Wilcox, R. E., Izett, G. A., and **Powers, H. A.,** 1970, The Yellowstone Park region as the source of the Pearlette-like ash beds of the Great Plains [abstract]: American Quaternary Association Abstracts of First Meeting, Bozeman, Montana, p. 151.

Wright, M. H., and **Shirk, G. H.,** 1950, The journal of Lieutenant A. W. Whipple: Chronicles of Oklahoma, v. 28, p. 235–283, 1 map [quotes Whipple's original penciled notebooks].

Zeller, D. E. (editor), 1968, The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, 81 p., 1 pl.

APPENDIX TO PART I

Measured Stratigraphic Sections

1. Weatherford Section, Custer County

Beginning at top in Cloud Chief gypsum in SE1/4 sec. 18, T. 12 N., R. 14 W., and proceeding downward to type Weatherford dolomite in SE1/4SE1/4 sec. 18 and SW1/4SW1/4 sec. 17, section measured along road and east of road along branch of Little Deep Creek for 60 feet or more of Rush Springs sandstone below Weatherford dolomite. Section then extrapolated to U.S. Army Corps of Engineers, Weatherford site, where 4-inch cores were taken near Weatherford airport in SE1/4SW1/4NW1/4 sec. 2, T. 12 N., R. 14 W. (elevation, 1,600 feet), for lower 220 feet of Rush Springs sandstone to Emanuel Bed and upper 6 feet of Marlow Formation.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION (top not exposed):	
Moccasin Creek Bed (top not exposed):	
Gypsum, white to red-brown, finely crystalline, thinly bedded, crinkly bedded, well-indurated; erodes into a ledge, with top eroded; locally 50 to 70 feet thick, and farther southwestward in Washita County, 115 feet thick. (Term Cloud Chief gypsum should be applied where unit is more than 40 feet thick) . . .	8.0+
WHITEHORSE GROUP (estimated total thickness, 520 feet)	
RUSH SPRINGS FORMATION (estimated total thickness, 400 feet):	
Sandstone, orange-brown, fine-grained, silty, quartzose, weakly indurated; covered in part	37.0
Weatherford Bed (type section):	
Dolomite, gray to pink, fine-grained, thinly laminated, crinkly bedded, well-indurated; erodes into prominent mappable escarpment; gradational into gypsum westward and in NW1/4SE1/4 sec. 18, it is 3.25 feet thick, but lower 2.25 feet is gypsum	1.0
Unnamed beds:	
Sandstone, orange-brown, fine-grained, silty, cross-bedded to even-bedded, moderately to weakly indurated, with a 2-inch calcitic zone 105 feet above base, a 1-foot zone of calcite nodules 90 feet above base, a 3-foot zone of calcite nodules 80 feet above base, and some greenish-gray streaks 5 feet above base . .	362.0
MARLOW FORMATION (estimated total thickness, 120 feet):	
Emanuel Bed:	
Sandstone, maroon to pink, calcitic, moderately indurated, wavy bedded	0.1
Unnamed beds:	
Sandstone, orange-brown, silty, weakly indurated; to bottom of core	6.2

2. Sugar Loaf Mound Section, Custer County

Beginning at top in Cloud Chief Formation in prominent knob southeast of Thomas in NE1/4 sec. 7, T. 14 N., R. 14 W., section measured into upper 42 feet of Rush Springs sandstone to base of hill, and then extrapolated eastward to Emanuel Bed in NE1/4NE1/4NE1/4 sec. 13, T. 14 N., R. 14 W. Top of Sugar Loaf Mound is 1,860 feet in elevation, and Emanuel Bed is 1,566 feet in elevation. Regional strike is west-northwest, and dip is to southwest at average rate of 16 feet per mile. Estimated thickness of Rush Springs sandstone is about 360 feet, and Marlow thickness of 110 feet is extrapolated from outcrops farther eastward, so total thickness of Whitehorse is estimated at about 470 feet.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION (exposed thickness, 51 feet, top eroded):	
Day Creek Bed:	
Dolomite, pink and white, finely crystalline, compact, silty, well-indurated, wavy-bedded, massive; caps hill	1.5
Siltstone, orange-brown, arenaceous, calcitic, well-indurated; with many 1- to 1.5-foot dolomite lenses	6.25
Dolomite, pink and white, well-indurated, compact, crinkly bedded; with vuggy laminae; weathers platy	2.5
Kiger Member:	
Siltstone, orange-brown to red-brown; with interbedded red-brown shale and orange-brown sandstone; covered in part	39.5
Moccasin Creek Bed:	
Dolomite, white and pink, mottled bluish-gray, dense, well-indurated, wavy-bedded; with vuggy laminae; erodes into ledge	1.5
WHITEHORSE GROUP (estimated total thickness, 470 feet)	
RUSH SPRINGS FORMATION (estimated total thickness, 360 feet):	
Siltstone and sandstone, orange-brown, fine-grained, quartzose, cross-bedded to even-bedded, moderately to weakly indurated	24.0
Weatherford Bed:	
Dolomite, white and pink, mottled bluish-gray, dense, well-indurated; erodes into ledge . .	1.5
Unnamed beds:	
Siltstone and sandstone, orange-brown; as above	17.0
Sandstone, orange-brown, fine-grained, quartzose, cross-bedded to even-bedded, moderately to well-indurated; covered in part	318.0
MARLOW FORMATION (estimated total thickness, 110 feet):	
Emanuel Bed:	
Dolomite, maroon to pink, medium-grained, well-indurated, wavy-bedded, arenaceous; erodes into ledge	0.1
Unnamed beds:	
Sandstone, orange-brown, silty, fine-grained, weakly indurated	25.0

3. Thomas Section, Custer County

Beginning at top in second high hill north of Thomas in NE¼ sec. 24, T. 15 N., R. 15 W., on west and south sides, extending from Cloud Chief Formation into Rush Springs Formation, section measured along creek in NW¼ sec. 19, T. 15 N., R. 14 W., to 137 feet below Weatherford Bed. Section then extrapolated along State Highway 33 to NW¼ sec. 22, T. 15 N., R. 14 W., for Emanuel and Relay Creek Beds of Marlow Formation. Weatherford occurs at elevation of 1,808 feet, and Emanuel at 1,560 feet.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION:	
Moccasin Creek Bed:	
Dolomite, white to pink, fine-grained, compact, well-indurated, thinly laminated, crinkly bedded, undulatory; erodes into prominent escarpment; caps two hills north of Indian Hill	2.0
WHITEHORSE GROUP (estimated total thickness, 410 feet)	
RUSH SPRINGS FORMATION (total thickness, 310 feet):	
Sandstone, orange-brown, fine-grained, quartzose, calcitic, weakly indurated, even-bedded; erodes into slope	42.0
Weatherford Bed:	
Dolomite, white to pink, very fine-grained, compact, dense, well-indurated, thinly laminated, crinkly bedded; erodes into ledge near base of hill, but caps Indian Hill in northeast corner of Thomas	1.5
Unnamed beds:	
Sandstone, orange-brown, even-bedded to cross-bedded; as above	62.0
Dolomite, light-pink to white, mottled orange-brown, fine-grained, arenaceous, thinly laminated, crinkly bedded, well-indurated; erodes into ledge	0.1
Sandstone, orange-brown, weakly indurated, cross-bedded; as above	33.5
Old Crow Bed:	
Dolomite, light-pink to white, well-indurated; as above; erodes into ledge	0.1
Unnamed beds:	
Sandstone, orange-brown, even-bedded to cross-bedded, moderately to weakly indurated; as above	171.0
MARLOW FORMATION (exposed thickness, 49.45 feet):	
Emanuel Bed:	
Dolomite, maroon to light-gray, fine-grained, thinly laminated, arenaceous, crinkly bedded, well-indurated; erodes into ledge	0.1
Unnamed beds:	
Sandstone, orange-brown, fine-grained, quartzose, calcitic, even-bedded, weakly indurated	17.25
Relay Creek Bed:	
Dolomite, maroon to dark-gray; as above; mostly covered	0.1
Unnamed beds:	
Sandstone, orange-brown, weakly indurated; as above; exposed to Canadian River bottom beneath bridge	32.0

4. East Clinton Core, Custer County

Beginning at top at elevation 1,705 feet in Cloud Chief Formation, in NW¼NW¼SE¼ sec. 9, T. 12 N., R. 16 W., a series of continuous 4-inch cores were taken to total depth of 227.7 feet, ending 70 feet in Rush Springs Formation, by U.S. Army Corps of Engineers at East Clinton site.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION (partial thickness, 157.7 feet, top eroded):	
Big Basin Member (partial thickness, 96 feet, top eroded):	
Siltstone, orange-brown, fine-grained, argillaceous, micaceous, moderately indurated, thinly laminated; with many thin wavy greenish-gray zones less than 0.5 inch thick	13.5
Sandstone, orange-brown, fine-grained, quartzose, calcitic, silty, moderately to well-indurated, thin-bedded, cross-bedded	11.8
Siltstone, orange-brown; as above	4.8
Shale, orange-brown, silty, micaceous, blocky, moderately indurated	0.3
Sandstone, orange-brown; as above	2.3
Siltstone and sandstone, orange-brown; as above	3.2
Shale, orange-brown; as above	0.5
Sandstone, orange-brown; as above	2.2
Shale, orange-brown, silty; as above	1.1
Siltstone, orange-brown; as above	1.9
Shale, orange-brown; as above	4.9
Siltstone and sandstone, orange-brown; as above	6.2
Siltstone, orange-brown; as above	3.1
Shale and siltstone, orange-brown; as above	1.0
Siltstone, orange-brown; as above	4.2
Shale, orange-brown, silty; as above	3.8
Siltstone, orange-brown; as above	8.4
Shale and siltstone, orange-brown; as above	2.4
Siltstone, orange-brown, calcitic; as above	10.1
Shale, orange-brown; as above	2.2
Shale and siltstone, orange-brown; as above	8.1
Day Creek Bed (thickness, 10.1 feet):	
Dolomite, pink to white, fine-grained, compact, well-indurated, vuggy; with some interbedded orange-brown siltstone	3.7
Sandstone, orange-brown, fine-grained, quartzose, dolomitic, well-indurated, thinly laminated	2.8
Dolomite, pink to white; as above	0.9
Sandstone, orange-brown, dolomitic; as above	2.4
Dolomite, pink to white; as above; with interbedded pink sandstone	0.3
Kiger Member (thickness, 43.1 feet):	
Sandstone, orange-brown, calcitic; as above; dolomitic in upper 1.1 feet	2.3
Siltstone, orange-brown, calcitic, arenaceous, as above	3.6
Sandstone, orange-brown, fine-grained, quartzose, calcitic, moderately to well-indurated	9.9
Siltstone, orange-brown, arenaceous, calcitic, quartzose, well-indurated, thinly laminated	20.1

Shale and siltstone, orange-brown, blocky, moderately to well-indurated, thinly laminated, calcitic to dolomitic	7.2
Moccasin Creek Bed (thickness, 8.5 feet):	
Dolomite, pink to white, fine-grained, compact, well-indurated, vuggy	2.1
Shale and siltstone, orange-brown; as above; with many 0.5- to 1-inch spots and layers of pink to white dolomite	3.9
Dolomite, pink to white; as above	2.5
WHITEHORSE GROUP (upper 70 feet cored)	
RUSH SPRINGS FORMATION (cored thickness, 70 feet to bottom of well):	
Sandstone, orange-brown, fine-grained, quartzose, calcareous, silty, well-indurated; with a 1-inch dolomite band 24 feet below top	32.7
Weatherford Bed:	
Dolomite, pink to white; as above	5.8
Unnamed beds:	
Sandstone, orange-brown, calcitic, moderately to well-indurated; as above	31.5

5. North Clinton Core, Custer County

Beginning at top at elevation 1,630 feet in Rush Springs Formation, section continuously cored to 227.7 feet in SE¼SE¼SE¼NW¼ sec. 36, T. 13 N., R. 17 W., with 4-inch cores recovered by U.S. Army Corps of Engineers at North Clinton site. Top of Rush Springs would occur approximately 20 feet above top of well, as determined from interval in high hill near center SW¼ sec. 2, T. 12 N., R. 17 W., about 1 mile southwest of core site, where Moccasin Creek gypsum caps hill and Weatherford gypsum occurs about 50 feet below. Each gypsum is about 2 to 5 feet thick, with undulatory bedding.

	Thickness (feet)
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (cored thickness, 227.7 feet, top and base not determined at site):	
Siltstone, orange-brown, arenaceous, gypsiferous, well-indurated	27.4
Siltstone, orange-brown, arenaceous, weakly indurated	2.3
Weatherford Bed:	
Gypsum, white to gray, mottled orange to pink, fine- to coarse-grained, well-indurated, massive to thinly laminated, selenitic; dolomitic in basal ½ inch	5.9
Unnamed beds (thickness, 119.4 feet):	
Siltstone, orange-brown, arenaceous, gypsiferous, moderately to well-indurated; mottled with greenish-gray specks and weakly indurated in places; with interbedded fine-grained quartzose sandstone	41.4
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated; with some moderately indurated beds	29.7
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, silty, moderately to well-indurated	22.1
Sandstone, orange-brown, fine-grained, quartzose, silty, moderately to weakly indurated; with a 1-foot well-indurated gypsiferous band 10 feet below top	21.4
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, moderately to well-indurated	4.8
Old Crow Bed:	
Gypsum, white to orange-brown, fine- to coarse-grained, well-indurated	0.5
Unnamed beds (partial thickness to bottom of core, 72.2 feet):	
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, moderately to well-indurated	18.1
Sandstone, orange-brown, fine-grained, quartzose, silty, moderately to weakly indurated	54.1

6. West Clinton Section, Custer County

Beginning at top in Doxey Shale in SW¼SE¼ sec. 11 and NE¼ sec. 14, T. 12 N., R. 18 W., section measured through upper 15 feet of Cloud Chief Formation, then extrapolated along road in SE¼ sec. 12, T. 12 N., R. 18 W., for next 58 feet, to Red Hills in SE¼SW¼ sec. 8, T. 12 N., R. 17 W., for lower 104 feet of Cloud Chief and upper 10 feet of Rush Springs. Section then extrapolated to NW¼NE¼ sec. 4, T. 12 N., R. 17 W., where lower 85 feet of Cloud Chief is present and southeastward upper 45 feet of Rush Springs is present, including Weatherford gypsum. Near center of SW¼ sec. 2, T. 12 N., R. 17 W., a 200-foot water well was drilled on Doyle Cabaniss property (elevation 1,580 feet), spudding in 2 feet of Moccasin Creek gypsum, with 45 feet of Rush Springs below to 3 feet of Weatherford gypsum, with 130 feet of sandstone and siltstone below to 10 feet of Old Crow gypsum and 10 feet of sandstone with good water below Old Crow. Green (1936, p. 1473) stated that interval from base of Doxey to Weatherford Bed was 250 feet, but these measurements give 225 feet for this interval.

	Thickness (feet)
FOSS GROUP	
DOXEY SHALE (top eroded, 36.5 feet exposed):	
Siltstone, red-brown, argillaceous, blocky, moderately indurated; with some interbedded red-brown shale; caps hill in sec. 11	11.0
Shale, red-brown, blocky, weakly indurated; with some interbedded red-brown siltstone	8.0
Shale, orange-brown to red-brown, silty, blocky; with some interbedded orange-brown siltstone; with two 1-inch greenish-gray siltstones 2.5 and 5 feet above base; section extrapolated to sec. 14	15.75
Siltstone, greenish-gray, mottled orange-brown, argillaceous, dolomitic, thin-bedded, well-indurated; with symmetrical ripple marks that strike NNW; erodes into mappable ledge beneath high, rounded, resistant hills of Doxey Shale and siltstone in badlands topography	1.75
CLOUD CHIEF FORMATION (total thickness, 177 feet):	
Big Basin Member (thickness, 123.9 feet):	
Shale, orange-brown to greenish-gray, silty, blocky, weakly indurated	0.5
Shale, orange-brown, blocky, weakly indurated; with some indurated orange-brown siltstone	3.0

Siltstone, greenish-gray to orange-brown, argillaceous, thin-bedded, moderately indurated	0.5
Siltstone, orange-brown, argillaceous, platy, moderately indurated	0.75
Shale, orange-brown, platy, weakly indurated	1.0
Siltstone, greenish-gray, argillaceous, moderately indurated	0.1
Siltstone and shale, orange-brown, thin-bedded, moderately to weakly indurated	5.0
Siltstone, greenish-gray to tan, mottled orange-brown, argillaceous, thin-bedded, well-indurated; with interbedded orange-brown shale and satin spar; erodes into ledge . . .	4.5
Shale, orange-brown, silty, blocky, weakly indurated; with some 1-inch satin-spar veins and layers; partly covered in lower half . .	58.0
Sandstone, orange-brown to greenish-gray, fine-grained, quartzose, well-indurated; erodes into prominent ledge capping Red Hills; section extrapolated to SE$^1/_4$SW$^1/_4$ sec. 8, T. 12 N., R. 17 W.	2.5
Shale and siltstone, orange-brown, blocky, moderately to weakly indurated, cross-bedded in northwest direction; with prominent 4-inch ledge in middle	1.5
Siltstone, orange-brown, mottled greenish-gray in middle, well-indurated, laminated, cross-bedded in northwest direction; erodes into ledge	0.5
Shale and siltstone, orange-brown, blocky, laminated, weakly indurated	1.5
Siltstone, orange-brown, mottled greenish-gray, thinly laminated, well-indurated; erodes into ledge	0.5
Shale, orange-brown, silty, blocky, weakly indurated	2.0
Siltstone, greenish-gray, argillaceous, platy, moderately indurated	0.1
Shale, orange-brown, silty, blocky, weakly indurated	5.0
Siltstone, greenish-gray, mottled orange-brown, argillaceous, thin-bedded, moderately indurated	0.2
Shale, orange-brown, blocky, weakly indurated; with some interbedded orange-brown sandstone	2.0
Sandstone, orange-brown, fine-grained, silty, thin-bedded, well-indurated; with 6-inch greenish-gray bed at base; erodes into prominent ledge	15.75
Shale and siltstone, orange-brown to red-brown, blocky, thin-bedded, moderately to weakly indurated	3.8
Sandstone, orange-brown to red-brown, fine-grained, quartzose, thin-bedded, well-indurated; greenish gray in upper 3 inches; grades into siltstone; erodes into ledge . . .	7.5
Shale, red-brown, silty, blocky, weakly indurated	6.0
Day Creek Bed(?):	
Sandstone, greenish-gray to orange-brown, fine-grained, quartzose, well-indurated, massive	1.75
Kiger Member (thickness, 53.25 feet):	
Shale, red-brown, silty, blocky, weakly indurated; with some 1-inch greenish-gray zones	5.0
Sandstone, red-brown, mottled greenish-gray, fine-grained, silty, moderately indurated	1.0
Shale, red-brown, silty, blocky, weakly indurated; with some 1-inch greenish-gray layers	2.25
Siltstone, red-brown, argillaceous, blocky, moderately indurated; mottled greenish gray in places	1.5
Shale, red-brown; as above	3.0
Siltstone, red-brown; as above	2.0
Shale, red-brown; as above	1.0
Sandstone, greenish-gray, fine-grained, silty, well-indurated, massive	0.5
Siltstone, red-brown, argillaceous, moderately indurated; with some interbedded red-brown shale	5.0
Shale, red-brown, silty, blocky, moderately indurated; with interbedded red-brown siltstone; partly covered; *Moccasin Creek* portion is mostly covered and appears to be a greenish-gray zone, but this part is a 2-foot gypsum in C SW$^1/_4$ sec. 2, T. 12 N., R. 17 W.	32.0
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (about 60 feet exposed; 200 feet drilled):	
Sandstone, orange-brown, fine-grained, quartzose, moderately to well-indurated; erodes into escarpment; measured to Washita River	10.0
Sandstone and some siltstone, orange-brown; as above; partly covered; section extrapolated to hill in NW$^1/_4$NE$^1/_4$ sec. 4, T. 12 N., R. 17 W., from base of hill to Weatherford Bed in SE$^1/_4$NE$^1/_4$ sec. 4 along road	35.0
Weatherford Bed:	
Gypsum, white, fine-grained, massive, well-indurated; erodes into prominent mappable escarpment	2.0–3.0
Unnamed beds:	
Sandstone and siltstone, orange-brown, fine-grained, quartzose; as above; section extrapolated to well on Doyle Cabaniss place . . .	130.0
Old Crow Bed:	
Gypsum, white, fine-grained, massive, well-indurated	10.0
Unnamed beds:	
Sandstone, orange-brown; as above; considered Rush Spring by a local driller, Mr. Wells; said to be more permeable than beds above and with less gypsiferous water	10.0+

7. South Putnam Core, Custer County

Beginning at top at elevation 1,935 feet, continuous 4-inch cores were taken by U.S. Army Corps of Engineers at South Putnam site to total depth of 226.5 feet, in SE$^1/_4$SE$^1/_4$NW$^1/_4$SW$^1/_4$ sec. 1, T. 15 N., R. 17 W., with 91 feet of Cloud Chief Formation in upper part and 135 feet of Rush Springs Formation in lower part.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION (top eroded, 91 feet cored):	

Siltstone, orange-brown, arenaceous, argillaceous, weakly indurated; grades into fine-grained quartzose sandstone	18.1
Siltstone, greenish-gray to orange-brown, arenaceous, weakly indurated; with some coarse quartz grains	0.3
Siltstone, orange-brown; as above; with 1-inch greenish-gray zone at base and 6.7 feet above base	9.1
Shale, light-red-brown, blocky, silty, weakly indurated; with some paper-thin calcite veins	4.9
Siltstone, greenish-gray, argillaceous, platy, weakly indurated; mottled orange brown	0.6
Sandstone, orange-brown to red-brown, fine-grained, quartzose, friable, weakly indurated	2.4
Siltstone, orange-brown to red-brown, arenaceous, quartzose, weakly indurated	2.8
Shale, light-red-brown, blocky, weakly indurated; mottled greenish gray at base	0.7
Sandstone, orange-brown, fine-grained, quartzose, silty, friable, weakly indurated	0.7
Siltstone, orange-brown, argillaceous, quartzose, weakly indurated	2.2
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	1.7
Siltstone, orange-brown; as above	0.7
Sandstone, orange-brown, cross-bedded; as above	1.1
Siltstone and shale, orange-brown, arenaceous, blocky, moderately indurated; mottled with greenish-gray patches	3.3
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated; with some interbedded siltstone	10.0
Siltstone and shale, orange-brown, quartzose, blocky, moderately to weakly indurated	6.0
Sandstone, orange-brown; as above	2.9
Siltstone, orange-brown, arenaceous, weakly indurated; with some vugs lined with calcite	3.1
Siltstone, greenish-gray, arenaceous, quartzose, weakly indurated	0.7
Sandstone and siltstone, orange-brown, fine-grained, quartzose, weakly indurated	11.2
Siltstone and shale, orange-brown; as above	0.5
Sandstone and siltstone, orange-brown; as above	4.8
Moccasin Creek Bed:	
Sandstone and siltstone, greenish-gray, arenaceous, quartzose, weakly indurated	0.5
Siltstone and shale, orange-brown to greenish-gray, blocky, weakly indurated	1.4
Siltstone, greenish-gray to orange-brown, arenaceous, weakly indurated	1.0
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (cored thickness to bottom of well, 135 feet):	
Siltstone, orange-brown, arenaceous, quartzose, weakly indurated	1.2
Shale and siltstone, orange-brown, blocky, moderately to weakly indurated; with 0.5-inch dolomite stringers 3 feet above base	16.1
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated	5.6
Siltstone, orange-brown, arenaceous, well-indurated; dolomitic at base	1.2
Sandstone, orange-brown; as above; with some interbedded siltstone	6.2
Siltstone and shale, orange-brown, moderately to well-indurated; with some greenish-gray patches	2.4
Sandstone, red-brown, fine-grained, quartzose, gypsiferous, well-indurated; mottled with greenish-gray patches	1.2
Siltstone, orange-brown, argillaceous, gypsiferous, well-indurated; with many small patches of selenite and gypsum spots	12.9
Weatherford Bed:	
Gypsum, white, mottled light-pink, finely crystalline, compact, well-indurated; with 0.5-inch greenish-gray dolomitic zone at base	5.4
Unnamed beds:	
Siltstone, orange-brown, gypsiferous, well-indurated, mottled red-brown; with some thin pink gypsum veins; grades into sandstone	6.3
Sandstone, red-brown, fine-grained, quartzose, silty, gypsiferous, well-indurated; with many thin gypsum stringers	6.1
Siltstone and sandstone, orange-brown, fine-grained, quartzose, well-indurated; with some thin gypsum stringers	21.9
Sandstone, red-brown, fine-grained, quartzose, gypsiferous, well-indurated	2.8
Sandstone and siltstone, orange-brown, fine-grained, quartzose, moderately indurated	3.6
Sandstone, red-brown, fine-grained, quartzose, gypsiferous, well-indurated	1.8
Sandstone, orange-brown to red-brown, fine-grained, quartzose, silty, moderately indurated	18.7
Siltstone and sandstone, orange-brown, fine-grained, quartzose, weakly indurated	3.8
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated; to bottom of core	18.6

8. South Leedey Core, Custer County

Beginning at top at elevation 1,940 feet in SW¼SW¼NE¼SE¼ sec. 6, T. 15 N., R. 20 W., section cored continuously to 227.4 feet at bottom, with recovery of 4-inch cores by U.S. Army Corps of Engineers at South Leedey site. Top 53.6 feet is Cloud Chief, and lower 173.8 feet is Rush Springs. Top 29.6 feet in core was not saved, so this part in addition to another 40 feet above is extrapolated from outcrop information along State Highway 34 to east, where lower 93.4 feet of Cloud Chief is exposed.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION (lower 93.4 feet exposed on outcrop, 53.6 feet in core):	
Big Basin Member (52.3 feet exposed on outcrop):	
Shale, red-brown, silty, blocky, weakly indurated	5.0
Siltstone, orange-brown, argillaceous, platy, moderately indurated; greenish gray at base	2.0
Shale, red-brown; as above	5.0
Sandstone, greenish-gray, fine-grained, quartzose, silty, calcitic, moderately indurated	0.2
Shale, red-brown; as above	5.0
Sandstone, greenish-gray, fine-grained, quartzose, silty, calcitic, weakly indurated	0.5

Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	0.5
Shale, red-brown; as above; mottled greenish gray in middle	1.5
Siltstone, greenish-gray, calcitic, well-indurated, platy, mottled pink	0.1
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated; greenish gray in basal 6 inches	2.5
Shale, red-brown; as above	23.0
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	7.0
Day Creek Bed:	
Dolomite, white, mottled tan, fine-grained, compact, well-indurated, platy, crinkly bedded	0.1
Kiger Member (thickness, 32 feet):	
Sandstone, orange-brown; as above	5.0
Shale, red-brown; as above	12.0
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	5.3
Siltstone, orange-brown, arenaceous, quartzose, weakly indurated	3.0
Sandstone, orange-brown, gypsiferous, well-indurated; as above	1.3
Siltstone and shale, orange-brown to red-brown, gypsiferous, well-indurated, blocky; with some interbedded sandstone and many thin satin-spar veins	5.4
Moccasin Creek Bed (thickness, 9 feet):	
Gypsum, white to red-brown, selenitic, coarse-grained, moderately indurated	0.4
Siltstone, orange-brown, gypsiferous, moderately indurated	2.4
Gypsum, white to gray, mottled orange-brown, finely granular, selenitic, well-indurated, compact	6.2
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (173.8 feet cored):	
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	11.1
Siltstone, orange-brown, arenaceous, quartzose, weakly indurated; mottled with some small greenish-gray spots	5.8
Sandstone, orange-brown; as above; mottled with some small greenish-gray spots	9.6
Siltstone and sandstone, orange-brown, fine-grained, quartzose, weakly indurated	10.4
Sandstone, orange-brown, weakly indurated; as above	3.5
Siltstone and sandstone, orange-brown; as above	4.3
Gypsum, white to orange-brown, medium-grained, selenitic, moderately indurated (Weatherford?)	0.1
Siltstone, orange-brown, arenaceous, gypsiferous, moderately indurated	1.3
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	6.1
Siltstone and sandstone, orange-brown; as above	2.7
Gypsum and siltstone, orange-brown, selenitic, well-indurated	0.5
Siltstone and sandstone, orange-brown; as above; with 3-inch gypsiferous band 7 feet below top	13.3
Gypsum and siltstone, white to orange-brown, arenaceous, moderately indurated	1.7
Sandstone, orange-brown, fine-grained, quartzose, silty, gypsiferous, moderately indurated	5.1
Siltstone, orange-brown, arenaceous, gypsiferous, weakly indurated	8.4
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated; gypsiferous in places	14.9
Siltstone, orange-brown, arenaceous, quartzose, gypsiferous, weakly indurated	4.1
Old Crow Bed:	
Gypsum, white, medium-grained, well-indurated, mottled light-orange; silty in basal 6 inches	2.0
Unnamed beds:	
Siltstone and sandstone, orange-brown, fine-grained, quartzose, weakly indurated; with some gypsum nodules	39.9
Gypsum, white mottled orange-brown, fine-grained, compact, well-indurated	0.9
Siltstone and sandstone, orange-brown; as above	5.0
Gypsum and sandstone, white to orange-brown, fine-grained, quartzose, selenitic, well-indurated	0.7
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	4.2
Sandstone and gypsum, white to orange-brown; as above	3.5
Gypsum, white to orange-brown, medium-grained, selenitic, well-indurated; silty in upper 8 inches	2.4
Siltstone, orange-brown, quartzose, weakly indurated	2.6
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated	1.9
Siltstone and sandstone, orange-brown, fine-grained, quartzose, gypsiferous, weakly indurated	7.8

9. Foss Dam Core Hole 30, Custer County

U.S. Bureau of Reclamation Core Hole 30, 1,000 feet north and 275 feet east of Core Hole 31, in SW1/4NE1/4NW1/4 sec. 2, T. 12 N., R. 19 W., elevation 1,604.1 feet on ground, spudding in Washita River alluvium to total depth of 281 feet. Cores are buried near Foss Dam site and are unavailable, but logs are available from U.S. Bureau of Reclamation, P.O. Box 1609, Amarillo, Texas. Core is 2 1/8 inches in diameter, and work was completed on September 25, 1956. First 65 feet is alluvium, next lower 82.4 feet is Cloud Chief, and remainder of rocks are Rush Springs, with Weatherford missing. Hole was logged by R. C. Redfield, and his descriptions are given here.

	Thickness (feet)
QUATERNARY SYSTEM	
PLEISTOCENE SERIES (thickness, 65 feet):	
Soil (clayey silt loam), dark brown	2.5
Silt, clayey, brown	2.5
Silt and fine sand, some clay, calcareous, brown	5.0
Silt and fine sand; same	5.0
Silt, some fine sand, clayey, calcareous, brown	5.0
Silt, a little fine sand, clayey, brown	5.0

Clay, silty, plastic, to silt, clayey, slightly calcareous, red-brown	5.0
Clay, silty, plastic, calcareous, red-brown	5.0
Silt, trace to some clay, calcareous, brown-red	5.0
Silt; same; with some gypsum crystals	5.0
Silt; same; laminated, with 0.9 feet of organic silt, peaty in part; gray and black	5.0
Silt, trace to some clay, calcareous, with some thin layers of organic silt, red-brown to tan and gray	5.0
Silt, trace to some clay, calcareous, red-brown	5.0
Silt; same; with weathered and broken shale at base	5.0
PERMIAN SYSTEM	
FOSS GROUP	
CLOUD CHIEF FORMATION (thickness of lower part, 82.4 feet):	
Big Basin Member (preserved thickness, 35 feet):	
Siltstone, hard, gypsiferous, laminated, broken, light-red; a vertical fracture healed with gypsum	2.5
Siltstone, hard, gypsiferous, micaceous, massive; with some clay shaly layers	7.0
Shale, silty clayey, slightly calcareous, gypsiferous, moderately hard, laminated, red; with some siltstone layers, hard, dolomitic and gypsiferous, gray; some vertical to low-angle joints	6.5
Shale, clayey to silty clayey, moderately hard, slightly calcareous, gypsiferous, red; some green-gray; and some laminae and veinlets of satin spar gypsum; and a 0.2-foot layer of gypsum 7 feet below top	19.0
Day Creek Bed (thickness, 6 feet):	
Gypsum, massive, finely crystalline; with a 1-foot shale layer, clayey, gypsiferous, moderately hard, red, and a 0.4-foot siltstone layer, hard, gypsiferous, gray, near the middle	6.0
Kiger Member (thickness, 35 feet):	
Siltstone, gypsiferous, hard; and siltstone, clayey, gypsiferous, moderately hard to friable, pink to red	8.5
Shale, clayey, silty to silty clayey, gypsiferous, moderately hard to soft, red; and siltstone, gypsiferous, hard, red; and some thin layers of gypsum	26.5
Moccasin Creek Bed (thickness, 6.4 feet):	
Gypsum, massive, fine-crystalline, pinkish-white; and a 0.7-foot layer of highly gypsiferous clayey shale at top	6.4
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (upper 133.6 feet cored to bottom of hole):	
Siltstone, gypsiferous, hard to friable, massive to laminated, light-red	13.6
Siltstone, gypsiferous, hard, calcareous, massive to laminated to cross-bedded, friable; light-red with gray spots; some tight joints, steep to low angle	20.0
Siltstone, slightly clayey, gypsiferous to slightly calcareous, moderately hard to friable, massive to laminated, light-red; joints vertical to low-angle	56.0
Siltstone, gypsiferous, hard, massive, light-red	4.0
Shale, silty clayey to clayey silty, calcareous, moderately hard to soft, massive to laminated, red	19.0
Siltstone, slightly clayey, soft, red; with some fine sand, rounded and polished; to bottom of well	21.0

10. Foss Dam Core Hole 31, Custer County

U.S. Bureau of Reclamation Core Hole 31, NW¼SE¼NW¼ sec. 2, T. 12 N., R. 19 W., elevation 1,602.7 feet on ground, spudding in Washita River alluvium to total depth of 308 feet. Cores are buried near Foss Dam site and are unavailable, but logs are available from U.S. Bureau of Reclamation, P.O. Box 1609, Amarillo, Texas. Core is 2⅛ inches in diameter, and work was completed on October 3, 1956. First 132 feet is alluvium, next lower 12.5 feet is Cloud Chief, and remainder of rocks are Rush Springs, with the Weatherford Bed occurring about 52 feet below Moccasin Creek gypsum. Hole was logged by R. C. Redfield, and his descriptions are herewith given. In descriptions, color red is probably red brown, and light red is probably orange brown, with siltstone probably grading into fine-grained sandstone.

	Thickness (feet)
QUATERNARY SYSTEM	
PLEISTOCENE SERIES (thickness, 132 feet):	
Soil, clayey silt loam, brown	2.5
Silt, trace clay, grading to clay, silty, calcareous, red	2.1
Clay, silty, calcareous, laminated, dull-red	2.4
Clay, silty, calcareous, laminated, compact; and layers of silt, trace clay, calcareous, soft, dull-red	8.0
Clay, and clay, silty, and fine sandy, calcareous, dull-red	5.0
Silt, clayey, calcareous, dull-red	5.0
Clay, to silt with clay, calcareous; with some gypsum crystals, red	7.0
Clay, silty, and silt with a little clay, calcareous, red (water level is here)	3.0
Sand, fine, silty; and silt with trace clay, calcareous, tan and red-brown	5.0
Silt, with trace to much clay, calcareous, dull-red to red-brown	5.0
Silt, with trace to some clay, calcareous, plastic, red-brown	5.0
Clay, silty, plastic, to silt with a little clay, calcareous, tan to red-brown	5.0
Silt, with trace clay, calcareous, tan	4.0
Silt, trace to some clay, moderately organic in part, calcareous, red-brown	6.0
Silt, with trace to some clay, calcareous, red-brown	5.0
Silt, with some fine sand in part; with trace to much clay, red-brown to tan	5.0
Clay, with trace to much silt, plastic, calcareous, red-brown	5.0
Clay, with trace to some silt, plastic; and silt, with trace clay, slightly organic, laminated, calcareous, red-brown	5.0
Silt, with trace to much clay, calcareous, red-brown; and some layers organic, black	5.0
Silt, with trace to some clay, calcareous, red-brown	5.0

Silt, with trace clay, calcareous, tan	5.0
Silt and fine sand, trace clay, calcareous, tan to red-brown	5.0
Sand, fine; some silt; some medium sand in lower part, tan to white	10.0
Sand, fine; a little silt; some medium to coarse sand, small gravel, and pieces of shale	2.0
Sand, fine, silty; some medium to coarse, small gravel, and trace to much clay, calcareous, tan to brown	5.0
Sand, fine; some silt; a little medium to coarse sand, and particles of shale, light-tan	8.0
Sand, fine to medium, silty; with trace clay, dark-tan	2.0
PERMIAN SYSTEM	
FOSS GROUP	
CLOUD CHIEF FORMATION (lower 12.5 feet preserved):	
Kiger Member (lower 5.6 feet preserved):	
Shale, clayey, clayey-silty, gypsiferous; with gypsum veinlets, red	5.6
Moccasin Creek Bed (total thickness, 6.9 feet):	
Gypsum, massive, finely crystalline; some siltstone, gypsiferous, hard; and a 2-foot shale, clayey, silty, gypsiferous, broken, red; with numerous satin spar veins	6.9
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (partial thickness to bottom of well, 163.5 feet):	
Siltstone, gypsiferous, massive to wavy bedded, hard to moderately hard, light-red	6.5
Siltstone, hard to friable, light-red; gypsiferous in part	3.0
Siltstone, gypsiferous, micaceous, hard; dolomitic in part; and some shale, clayey silty, gypsiferous, moderately hard, light-red and gray	9.0
Shale, clayey, silty, gypsiferous, hard, laminated; and sandstone, fine-rounded and polished grains, silty, gypsiferous, hard, light-red; a few joints	7.0
Shale, clayey, silty, gypsiferous, hard, massive, light-red; and clay shale, soft; red at base; joints at 45° angles	8.5
Shale, clayey silty, gypsiferous, hard, light-red; massive to some laminated; with numerous veinlets of satin spar; with a 0.7-foot bed of finely crystalline gypsum and a 0.5-foot dolomitic siltstone layer, hard, gray	12.5
Shale, silty, clayey, gypsiferous to slightly calcareous, hard to soft, massive; with a 0.6-foot bed of massive gypsum	6.0
Weatherford Bed (thickness, 3.4 feet):	
Gypsum, finely crystalline, massive; broken, fissured, and grouted with shale in upper part	3.4
Unnamed beds (thickness, 107.6 feet):	
Shale, clayey, silty, calcareous, laminated, fairly soft; and shale, same, gypsiferous, hard; and siltstone, gypsiferous, hard, massive, dark- to light-red	21.6
Shale, clayey silty, calcareous and soft to gypsiferous and hard, red	9.0
Siltstone, trace to some clay, slightly calcareous, soft, red; clayey shale from 276 to 278 feet	67.0
Siltstone, soft; to total depth of 308 feet	10.0

11. Alfalfa Section, Custer County

Beginning at top in Doxey Shale in high hill south of U.S. Highway 66 and proceeding down section into Cloud Chief Formation, section measured in NW¼NE¼NW¼ sec. 33, T. 12 N., R. 18 W., southeast of Alfalfa railroad station.

	Thickness (feet)
FOSS GROUP	
DOXEY SHALE (lower 53 feet exposed):	
Siltstone, red-brown, argillaceous, well-indurated, blocky, mottled tan; moderately indurated where interbedded with shale; erodes into series of resistant ledges; caps rounded hills in badlands topography	18.0
Shale, red-brown, silty, blocky, weakly indurated; with some interbedded red-brown siltstone	3.5
Silstone and shale, red-brown; as above; erodes into 3 ledges	1.5
Siltstone, red-brown, resistant; as above	4.0
Siltstone and shale, red-brown; as above; erodes into 3 ledges	2.0
Shale, red-brown, mottled orange-brown, blocky, weakly indurated; with some interbedded red-brown siltstone	6.5
Siltstone, red-brown to orange-brown, moderately indurated; with some interbedded orange-brown shale; erodes into 3 ledges; with a 1-inch greenish-gray siltstone at base	1.5
Shale, red-brown, silty, blocky, weakly indurated; with some interbedded orange-brown siltstone	7.25
Siltstone, greenish-gray to orange-brown, mottled red-brown, argillaceous, blocky, weakly indurated	1.75
Shale, red-brown to orange-brown, blocky, weakly indurated	2.0
Shale and siltstone, greenish-gray, mottled orange-brown, dolomitic, thin-bedded, moderately indurated	0.5
Shale, red-brown to orange-brown, silty, blocky, weakly indurated	0.5
Shale and siltstone, greenish-gray, mottled tan, dolomitic, silty, moderately indurated	0.1
Shale, orange-brown, silty, laminated, weakly indurated	0.5
Shale and siltstone, tan, thinly laminated, moderately indurated; erodes into ledge	0.2
Shale, red-brown, silty, blocky, weakly indurated	0.3
Shale and siltstone, greenish-gray, dolomitic, thin-bedded, moderately indurated; with some interbedded red-brown shale; erodes into ledge	1.0
Shale, greenish-gray and red-brown, silty, blocky, weakly indurated, thin-bedded	2.0
CLOUD CHIEF FORMATION (upper 42 feet exposed):	
Shale, orange-brown, blocky, weakly indurated	5.0
Shale, greenish-gray, silty, dolomitic, moderately indurated; mottled orange brown in middle	0.25

Shale, orange-brown; as above	2.0
Shale, greenish-gray, dolomitic, moderately indurated, platy to blocky; with four 1- to 3-inch beds of red-brown shale	2.75
Shale, orange-brown, blocky, weakly indurated	6.0
Shale, greenish-gray; as above; with interbedded orange-brown shale	0.5
Shale, orange-brown, blocky, weakly indurated	1.75
Siltstone, greenish-gray, argillaceous, platy, moderately indurated	0.1
Shale, orange-brown; as above	1.5
Siltstone, greenish-gray; as above	0.25
Shale, orange-brown, crinkly bedded; as above; with many 1-inch satin-spar layers	11.5
Shale, red-brown to orange-brown, blocky, weakly indurated, partly covered by U.S. Highway 66	5.0
Siltstone, greenish-gray, arenaceous, platy, moderately indurated; erodes into ledge	0.1
Siltstone, red-brown, argillaceous, blocky, weakly indurated	0.4
Siltstone, greenish-gray, mottled orange-brown, argillaceous, blocky, weakly indurated	0.4
Siltstone and mudstone conglomerate, greenish-gray, mottled tan, fine-grained, thin-bedded, well-indurated; erodes into ledge	2.0
Shale, orange-brown, blocky, weakly indurated; exposed to west lane of U.S. Highway 66.	3.0

12. North Carpenter Core, Custer County, Roger Mills County

Beginning at top in Elk City Sandstone on outcrop along road and west of road in NE¼ sec. 1, T. 12 N., R. 21 W., Roger Mills County, upper 32 feet of Doxey Shale was measured below 8 feet of Elk City, and then remainder of section was extrapolated to U.S. Army Corps of Engineers North Carpenter site in SE¼SW¼NW¼ sec. 31, T. 13 N., R. 20 W., Custer County, at elevation of 1,940 feet, where 4-inch cores were recovered to total depth of 228.6 feet, penetrating top 67.3 feet of Cloud Chief Formation.

	Thickness (feet)
ELK CITY SANDSTONE (8 feet exposed):	
Sandstone, orange-brown, fine-grained, quartzose, massive, friable; with 1-inch basal greenish-gray zone of sandstone, siltstone, and shale	8.0+
FOSS GROUP	
DOXEY SHALE (approximate total thickness, 195.65 feet):	
Shale, red-brown, silty, blocky, weakly indurated	5.25
Siltstone, red-brown, micaceous, argillaceous, blocky, moderately indurated; erodes into ledge	0.25
Shale, red-brown; as above	2.5
Siltstone, red-brown; as above; with some interbedded red-brown shale	1.5
Shale, red-brown; as above; with some interbedded red-brown siltstone	6.0
Siltstone, greenish-gray to red-brown, argillaceous, blocky, moderately indurated; erodes into ledge	0.1
Shale, red-brown; as above	1.0
Siltstone, greenish-gray; as above	0.1
Shale, red-brown; as above	0.6
Siltstone, greenish-gray; as above	0.1
Shale, red-brown; as above	0.8
Siltstone, greenish-gray; as above	0.1
Shale, red-brown; as above	4.2
Siltstone, orange-brown, arenaceous, thin-bedded, platy, moderately indurated; mottled greenish-gray at top; erodes into ledge	1.0
Siltstone, greenish-gray, arenaceous, laminated, moderately indurated; erodes into ledge	0.1
Shale, red-brown, silty, blocky; with some interbedded red-brown siltstone	3.2
Siltstone, red-brown and greenish-gray, argillaceous, thinly laminated, moderately indurated	0.1
Shale, red-brown; as above	4.0
Siltstone, greenish-gray, mottled orange-brown, thinly laminated; as above; erodes into ledge	1.2
Shale, red-brown; as above	2.25
Siltstone, orange-brown, argillaceous, quartzose, moderately indurated, thinly laminated, calcitic; with some interbedded red-brown shale and 1-inch greenish-gray spots and layers; extrapolated into well	30.3
Siltstone, greenish-gray to orange-brown, argillaceous, thinly laminated, moderately indurated; with interbedded red-brown shale	0.7
Siltstone, orange-brown; as above	1.2
Siltstone, greenish-gray to orange-brown; as above	0.3
Siltstone, orange-brown; as above	3.1
Siltstone, greenish-gray to orange-brown; as above	0.3
Siltstone, orange-brown; as above; with some greenish-gray spots and layers 9 to 13 feet above base	33.4
Shale, red-brown, mottled orange-brown, silty, blocky, thinly laminated, moderately indurated; with some interbedded orange-brown siltstone and calcite veins	24.4
Dolomite, tan to greenish-gray, argillaceous, silty, thinly laminated, moderately indurated	0.4
Shale, red-brown, mottled orange-brown, well-indurated; as above; with calcite veins and zones 8 to 13 feet above base	16.6
Siltstone, orange-brown, micaceous, argillaceous, quartzose, thinly laminated, well-indurated	10.8
Shale, red-brown, mottled orange-brown; as above; with interbedded orange-brown siltstone	6.8
Shale and siltstone, orange-brown, mottled greenish-gray; as above	1.8
Shale, red-brown, mottled orange-brown; as above; with interbedded orange-brown siltstone	8.7
Shale and siltstone, orange-brown, mottled greenish-gray; as above	9.5
Shale, red-brown, mottled orange-brown; as above; with some greenish-gray zones in upper 2 feet	5.5
Siltstone, orange-brown; as above	4.7
Shale, red-brown, mottled orange-brown, silty, blocky; with dolomite streaks and greenish-gray spots in basal 1 foot	2.8
CLOUD CHIEF FORMATION (upper 67.3 feet cored):	

Siltstone and shale, orange-brown, quartzose, blocky, weakly to moderately indurated; with some 1-inch greenish-gray spots and layers	21.7
Shale, orange-brown, gypsiferous, silty, thinly laminated, moderately indurated; with many 1- to 2-inch satin-spar veins and layers . .	29.7
Shale, orange-brown, silty, blocky, moderately to weakly indurated	3.0
Sandstone, orange-brown, fine-grained, quartzose, silty, moderately indurated; mottled with some greenish-gray specks	12.9

13. North Canute Section, Custer County

Beginning at top in Elk City Sandstone in SE¼SE¼ sec. 34, T. 12 N., R. 20 W., along north side of road, and proceeding down section into Doxey Shale; section measured eastward along ditch.

	Thickness (feet)
Elk City Sandstone (34 feet exposed):	
Sandstone, orange-brown, fine-grained, quartzose, silty, friable, weakly indurated, laminated	10.0
Shale, red-brown, mottled greenish-gray, blocky, weakly indurated	1.2
Sandstone, orange-brown, fine-grained, quartzose, silty, massive, friable, moderately to weakly indurated	2.0
Shale, red-brown; as above	0.2
Sandstone, orange-brown; as above	0.4
Shale, red-brown; as above	0.5
Sandstone, orange-brown; as above	5.0
Shale, maroon to light-greenish-gray, laminated, weakly indurated; erodes into prominent purple and white zone	0.4
Siltstone, orange-brown, argillaceous, blocky, weakly indurated	0.5
Sandstone, orange-brown, fine-grained, quartzose, cross-bedded, thinly laminated, friable, weakly indurated	13.0
Sandstone, greenish-gray, fine-grained, quartzose, friable, laminated, weakly indurated; with 1-inch argillaceous siltstone and shale at base	0.75
FOSS GROUP	
Doxey Shale (10 feet exposed):	
Shale, red-brown, silty, blocky, weakly indurated	10.0+

14. West Eakly Core, Washita County

Beginning at top in Cloud Chief gypsum at elevation of 1,605 feet, and proceeding down section into Rush Springs Formation, continuous 4-inch cores were taken by U.S. Army Corps of Engineers at West Eakly site to total depth of 224.7 feet, in SE¼NE¼NW¼ sec. 3, T. 9 N., R. 14 W., about 7 miles west-southwest of Eakly and 4 miles west of "Hastings Moore's Laboratory."

	Thickness (feet)
FOSS GROUP	
Cloud Chief Formation (lower 70.2 feet cored):	
Gypsum, white to light-pink, fine-grained, well-indurated, alabaster-like; mottled with greenish-gray dendrites; with many 0.5-inch vuggy zones	24.8
Anhydrite, gray to light-pink, fine-grained, well-indurated; with some white to light-pink gypsum stringers and 0.5-inch pink gypsum crystals	40.0
Gypsum, gray to light-pink, fine-grained, well-indurated; interbedded with anhydrite in upper 2 feet; with thinly laminated dolomite in lower 2 inches	5.4
WHITEHORSE GROUP	
Rush Springs Formation (154.5 feet cored):	
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, moderately to weakly indurated; calcitic in upper 6 inches	44.1
Weatherford Bed:	
Dolomite, pink to maroon and greenish-gray, fine- to medium-grained, well-indurated, thinly laminated, crinkly bedded	0.7
Unnamed beds:	
Sandstone, orange-brown, moderately to well-indurated, cross-bedded to even-bedded; as above; with many 0.125-inch light-colored calcitic sand balls and some medium-sized sand grains	63.6
Sandstone, orange-brown, medium-grained, cross-bedded, thinly bedded, moderately indurated	2.2
Sandstone, orange-brown, fine-grained; as above; grades into some medium-grained sandstone; with some 0.25-inch calcitic sand balls	43.9

15. North Cheyenne Core, Roger Mills County

Beginning at top in Doxey Shale in high hill in SW¼ sec. 31, T. 14 N., R. 23 W., about 90 feet of section measured down east bluff along creek into Cloud Chief Formation (only upper 39 feet of Cloud Chief is used in description). Section then extrapolated to U.S. Army Corps of Engineers North Cheyenne site in NW¼SE¼SW¼ sec. 32, T. 14, N., R. 23, W., at elevation of 1,980 feet, where 4-inch cores were taken to total depth of 226.5 feet. Upper 22.5 feet is Pleistocene clay, and dip is about 3° south, with Doxey base about 17 feet above top of well; upper 39 feet of Cloud Chief is eroded away, and this part of section is extrapolated from outcrop.

	Thickness (feet)
FOSS GROUP	
Doxey Shale (exposed thickness, 26.5 feet; elevation, 2,170 feet at top of hill):	
Shale, red-brown, silty, blocky	5.0
Siltstone, red-brown, argillaceous, thin-bedded, blocky, well-indurated; erodes into ledge	3.5
Shale, red-brown, silty, blocky, weakly indurated; with some interbedded red-brown siltstone; greenish-gray in basal 1 foot . . .	18.0
Cloud Chief Formation (total thickness, 190 feet):	
Big Basin Member (total thickness, 127 feet):	
Shale, orange-brown, blocky, weakly indurated; with some 1-inch greenish-gray streaks in middle	18.5

Siltstone, greenish-gray, argillaceous, blocky, moderately indurated; erodes into ledge	0.2
Shale, orange-brown; as above	13.0
Siltstone, orange-brown, argillaceous, thin-bedded, weakly indurated; with some interbedded greenish-gray layers	8.0
Siltstone, orange-brown, argillaceous, calcitic, quartzose, thinly laminated, platy, weakly to moderately indurated; extrapolated 22.5 feet down in well to top of this unit	2.7
Shale, orange-brown, silty, blocky to platy, moderately indurated; mottled with some greenish-gray spots; grades into siltstone	2.1
Siltstone, orange-brown, micaceous; as above; with greenish-gray sandstone streaks 0.4-foot thick and 1-foot thick, 7.2 and 1.3 feet above base, respectively	21.3
Siltstone, orange-brown, argillaceous, calcitic, blocky, moderately indurated; with some interbedded orange-brown shale and greenish-gray streak 3.1 feet above base	13.4
Siltstone, greenish-gray, mottled orange-brown, quartzose, moderately to well-indurated, thinly laminated	0.9
Shale, red-brown, platy, moderately indurated; with interbedded orange-brown siltstone	0.3
Siltstone, orange-brown to greenish-gray, arenaceous, quartzose, thinly laminated, moderately indurated	0.7
Shale, red-brown; as above	0.3
Sandstone and siltstone, orange-brown and greenish-gray, fine-grained, quartzose, micaceous, gypsiferous, well-indurated, thinly laminated	2.7
Sandstone, orange-brown, fine-grained, quartzose, micaceous, silty, weakly indurated	3.1
Siltstone, orange-brown; as above	2.8
Sandstone, orange-brown; as above	1.4
Siltstone, orange-brown; as above	9.8
Sandstone, orange-brown, mottled greenish-gray; as above	2.3
Siltstone, orange-brown; as above; with some interbedded shale	10.2
Sandstone, orange-brown, mottled greenish-gray, fine-grained, quartzose, micaceous, massive, weakly indurated	4.5
Siltstone, orange-brown; as above	1.9
Shale, red-brown, silty, blocky, weakly indurated	2.6
Siltstone, orange-brown and greenish-gray, quartzose, arenaceous, gypsiferous, moderately to well-indurated	1.3
Sandstone, orange-brown, mottled greenish-gray, gypsiferous, well-indurated; as above	1.4
Shale, red-brown, silty, blocky, gypsiferous, moderately to weakly indurated	2.0
Day Creek Bed (thickness, 6.3 feet):	
Gypsum, white, fine-grained, well-indurated; with some interbedded orange-brown siltstone and sandstone	0.5
Siltstone and sandstone, orange-brown, mottled greenish-gray, fine-grained, quartzose, gypsiferous, massive, moderately to well-indurated	5.3
Gypsum, white, fine-grained, well-indurated, massive	0.5
Kiger Member (thickness, 51.3 feet):	
Siltstone, orange-brown, quartzose, gypsiferous, moderatly indurated; with interbedded red-brown shale	4.0
Sandstone, orange-brown, mottled greenish-gray, fine-grained, silty, quartzose, gypsiferous, massive, well-indurated	1.4
Shale, red-brown, silty, gypsiferous, blocky, weakly indurated	0.9
Sandstone and siltstone, orange-brown, fine-grained, quartzose, micaceous, gypsiferous, well-indurated, massive	2.4
Shale, red-brown; as above	1.3
Sandstone and siltstone, orange-brown; as above	3.4
Shale, red-brown, silty, gypsiferous, blocky, weakly indurated; grades into orange-brown siltstone	7.9
Sandstone and siltstone, orange-brown to greenish-gray, fine-grained, quartzose, gypsiferous, well-indurated	6.2
Siltstone, orange-brown, argillaceous, gypsiferous, blocky, well-indurated	2.7
Sandstone and siltstone, orange-brown to greenish-gray; as above	9.1
Siltstone, orange-brown, argillaceous, gypsiferous, blocky, weakly indurated; with many thin satin-spar beds up to 1 inch thick	7.2
Shale, red-brown, silty, gypsiferous, blocky, weakly indurated; with many satin-spar seams up to 1 inch thick	4.8
Moccasin Creek Bed (thickness, 4.5 feet):	
Gypsum, white to grayish-orange, fine-grained, well-indurated; with interbedded orange-brown siltstone; maroon at base	0.7
Shale and siltstone, orange-brown, gypsiferous, blocky	0.9
Gypsum, white; as above	0.5
Shale, red-brown, gypsiferous; as above	0.5
Gypsum, white to gray, fine-grained, well-indurated	1.9
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (cored thickness, 54.2 feet to bottom of well):	
Sandstone, orange-brown, fine-grained, silty, quartzose, gypsiferous, moderately to well-indurated	25.6
Sandstone, orange-brown, fine-grained, silty, quartzose, micaceous, massive, moderately to weakly indurated; gypsiferous in places	14.9
Sandstone, orange-brown, moderately to well-indurated; as above; exposed to bottom at total depth of 226.5 feet	13.7

16. One Horse Creek Section, Dewey County

Beginning at top in Moccasin Creek Bed of Cloud Chief Formation in NW¼ sec. 27, T. 16 N., R. 15 W., at elevation of 1,820 feet, and proceeding down section to type One Horse Gypsum (Weatherford Bed now) east of road. Section then measured to northeast in SE¼ sec. 22 to type Old Crow Bed and in NE¼ sec. 22 to 90 feet below Old Crow in tributaries to One Horse Creek to north. Section then extrapolated to NW¼ sec. 25 and SW¼SW¼ sec. 24, T. 16 N., R. 15 W., to Emanuel and Relay Creek Beds in bluffs along Canadian River bottoms.

	Thickness (feet)
FOSS GROUP	
CLOUD CHIEF FORMATION:	
Moccasin Creek Bed:	
Dolomite, light-pink to white, fine-grained, well-indurated, vuggy, thinly laminated; grades into gypsum; erodes into ledge in road; also exposed in south-central part of sec. 29 and south-central part of sec. 19, T. 16 N., R. 15 W., and 30 feet above One Horse Gypsum	0.5
WHITEHORSE GROUP (estimated total thickness, 380 feet)	
RUSH SPRINGS FORMATION (total thickness, 280 feet):	
Sandstone, orange-brown, very fine-grained, quartzose, even-bedded, silty, weakly indurated; covered in lower 10 feet	32.0
Weatherford Bed (type One Horse Gypsum):	
Gypsum, white and pink, fine-grained, thinly laminated, well-indurated, crinkly bedded; erodes into prominent escarpment	4.0
Unnamed beds (thickness, 84 feet):	
Sandstone, orange-brown, weakly indurated; as above	14.0
Sandstone, orange-brown, gypsiferous, platy, well-indurated; as above; erodes into ledge	2.0
Sandstone, orange-brown, very fine-grained, quartzose, silty, weakly indurated	4.0
Sandstone, orange-brown, gypsiferous, platy, moderately indurated; as above; with many 1-inch flat gypsum nodules	5.0
Sandstone, orange-brown, weakly indurated; as above; covered in part	16.0
Sandstone, orange-brown, very fine-grained, quartzose, silty, moderately to weakly indurated, even-bedded	43.0
Old Crow Bed (type section):	
Gypsum, light-pink to white, fine-grained, thinly laminated, well-indurated; erodes into prominent mappable escarpment	2.5
Gypsum and sandstone, orange-brown to light-pink, fine-grained, moderately to well-indurated, platy, thinly laminated	4.0
Unnamed beds (thickness, 153.5 feet):	
Sandstone and gypsum, orange-brown, fine-grained, platy, weakly indurated	3.0
Sandstone and gypsum, orange-brown, well-indurated; as above; erodes into ledge	10.5
Sandstone, orange-brown, weakly indurated; as above	15.0
Sandstone and gypsum, orange-brown, well-indurated; as above; erodes into ledge	5.0
Sandstone, orange-brown, weakly indurated, cross-bedded; as above; with some 0.5- to 1-foot impure indurated gypsiferous bands	120.0
MARLOW FORMATION (exposed thickness, 30 feet):	
Emanuel Bed:	
Dolomite, maroon to light-pink, fine-grained, arenaceous, platy, crinkly bedded, well-indurated; erodes into ledge; section extrapolated to NW¼ sec. 25, T. 16 N., R. 15 W. just north of creek	0.1
Unnamed beds:	
Sandstone, orange-brown, fine-grained, quartzose, cross-bedded, moderately indurated	27.0
Relay Creek Bed:	
Gypsum, white and pink, thinly laminated, well-indurated; erodes into prominent ledge about 2 feet above Canadian River flood plain; farther north along river, bed is almost 10 feet thick in NW¼ sec. 4 and NE¼ sec. 5, T. 16 N., R. 15 W., last remnant of which was found in NW¼ sec. 6, T. 17 N., R. 15 W., at elevation of 1,630 feet, where it is covered by alluvium	1.0
Unnamed beds:	
Sandstone, orange-brown, fine-grained, quartzose, even-bedded, weakly indurated	2.0

17. West Leedey Core, Dewey County

Beginning at top in Doxey Shale, section measured along road in SE¼SW¼ sec. 6, T. 16 N., R. 20 W., ending 11 feet below top of Cloud Chief Formation. Section then extrapolated to NW¼SE¼SW¼SE¼ sec. 7, T. 16 N., R. 20 W., where 4-inch cores were taken by U.S. Army Corps of Engineers at West Leedey site, extending through Cloud Chief into 92 feet of Rush Springs Formation, to total depth of 226 feet. Elevation of site is 2,090 feet and is 37 feet below base of Doxey Shale, contact being in adjacent hill to west. This is provisional type section for Cloud Chief Formation and type Big Basin Member.

	Thickness (feet)
FOSS GROUP	
DOXEY SHALE (exposed thickness, 74 feet):	
Shale, red-brown, silty, blocky, moderately indurated	20.0+
Siltstone, red-brown, moderately to well-indurated, thinly laminated; mottled with tan dolomitic streaks; with some interbedded red-brown shale; erodes into ledge	3.5
Shale, red-brown; as above	12.0
Siltstone, tan, dolomitic, argillaceous, thinly laminated, well-indurated; mottled red brown in places; erodes into prominent ledge	2.5
Shale, red-brown; as above	0.75
Siltstone, red-brown; as above	0.75
Shale, red-brown; as above	1.75
Siltstone, red-brown; as above	0.75
Shale, red-brown; as above; with some interbedded tan dolomitic shale and siltstone beds and veins; partly covered in lower 5 feet	32.0
CLOUD CHIEF FORMATION (total thickness, 171 feet; type section):	
Big Basin Member (total thickness, 126 feet; type section):	
Sandstone, orange-brown, fine-grained, silty, quartzose, moderately to well-indurated, thin-bedded; with a 1- to 3-inch greenish-gray ledge at top and one at base	6.0
Shale, orange-brown, silty, platy, weakly indurated	3.5
Sandstone, orange-brown; as above; with alternating orange-brown shale; partly covered in lower 26 feet to top of well	27.5
Siltstone, orange-brown, arenaceous, thinly laminated, moderately indurated; mottled	

with some greenish-gray spots; cross-bedded in basal 4 inches	16.8
Sandstone, orange-brown, fine-grained, silty, quartzose, moderately indurated	0.4
Shale, orange-brown, mottled greenish-gray, silty, blocky, thinly laminated, weakly indurated	1.2
Siltstone, orange-brown; as above	6.9
Siltstone, red-brown to orange-brown, argillaceous, thinly laminated, platy, weakly indurated; mottled with greenish-gray spots	2.3
Siltstone, orange-brown, mottled greenish-gray, arenaceous, quartzose, weakly indurated	1.2
Siltstone, orange-brown, mottled greenish-gray, argillaceous, blocky, weakly indurated	3.6
Shale, orange-brown, silty, platy, weakly indurated	7.5
Siltstone, orange-brown, arenaceous, blocky, weakly indurated; mottled with greenish-gray spots	7.2
Shale, red-brown to orange-brown, silty, blocky, weakly indurated	4.7
Siltstone, orange-brown, argillaceous, blocky, weakly indurated; mottled greenish gray in upper 2 inches	7.1
Siltstone, orange-brown, mottled greenish-gray, arenaceous, moderately indurated	1.3
Sandstone, orange-brown to greenish-gray, fine-grained, silty, quartzose, weakly indurated	2.4
Siltstone, orange-brown to greenish-gray, argillaceous, blocky, weakly indurated	2.9
Siltstone, orange-brown to red-brown, argillaceous, blocky, weakly indurated	2.6
Siltstone, orange-brown, arenaceous, moderately indurated	2.0
Siltstone, red-brown to orange-brown, argillaceous, moderately indurated	1.0
Sandstone, greenish-gray, mottled orange-brown, fine-grained, quartzose, silty, gypsiferous, well-indurated	3.4
Shale, red-brown, silty, gypsiferous, blocky, selenitic, moderately indurated	2.1
Siltstone, orange-brown, argillaceous, blocky, moderately indurated	1.7
Siltstone, orange-brown to greenish-gray, arenaceous, gypsiferous, moderately indurated	3.3
Shale, red-brown to orange-brown, silty, gypsiferous, blocky, weakly indurated; with some 0.25-inch satin-spar veins	7.5
Day Creek Bed:	
Gypsum, white to light-orange, fine-grained, selenitic, well-indurated	3.0
Kiger Member (total thickness, 28.8 feet):	
Shale, red-brown, silty, blocky, weakly indurated	2.3
Shale, red-brown; as above; with many 1- to 2-inch selenite nodules	0.8
Gypsum and sandstone, greenish-gray, mottled red-brown, fine-grained, quartzose, silty, well-indurated	0.5
Siltstone, orange-brown, arenaceous, gypsiferous, well-indurated	2.0
Siltstone, orange-brown, argillaceous, gypsiferous, blocky, weakly indurated	1.8
Siltstone, orange-brown, arenaceous, well-indurated	1.3
Siltstone, orange-brown, argillaceous, moderately indurated	0.6
Gypsum, white, fine-grained, well-indurated; with interbedded red-brown blocky shale	0.8
Shale, red-brown, silty, blocky, weakly indurated	1.8
Sandstone, orange-brown, fine-grained, quartzose, silty, gypsiferous, well-indurated	0.9
Siltstone, orange-brown, arenaceous, gypsiferous, moderately indurated	3.8
Siltstone, orange-brown, argillaceous, gypsiferous, moderately indurated; with many 0.5-inch satin-spar veins	12.4
Moccasin Creek Bed (total thickness, 13.5 feet):	
Gypsum, white to light-orange, fine-grained, selenitic, argillaceous, well-indurated	3.0
Shale, red-brown to orange-brown, silty, gypsiferous, blocky, weakly indurated; with some 0.5-inch greenish-gray spots	4.4
Gypsum, white to light-orange, fine-grained, well-indurated	0.7
Siltstone, red-brown to orange-brown, argillaceous, gypsiferous, weakly indurated; grades into shale	3.3
Gypsum, white to light-orange; as above; red-brown and dolomitic in basal 8 inches	2.1
WHITEHORSE GROUP	
RUSH SPRINGS FORMATION (upper 91.6 feet cored):	
Shale, red-brown, gypsiferous, blocky, weakly indurated	1.3
Sandstone, greenish-gray, fine-grained, quartzose, gypsiferous, well-indurated	0.3
Sandstone, orange-brown, fine-grained, quartzose, silty, well-indurated	5.8
Siltstone, orange-brown, arenaceous, gypsiferous, moderately indurated; with well-indurated 0.5-foot band 1 foot above base	7.7
Siltstone, orange-brown, argillaceous, gypsiferous, weakly to moderately indurated	2.5
Siltstone, orange-brown, arenaceous, weakly indurated; grades into fine-grained quartzose sandstone	6.5
Weatherford Bed:	
Gypsum, white to gray, fine-grained, selenitic, well-indurated; mottled greenish gray in lower 0.5 inch	1.1
Unnamed beds:	
Siltstone, orange-brown, gypsiferous, arenaceous, well-indurated	4.0
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	1.0
Sandstone, orange-brown, fine-grained, quartzose, silty, gypsiferous, well-indurated	4.4
Sandstone, orange-brown, fine-grained, quartzose, silty, weakly indurated	3.5
Siltstone, orange-brown, arenaceous, gypsiferous, well-indurated; with 1-inch white gypsum 5.3 feet above base	9.8
Siltstone and sandstone, orange-brown, fine-grained, quartzose, weakly indurated	2.9
Siltstone and sandstone, orange-brown, fine-grained, quartzose, gypsiferous, well-indurated	1.5
Siltstone, orange-brown, fine-grained, arena-	

ceous, moderately indurated, with some 0.125-inch satin-spar veins 5.9
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, silty, well-indurated; with interbedded siltstone 5.4
Siltstone, orange-brown, argillaceous, arenaceous, gypsiferous, moderately to well-indurated 4.2
Sandstone, orange-brown, fine-grained, quartzose, gypsiferous, well-indurated 1.7
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated 2.5
Siltstone, orange-brown, arenaceous, gypsiferous, moderately indurated 1.5
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated 3.2
Siltstone, orange-brown, arenaceous, quartzose, moderately indurated 1.8
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated 3.1
Siltstone, orange-brown, arenaceous, gypsiferous, moderately indurated 1.9
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated 1.4
Sandstone, orange-brown, fine-grained, quartzose, moderately indurated; with interbedded siltstone 1.2
Sandstone, orange-brown, fine-grained, quartzose, weakly indurated; with some well-indurated gypsiferous beds 2.5
Siltstone, orange-brown, argillaceous, arenaceous, moderately indurated; to bottom of core at total depth of 226 feet 3.0

18. South Harmon Section, Ellis County

Beginning at top in Doxey Shale, and proceeding down section in NW1/4 sec. 26, T. 18 N., R. 22 W., west of road in high hill; section then extrapolated east of road and southward to bluffs north of Canadian River, extending from Cloud Chief Formation into Rush Springs Formation. Section then extrapolated to stratigraphic test in NW1/4 sec. 23, T. 17 N., R. 22 W., 910 feet south and 50 feet east of northwest corner, at elevation of 1,975 feet [given as 1,957 feet, but this does not check out with location]. Top of well is about 35 feet stratigraphically below top of Rush Springs.

Thickness (feet)

FOSS GROUP
DOXEY SHALE (lower 10 feet exposed):
Shale, red-brown, silty, blocky, weakly indurated 10.0
CLOUD CHIEF FORMATION (total thickness, 124 feet):
Siltstone, orange-brown to greenish-gray, calcitic, thinly laminated, crinkly bedded, well-indurated; erodes into ledge 3.0
Shale and siltstone, red-brown to orange-brown, blocky, weakly indurated 34.0
Gypsum and sandstone, red-brown to orange-brown, fine-grained, thinly laminated, well-indurated; erodes into ledge 10.0
Shale, orange-brown, silty, even-bedded, weakly to moderately indurated, with some 1- to 2-foot orange-brown fine-grained sandstone beds 21.0
Sandstone, orange-brown, fine-grained, quartzose, thin-bedded, even-bedded, well-indurated; erodes into ledge; with 1/2-inch selenite layers about 5 feet above base 25.0
Shale, red-brown to orange-brown, silty, blocky, weakly indurated 30.0
Moccasin Creek Bed:
Gypsum, white, mottled light-greenish-gray to red-brown, thinly laminated, well-indurated, crinkly bedded; erodes into prominent ledge and mappable escarpment 1.0
WHITEHORSE GROUP (thickness, 385 feet)
RUSH SPRINGS FORMATION (total thickness, 285 feet):
Sandstone, orange-brown, gypsiferous, thinly laminated, moderately indurated 7.25
Shale, red-brown, silty, blocky; exposed . . . 5.0
Sandstone and shale, as above, with some white gypsum streaks; extrapolated to well, with top of well about 35 feet below top of Rush Springs 193.0
Sandstone, orange-brown, fine-grained, with some gypsiferous streaks 80.0
MARLOW FORMATION (thickness, 100 feet):
Gypsum, white, with some shale streaks; in several beds, probably representing Emanuel and Relay Creek Beds 20.0
Sandstone, orange-brown, fine-grained, with some gypsiferous streaks near top and some silty shale in basal 20 feet 80.0
EL RENO GROUP
DOG CREEK SHALE (thickness, 95 feet):
Shale, red-brown, with bluish streak about 50 feet down (Southard?) 80.0
Haskew Gypsum Member:
Gypsum, white, crystalline 10.0
Unnamed member:
Shale, red-brown 5.0
BLAINE FORMATION (thickness, 105 feet):
Shimer Member:
Anhydrite, grayish-white, crystalline 33.6
Altona Dolomite Bed:
Dolomite, gray, silty 1.3
Unnamed beds:
Shale, bluish-gray 1.2
Shale, red-brown, with thin gypsum streaks 6.2
Nescatunga Member:
Anhydrite, grayish-white, crystalline 14.1
Magpie Bed:
Shale, gray, dolomitic 1.2
Unnamed bed:
Shale, red-brown 1.0
Kingfisher Creek Bed:
Anhydrite, grayish-white, crystalline 12.0
Dolomite, gray 1.0
Unnamed bed:
Shale, bluish-gray and red-brown 1.7
Medicine Lodge Gypsum Member:
Anhydrite, gray, with thin dolomitic streaks near base 7.2
FLOWERPOT SHALE (30 feet drilled):
Shale, red-brown and bluish-gray, with thin gypsum streaks to total depth of 580 feet 30.0

INDEX

(**Boldface** numbers indicate main references; parentheses indicate page numbers of figures; brackets indicate page numbers of tables)

Acme Brick Co. 47
Ahlen, J. H., and others, cited 8, 18, 31
Alberto-Culver Co. 50
Alfalfa section 78, 79
Alibates Bed 27, 32, 34, 36
Alibates Creek 34
Alibates Dolomite 1, 31, 34
alluvium 2, 18, 64, 66
Amarillo Mountains 35
Anadarko, Oklahoma 9, 11
Anadarko basin 1, 6
Anadarko syncline 4
anhydrite 34, 49, 54
Anthon, Oklahoma 3
aquifers 66
aragonite 23
Arapaho, Oklahoma 3
Arbuckle Mountains 19, 37
Artesia Formation 8
Artinskian, Kungurian, and lower Kazanian, Russia 6
Atoka, Oklahoma 19
Aviculopecten vanvleeti 9, 18
Baca County, Colorado 43, 44
Barnes, Dr. Virgil E. 6, 8
Barnitz Creek 3, 42, 46
Base of the Permian—a Century of Controversy, The 6
Baylea capertoni 9, 18
Bear Creek 21, 41
Beaver County, Oklahoma 9, 37
Beckham County, Oklahoma 1, 6, 32, 35
Beede, J. W., cited 9
Bellerophon sp. 18
Bellis, William H. 4, 34
Belvidere, Kansas 37, 39
Belvidere Beds 38
Belvidere Shales 37
Berlin, Oklahoma 36
Bessie, Oklahoma 3, 19
Bessie Member of Quartermaster Formation 32
Big Basin Member of Cloud Chief Formation 1, 5, 20, 21, 25, **26-28,** 29, 30
Black Hill Shale 38
Blaine County, Oklahoma 8, 17
Blaine Formation 20, 34, 54, 62
Blake, W. P., cited 42
Blue Cut Shales 38
Borger, Texas 6, 7, 18, 32, 34
Branson, Carl C. 4
Buckstaff, Sherwood, cited 32
Bullard, F. M., cited 38, 39, 42
Burns Flat area 36
Butler, Oklahoma 3, 4
Buttram, Frank, cited 49
Caddo County, Oklahoma 9, 11, 21, 41
calcite 1, 11, 23, 49, 50
calcium carbonate 45
caliche deposits 44, 45, (46)
Camargo, Oklahoma 17, 28
Camp Supply Beds 37
Canadian County, Oklahoma 9
Canadian River 1, 3, 4, 5, 8, 10, 17, 21, 31, 34, 41, 61, 63, 65
  Pleistocene deposits 44
Canute, Oklahoma 36, 37
Capitan of Texas 9, 18, 31
Carbonera Formation, Mexico 38
Carr, J. E., and Bergman, D. L., cited 61
Castile-Salado (basal Ochoan) rocks 34
Castile-Salado gypsum 31, 34
Cave Creek, Comanche County, Kansas 7
Cave Creek Formation 23
celestite 23
Centennial Mound Dolomite 25
Chambers, Fred 4
Champion Shell Bed 38, 39, 42
Cherry Canyon Formation 18
Cheyenne, Oklahoma 17, 30, 31
Cheyenne Sandstone 37, 38, 43
Chickasha Formation 5
Childress Dolomite 8
Choctaw County, Oklahoma 38
Cimarron County, Oklahoma 37, 42, 43, 44
Cimarronian Series 6, 19
Clapp, F. G., cited 10
Clark County, Kansas 26
clay 1, 11, 44, 45, 47, 48, (48), 49
Clinton, Oklahoma 1, 2, 3, 11, 19, 23, 24, 31, 47, 64, 65
Cloud Chief Formation 1, 2, 4, 5, 6, 7, 10, 11, 13, 17, 18, 19, **20-32,** (25), (27), (28), 34, 35, 36, 41, 47, 49, 50, 62
  in Custer County **20-32**
  in Dewey County 20, 27, 28, 29, 30
  in Roger Mills County 20, 21, 27, 30, 31
  origin of sand in 32
Cloud Chief gypsum 19, 21, 41
Collingsworth County, Texas 18
Comanchean Series **37-44**
  Fredericksburg Group 37
  Trinity Group 37
  Washita Group 37
Comanche County, Kansas 6, 43
Comet Creek 37, 42
Comet Creek Bed 37
Composita 9, 18
  mexicana 9, 18
  subcircularis 9, 18
Condra, G. E., and Reed, E. C., cited 43
Conocardium oklahomense 9
Cope, E. D., cited 37
Cordell, Oklahoma 3, 37
Cragin, F. W., cited 6, 10, 17, 20, 23, 25, 26, 37
Cretaceous rocks 4, 5, 37
Cretaceous System 1, **37-44**
Curtis, N. M., cited 60
Custer City, Oklahoma 3, 4, 49, 65
Custer County, Oklahoma 1, 2, (2), 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 17, 18, 19, 20, 25, 26, 32, 35
Custerian Series 4, 5, **6-37**
Custerian Stage 6
Cyclites depressus 9
Cyclobathmus haworthi 9, 18
Cyril beds 10
Cyril Gypsum 21
Dakota City, Nebraska 43
Dakota Group 1, 5, **43-44,** (44)
Dakota rocks 37
Davis, Roy D. 4, 11
Day Creek Bed of Cloud Chief Formation 1, 4, 5, 6, 7, 10, 20, 23, 24, **25-26,** 27, 28, 29, 30, 50—*see also* Day Creek Dolomite
Day Creek Dolomite 1, 4, 5, 6, 7, 10, 20, 23, 24, 25, 26, (26), (27), (28), 30—*see also* Day Creek Bed
Deer Creek 3, 5, 50
  Pleistocene deposits 44
DeFord, R. K., and Lloyd, E. R., cited 8-9, 18, 31
Dewey County, Oklahoma 4, 6, 7, 8, 10, 11, 13, 17, 20, 27
Dewey Lake Formation 34, 36
Dippel, Ernest E. ("Bill") 60
Dobrovolny, Ernest, cited 42
Doe Creek Lentil of Marlow Formation 9, 35, 36
Dog Creek Shale 6, 8, 18, 62
dolomite 1, 3, 7, 8, 9, 10, 11, 13, 15, 16, 17, 18, 19, 20, 21, (22), (23), 25, (26), 29, 30, 31, 32, 34, 36, 50, [52], [53]—*see also* Weatherford Bed
Doxey Shale 1, 2, 4, 5, 6, 19, 20, 27, (29), 31, **32-35,** (33), 36, 37, 43, 54, (59), 63
Dozierella gouldii 9, 18
Dozier Lentil, Collingsworth and Hall Counties, Texas 18
Duck Creek Formation 39, 42
Dunbar, C. O., cited 6
Duncan Sandstone 5, 7, 62
Eagle City, Oklahoma 29, 32
East Clinton core 12, 15, 21, 24, 27, 72, 73
Edmondia rotunda 18
Eifler, Gus 31

Elk City, Oklahoma 35
Elk City Sandstone Member of Quartermaster Formation 1, 4, 5, 6, 32, 33, (33), 34, **35-37,** (35), 63
in Beckham County 35, 36
in Washita County 36, 37
Ellis County, Oklahoma 6, 18, 27, 32, 37
Elm Creek 41
El Reno Group 6, 62
El Reno time 18
Emanuel Beds of dolomite and gypsum 1, 4, 7, 8, (8), 9, 11, 18
Emanuel-Relay Creek zone 18
Eskota Gypsum 8, 18
Evans, Noel, cited 7, 10, 19, 21, 25
False Wichita 42
Fay, R. O., cited 5, 6, 7, 8, 10, 11, 18, 19, 20, 23, 25, 26, 38
Finch, W. I., cited 60
Finnell System 50
flint 34
Flood, Edith 4
Flowerpot Shale 5, 54, 62
Fort Supply 37
Fort Worth Limestone 38, 39
Foss, Oklahoma 19
Foss Dam 4, 23, 46
Foss Dam core holes 76, 77
Foss Group 1, 4, 5, **19-35,** 37
Foss Reservoir 3, 19, 23, 64
Fran-O-Lite Minerals, Inc. 50
Fullington Shales 38
Fuson Shale 43
Georgetown Limestone 39
Girtyspira? alvaensis 9
Goat Seep Limestone 18
Goodland Limestone 42
Gould, C. N., cited 6, 10, 18, 19, 20, 31
Grady County, Oklahoma 9, 11, 19
Graneros Shale 43
Grayburg Formation 8, 9
Grayson Formation 39
Green D. A., cited 19, 20, 36
Greenfield, Oklahoma 7, 8, 20
Greenfield Limestone 7
Greenhorn Limestone 43
Greer division 19, 20
Gregg, Josiah 4, 12
Gregory, J. N., cited 6
Griggs, R. L., and Read, C. B., cited 42
Griley, H. L., cited 19, 20, 21, 32, 35, 36
Gryphaea 38
arcuata 38
corrugata 38, 39
roemeri 38
Gryphaea (Texigryphaea) 38
Gryphellina sellardsi 9, 18
Guadalupean age 18
Guadalupean-Ochoan boundary 1, 5
Guadalupean rocks 4, 5, 9, 31, 34, 36
gypsite 45
gypsum 1, 3, 4, 6, 7, 8, 9, 10, 11, 13, 15, (15), 16, 17, 18, 19, 20, 21, (22), 23, (24), 28, 29, 30, 31, 32, 34, 42, 46, 49—*see also* Weatherford Bed
Gypsum Creek 41
Hall, James, cited 42
Hall County, Texas 7, 18, 31, 32
Ham, William E. 4, 44, 49
Ham, William E., and Curtis, N. M., Jr., cited 21, 49
Ham, William E., and Jordan, Louise, cited 6, 7
Hammon, Oklahoma 3, 4, 17, 19
Harper County, Oklahoma 9, 10, 25, 27, 29, 32, 37
Hattin, D. E., cited 43
Hemphill County, Texas 17, 18, 31, 32
Hill, Leon 4
Hill, R. T., cited 37
Hobart, Oklahoma 3
Homer, Nebraska 43
Hutchinson County, Texas 31, 32, 34
Imlay, R. W., cited 38
Indianapolis, Oklahoma 3
Indian Hill 3, 12, 36, 44
Izett, G. A., and others, cited 49
Jewett, J. M., and others, cited 26
Johnson, Ralph 36
Jordan, Louise, and Vosburg, D. L., cited 54
Jurassic 38
Jurassic age 42
Kansas 7, 10, 20, 26, 27
Kansas Geological Survey 6, 20
Kauffman, E. G., and others, cited 43
Kazanian and Bakmuth faunas, Russia 9, 18
Kazanian Stage, Russia 5, 6
Kensley, Philip 4
Kent Co., Rome, New York 50
Kiamichi Formation 37, 42
Kiamichi River 38
Kiger Creek, Clark County, Kansas 23
Kiger Member of Cloud Chief Formation 1, 4, 20, 21, **23-25,** 28, 29, 30, 32
Kiowa County, Kansas 37, 38
Kiowa County, Oklahoma 3
Kiowa Formation 1, 5, **37-43,** (41), 43, 44, 63
Kiowa Limestone 43
Kiowa Shale 37, 38, 39
Kungurian Stage, Russia 5, 6
Lakota Sandstone 43
Laminack, Jim 47
Leedey, Oklahoma 31
Leonardian and Lower Guadalupean of Texas 6
Lepetopsis? haworthi 18
Lewis, F. E., cited 8, 9
limestone 1, 5, 37, 38
Lioclema dozierense 9, 18
McLaughlin, T. G., cited 44
Major County, Oklahoma 6
Marcou, Jules, cited 37, 38, 41, 42, 43
Marcou Creek 42
Marlow, Oklahoma 7
Marlow Formation 1, 2, 4, 6, **7-9,** 11, 17, 20, 35, 36, 63, 66
Measured stratigraphic sections
Alfalfa section 78-79
East Clinton core 72-73
Foss Dam Core Hole 30—76-77
Foss Dam Core Hole 31—77-78
North Canute section 80
North Carpenter core 79-80
North Cheyenne core 80-81
North Clinton core 73
One Horse Creek section 81-82
South Harmon section 84
South Leedey core 75-76
South Putnam core 74-75
Sugar Loaf Mound section 71
Thomas section 72
Weatherford section 71
West Clinton section 73-74
West Eakley core 80
West Leedey core 82-84
Meek, F. B., and Hayden, F. V., cited 43
Mesa Rica Sandstone Member of Purgatoire Formation 42
Miser, H. D., and others, cited 7, 10, 17, 19, 20, 21, 30, 32, 42
Missouri River 43
Moccasin Creek Bed of Cloud Chief Formation 1, 4, 6, 7, 10, 11, 12, 13, 15, 16, (16), 17, 18, 19, 20, **21-23,** (22), 23, (23), 24, (24), 28, 29, 30, 31, 32
Möllhausen, cited 39, 41
Moore, R. C., cited 5, 6
Moore County, Texas 18, 31, 34
Moorewood, Oklahoma 3
Morrison Formation 37
Murchisonia gouldii 18
Myalina 34
acutirostris 34
sp. 9, 18
Nasser, C. W., cited 49
Naticopsis transversus 9, 18, 34
Newell, N. D., cited 5, 9
New Mexico 5, 8, 32, 34, 35, 42
Nicholson, Alex. 4
nomenclatural diagram of rock units (4)
North Canute section 80
North Carpenter core 79, 80
North Cheyenne core 17, 80, 81
North Clinton core 73
Norton, S. G., cited 26
Nuttall, Thomas, cited 38
Oak Creek 42
O'Brien, B. E., cited 11
Ochoan rocks 1, 5, 6, 31, 34, 36
O'Connor, H. G., cited 23, 26
Ogallala Formation 18, 31, 32, 37, 42

Oklahoma 5, 6, 7, 10, 18, 23, 28, 31, 32, 34, 35, 36, 38
Oklahoma Geological Survey 54, 61
Old Crow Bed of gypsum and dolomite 1, 4, 10, 11, (12), (13), 17, 18
Olson, E. C., cited 5, 36
Omadi Sandstone 43
One Horse Creek section 81, 82
One Horse Gypsum 10, 11, (12), (15), 17
Ostrea 38
  knorri 38
  liassica 38
  wardi 38
Ouachita Mountains 18, 19, 32, 37
Ozarks, the 18, 19, 32
Pajarito Shale Member of Purgatoire Formation 42
Pakistania schucherti, 9, 18
Parallelodon sp. 18
Pennsylvanian beds 43
Permian red beds 1, 5, 6, 19, 23, 31, 35, 38
Permian System 1, **5-37**, 43
Permophorus 9, 18
  albequus 9, 18
  a. longus 9, 18
Plagioglypta girtyi 18
Pleistocene deposits 1, 3, 4, 37, 43, 45, (45), 46, (46)
  Canadian River 1, 5, 44
  Deer Creek 1, 5, 44
  Washita River 1, 5, 44
Pleistocene rivers 35, 39
Pleistocene Series **44-47**
Plum Creek, Texas 18
post-Foss rocks **35-37**
post-Ochoan 5, 6
Potrero Formation 39
Potter, D. R., cited 43
Potter County, Texas 31, 34
Powers, H. A., and Wilcox, R. E., cited 49
Pseudodielasma perplexa 9, 18
Purgatoire Formation 42
Putnam, Oklahoma 30
Quartermaster Creek 3, 4, 19, 21
Quartermaster Dolomite, Formation, Group 4, 19, 20, 32, 35
quartzite 1, 5, 37, 43, 46
quartzose limestone 21
quartzose sandstone 11, 13, 17, 37
Quaternary System **44-46**
Queen Sandstone, New Mexico 18
Quinlan, Oklahoma 6
Ranch, George Leaverton 18
Red Bed Plains 3
Red Bluff beds 25
Red River 38
Red Rock Uranium Co. 54
Reed of U.S. Geological Survey 36
Reeves, Frank, cited 7, 21
Relay Creek Bed, Dolomite 1, 4, 7, 8, 9, (9), 10
Roberts County, Texas 32, 34
Roger Mills County, Oklahoma 3, 19, 21, 27, 31, 35, 36, 42
Roswell Geological Society 8, 18, 31
Roth, Robert, and others, cited 34
Rush Springs, Oklahoma 9
Rush Springs Formation 1, 2, 4, 6, 7, **9-20**, 21, 23, 26, 29, 30, 31, 35, 44, 61, 63, 65, 66
Rustler Limestone 31, 34, 36
Saddlehorse Gypsum Lentil 18, 31, 32, 34—*see also* Moccasin Creek Bed
salt 1, 4, 54
San Angelo Formation 5
San Angelo Geological Society guidebook 6
sand and gravel 1, 18, 50, 54, [55-57]
sandstone 1, 2, 3, 7, 9, 11, (12), 13, 15, 16, 17, 21, 23, 24, 26, 27, 28, (28), 29, 30, 32, 35, (35), 36, 37, 43, (44), 46, 50
Sandstone Creek 35, 36
Sandstone Creek Lentil 1, 36, 37
Sanford Dam cores 18, 31
Sawyer, R. W., cited 7, 9, 10, 20
Say, Thomas, cited 39
Schizodus oklahomensis 9, 18, 34
Seiling, Oklahoma 17, 29, 30
Seven Rivers Formation 31
shale 1, 4, 5, 9, 10, 15, 19, 21, 22, 23, (25), 26, 27, 29, 32, 33, 34, 35, 37, 38, 43
Siltstone 1, 5, 7, 11, 13, 15, 19, 21, 23, 24, (25), 27, 28, 29, (29), 30, 32, 33, 36, 37, 44
South Harmon section 84
South Leedey core 17, 75, 76
South Putnam core 23, 28, 74, 75
Southwestern Gypsum Co. 49
Spirorbis sp. 9, 18
Stacey, Bill 36
Stafford, Oklahoma 3
Stenzel, H. B., cited 38
Stephens County, Oklahoma 7, 9
Stephenson, C. D., cited 7, 37
Stovall, J. W., cited 42, 43
stratigraphy **4-46**
Streptacis permiana 18
Strong City, Oklahoma 17
Sugar Loaf Mound 3, 12, 15, 23, 24, 26, 44
Sugar Loaf Mound section 71
Swineford, Ada, cited 49
Sylvester-Bradley, P. C., cited 38
Taloga, Oklahoma 17, 30
Taloga Formation 20
Tansill Formation 31, 34, 36
Taosia dozierensis 18
Tatarian Stage, Russia 5, 6
Tecovas Formation, Texas 37
Tertiary age 31, 36, 42
Tertiary Ogallala deposits 37
Tester, A. C., cited 43
Texas 5, 6, 7, 18, 32, 34
Texas Bureau of Economic Geology 6
Texas County, Oklahoma 18, 37, 43
Texas Panhandle 1, 10, 31, 32, 34, 35, 36
Texigryphaea 38, 42, 43
  belviderensis 39, 42
  corrugata 39
  gibberosa 39
  hilli 38, 39
  marcoui 39
  mucronata 39
  navia 38, 39, (40), 42, 43
  pitcheri 39
  roemeri 39
  tucumcarii 38, 39, 42
  washitaensis 39
Texigryphaea limestone 1, 5
Thomas, Oklahoma 3, 11, 12, 15, 21, 23, 26, 44
Thomas section 72
Thompson, John 4
Thuringian deposits 5
Tomlinson, C. W., and others, cited 6
Trail Creek 29
Triassic 5, 34, 37
Trujillo Formation 37
Tucumcari Shale 38, 39, 42
Twenhofel, W. H., cited 38
Union County, New Mexico 34, 35
U.S. Board on Geographic Names 42
U.S. Bureau of Reclamation 4, 46
U.S. Geological Survey 36, 61
U.S. Highway 183 3, 39
U.S. Highway 66 (Interstate 40) 3, 28
Upper Permian, North America 5
  Guadalupean Stage 5
  Ochoan Stage 5
Upper Permian, Russia 5
  Kazanian Stage 5, 6
  Kungurian Stage 5, 6
  Tatarian Stage 5, 6
uranium 1, 54, [58], 60
vanadium 1, 2, 54, [58], 60
Verden Lentil of Marlow Formation 9, 36
Vici, Oklahoma 29
volcanic ash (Pearlette) 1, 5, 37, 44, 45, (45), 49, 50, [51]
Walnut Clay 42
Washita County, Oklahoma 3, 10, 12, 17, 20, 36, 37, 44, 64
Washita Group **37**
Washita River 1, 2, 3, 5, 17, 23, 25, 26, 50, 61, 65
  Pleistocene deposits 45, 46
water 1, 2, **61-66**
  availability 62, 65
  irrigation use 65
  municipal use 65
  potential development 66
  rural use 66
  source, occurrence, and movement 61
  storage 61, 62
Weatherford, Oklahoma 2, 3, 4, 5, 9, 15, 16, 29, 65

Weatherford Bed of gypsum and dolomite 1, 4, 7, 10, 11, 12, 13, (13), 14, (14), 15, (16), 17, 19, 20, 23, 29, 30, 31, 50—*see also* gypsum and dolomite
Weatherford section 71
Wellington Formation 6
West Clinton section 73, 74
West Eakly core 12, 80
West Leedey core 20, 27, 82, 83, 84
West Moccasin Creek 23, 25
Whipple, A. W., cited 39, 42
Whitehorse Formation 23
Whitehorse fossils 5, 9
Whitehorse Group 1, 2, 4, **6–19,** 20, 32, 62, 63
Whitehorse sandstone 7, 19, 20
Wilcox, R. E., cited 49
Wilcox, R. E., and Izett, G. A., cited 49
Wood Creek 42
Woods County, Oklahoma 6, 7, 10, 11, 21, 23, 25, 27, 29, 32, 35, 43
Woodward County, Oklahoma 7, 9, 10, 25, 27, 29, 32, 35
Worthenia beedei 18
Wright, M. H., and Shirk, G. H., cited 39
Yates Sand, New Mexico and Texas 31, 32, 34
Zechstein 5
Zeller, D. E., cited 6