Salt Creek Canyon (north fork) looking southeast from top of Blaine escarpment in sec. 23, T. 18 N., R. 12 W. The Ferguson Salt Plain is approximately 200-250 feet below the top of the Blaine escarpment. The salt is precipitated from salt water flowing from many salt springs in the Flowerpot Shale about 100 feet below the base of the Blaine Formation. The Shimer Gypsum caps the hill on the left and the prominent Nescatunga Gypsum forms the next lower ledge, 40 feet below the Shimer ledge. The Medicine Lodge Gypsum is barely discernible about 40 feet below the Nescatunga ledge.
Photograph by Myron E. McKinley

OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, *Director*

BULLETIN 89

GEOLOGY AND MINERAL RESOURCES OF BLAINE COUNTY, OKLAHOMA

PART I.—STRATIGRAPHY AND GENERAL GEOLOGY OF BLAINE COUNTY

by

ROBERT O. FAY

PART II.—ECONOMIC GEOLOGY AND PETROLOGY OF GYPSUM AND ANHYDRITE IN BLAINE COUNTY

by

WILLIAM E. HAM

PART III.—PETROLEUM GEOLOGY OF BLAINE COUNTY

by

JOHN T. BADO AND LOUISE JORDAN

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CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND MINERAL RESOURCES OF BLAINE COUNTY, OKLAHOMA

ABSTRACT

Blaine County, comprising nearly 1,000 square miles in central western Oklahoma, is a part of the Great Plains, ranging in elevation from 1,900 feet in the northwestern part to 1,100 feet in the northeastern part. The Cimarron, North Canadian, and Canadian Rivers flow southeastward through the county.

Part I.—Stratigraphy and general geology. The geologic section of Blaine County consists of 1,200 feet of Permian redbeds, chiefly of the Leonardian and Guadalupean Series, overlain by a thin veneer of unconsolidated Pleistocene deposits, generally less than 100 feet thick. In ascending order, the Permian rocks consist of the Cedar Hills Member of the Hennessey Shale (Leonardian), overlain by the El Reno Group (Guadalupean), which consists of the Flowerpot Shale, Blaine Formation, and Dog Creek Shale. The El Reno Group is overlain by the Whitehorse Group (Guadalupean), consisting of the Marlow Formation and overlying Rush Springs Sandstone. The overlying Cloud Chief Formation is here considered to belong to the Guadalupean Series. All formations are conformable with beds above and below.

The Cedar Hills Member is a reddish-brown clay shale with some thin light greenish-gray siltstone beds, about 105 feet thick. The Flowerpot Shale is a 450-foot-thick reddish-brown silty blocky clay shale, with a southward-thickening wedge of Chickasha conglomerate, sandstone, and siltstone in the middle. The upper 50 feet of the Flowerpot Shale contains much gypsum. The Blaine Formation consists of 75 to 100 feet of rock containing four named massive gypsum members; three immediately underlain by named dolomite beds separated by unnamed sequences of reddish-brown gypsiferous silty clay shales: (ascending) Cedar Springs Dolomite (new name), Medicine Lodge Gypsum, Kingfisher Creek Gypsum (new name), Magpie Dolomite, Nescatunga Gypsum, Altona Dolomite, and Shimer Gypsum. The Dog Creek Shale is an even-bedded reddish-brown clay shale, 157-200 feet thick, with two prominent thin dolomite beds, named the Watonga and Southard Dolomites (new names), approximately 50 and 100 feet above the Altona Dolomite, respectively. The lower 50 feet of the Dog Creek Shale is highly gypsiferous. The Whitehorse Group is a moderate reddish-brown to reddish-orange fine-grained cross-bedded sandstone, subdivided by the Emanuel and Relay Creek Dolomite Beds of the Marlow Formation. The Marlow is approximately 100 feet thick, with the thin Emanuel Dolomite Bed at the top and the Relay Creek Dolomite about 20 feet below the Emanuel Dolomite. These dolomites are normally about one inch thick, except in the type area where they are a foot or more thick. The Rush Springs Sandstone is approximately 180 feet thick in northern Blaine County and 230 feet thick in southwestern Blaine County and adjacent Custer County. The Cloud Chief Formation consists of approximately 100 feet of fine-grained sandstone similar to the Whitehorse, the base being marked by a thin pinkish-white crinkly bedded dolomite, tentatively correlated as the Weatherford Dolomite. Near the top of the exposed Cloud Chief are several thick fine-grained white to pink to gray variegated dolomites.

The Pleistocene deposits consist of 100 feet or less of gravel, sand, silt, and clay deposited in three to five terraces along the main rivers. The high-terrace level of each river system contains volcanic ash of the Pearlette (Late Kansan) type. In each terrace level on either side of each river, there are thick deposits of gravel and sand on the northeastern side of the river and thin deposits of clay and silt on the southwestern side of the river.

The Permian beds dip about 14 feet per mile southwest and strike north-northwest in the northern part of the county and west-northwest in the southern part of the county, with many minor crenulations and terraces. A broad southwestward-plunging synclinal trough is probably present in the Canton area, and a southwestward-plunging nose is probably present in the Greenfield-Hitchcock area.

Part II.—Economic geology and petrology of gypsum and anhydrite. Blaine County is the center of gypsum mining in Oklahoma and is a leading source of high-purity gypsum and gypsum products in the United States. Cumulative recorded production within the state since 1894 is slightly more than 12 million tons, of which approximately 95 percent originated from gypsum members of the Blaine Formation in Blaine County. Three companies operating in the county—United States Gypsum Company, Universal Atlas Cement Company, and S. A. Walton and Son—produced an all-time record of 454,000 tons in 1960.

White, flat-lying beds of the Shimer and Nescatunga ledges are of equal commercial importance, each yielding about half the annual tonnage. They range in thickness from 8 to 15 feet, and are worked in open-face quarries after removal of 5 to 30 feet of shale overburden. Chemical analysis shows that the gypsum is 97.25 to 98.92 percent pure. It is processed to make plasters, wallboard, special cements, and fillers. Crude gypsum is used as portland-cement retarder and as a soil conditioner.

Reserves of gypsum, of the same chemical quality, and which are workable under the same conditions as that presently being mined, are estimated to be 280 million tons. At the 1960 rate of consumption these deposits would supply the United States demand for 19 years.

Anhydrite crops out in the lower half of the Nescatunga Member in the northern part of Blaine County, and has a workable surface reserve of 42 million tons. In subsurface, down to a total depth of 500 feet, the Nescatunga is anhydrite with an average thickness of 13 feet. Available by underground mining is a recoverable reserve of 2.9 billion tons, sufficient for unlimited large-scale production of anhydrite for future chemical use.

Thin-section and geochemical investigations show that all the gypsum of the Blaine Formation has been derived from the hydration of anhydrite. The anhydrite itself has passed through three stages of crystallization before being transformed into gypsum at the surface. It is judged to have been deposited as hemihydrate or gypsum, as the desiccation product of evaporating shallow seas. Conversion into anhydrite probably took place at slight depths below the sea floor, while the sediment was bathed with water rich in strontium and boron. The resulting anhydrite contains 1,475 ppm strontium and 72 ppm boron, each of which is absorbed or isomorphously present in the space lattice. On weathering and conversion into gypsum, the strontium and boron of the anhydrite are rejected by the gypsum space lattice but are retained in the gypsum rock as epigenetically formed discrete clusters of celestite, probertite, ulexite, and priceite. These minerals, together with dolomite, calcite, and thenardite, characterize the modern gypsum deposits.

Gypsum beds of the Blaine show three stages of crystal development. The first or incipient stage of gypsification results from the isolated sprouting of selenite porphyroblasts in anhydrite. They invariably retain oriented microscopic inclusions of anhydrite. The succeeding microgranular or alabaster stage, marked by crystalloblastic grains 20 to 50 microns in diameter, comprises about half the beds and probably is a direct replacement of anhydrite, whereas the latest stage consists of visibly crystalline panidiomorphic to idiomorphic selenite grains that evidently grew by recrystallization of the alabaster. The complex history of gypsum development is recorded by the presence of all three stages in single hand specimens.

Part III.—Petroleum geology. Since the discovery of commercial natural gas in 1956 in Northwest Okeene Field, northern Blaine County, six additional areas have been found with gas and gas-condensate production from reservoirs in Late Mississippian and Early and Middle Pennsylvanian rocks. Exploration of the county is still in its early stage and many townships have not yet had a significant exploration test. No field area has been delineated. Hydrocarbons are found in stratigraphic-type traps. Calculated open flow in initial potential tests ranges from 1 to 43 million cubic feet of gas per day.

Rocks of all systems, dipping gently southwestward toward the Anadarko syncline and penetrated by drilling for oil and gas, range in age from Early Ordovician to Late Permian. The rock section above the Hunton Group (Devonian-Silurian) ranges in thickness from 8,500 feet in the north to more than 13,000 feet in the southernmost townships. The top of the Arbuckle Group (Early Ordovician), penetrated at 9,700 feet in northeastern Blaine County, is believed to be at a depth of more than 18,500 feet below the land surface in the southwestern part of the county. Most of the drilled holes have not tested the rock sequence older than Late Mississippian.

PART I.—STRATIGRAPHY AND GENERAL GEOLOGY OF BLAINE COUNTY

ROBERT O. FAY

INTRODUCTION

Blaine County, in central western Oklahoma, comprises an area of almost 1,000 square miles (fig. 1). Watonga is the county seat, located centrally, and has a population of 3,252. Smaller towns are Canton (887), Eagle City, Geary (1,416), Greenfield (128), Hitchcock, Homestead, Hydro (697), Longdale (218), Okeene (1,614), and Southard. State Highways 3, 33, and 51 extend east-west through Blaine County, and U. S. Highways 270 and 281 and State Highways 8, 51A, and 58, extend north-south through the county. Economically, the county is known for its wheat, cattle, and gypsum products, with some natural gas production. Roman Nose State Park, about eight miles north of Watonga, and Canton Lake, in northwestern Blaine County, are recreational areas that are visited by thousands of persons each year.

Three rivers pass southeastward through Blaine County: the Cimarron River in the northeastern corner, the North Canadian River in the center, and the Canadian River in the southwestern part. The elevation of the Cimarron River is 1,090 feet above sea level, and that of the North Canadian and Canadian Rivers is ap-

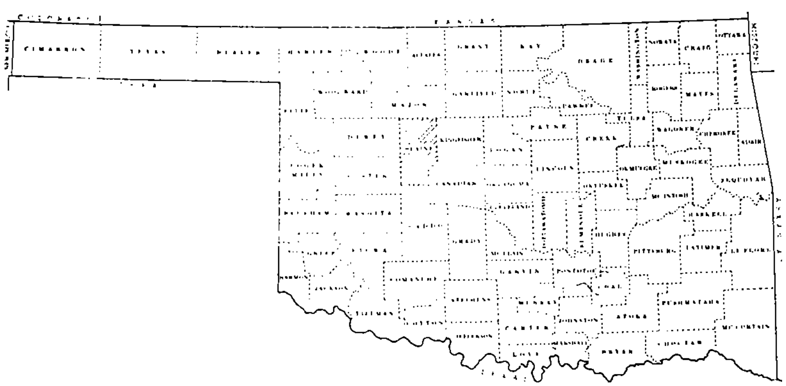


Figure 1. Index map of Oklahoma showing location of Blaine County.

proximately 1,500 feet in central Blaine County. This difference in elevation is partly explained by the fact that the Cimarron River has been cutting down through weakly resistant rocks, whereas the Canadian and North Canadian Rivers have been eroding through more resistant rocks, leaving high ridges or escarpments between and parallel to the rivers.

The escarpment between the Cimarron and North Canadian Rivers is approximately 1,670 feet in elevation at the northern end in Blaine County, and about 1,480 feet above sea level in southern Blaine County, being held up by resistant gypsum and dolomite ledges. This ridge, termed the Gypsum Hills, is the first line of hills if approached from the east. Early settlers, coming westward, called them the first line of hills because they form an unbroken escarpment, extending in a northwestward direction as far as the eye can see, being 400 to 500 feet above the Cimarron River. Going westward over the first line of hills, the settlers noticed a higher escarpment about 10 miles west of the first one, between the North Canadian and Canadian Rivers. They called this escarpment the second line of hills. It has also been named the Western Sandstone Hills because it is composed mostly of reddish-brown sandstone. Elevations on top of this escarpment range from 1,900 feet in northwestern Blaine County to 1,600 feet in southern Blaine County, being about 300 feet above the Canadian and North Canadian Rivers. These escarpments are covered with sand and gravel deposits that are almost 100 feet thick in places. The valley sides along the northeastern faces of these ridges have thin veneers of clay and silt covering the bedrock, with scarcely any gravel or thick sand.

ACKNOWLEDGMENTS

Many people of Blaine County helped in various ways to make this report complete, especially Gerald Curtin, editor, *Watonga Republican;* Dale Underwood and William I. Blosser of the U. S. Gypsum Company, Southard; Perry Gorby, quarry superintendent of Universal Atlas Cement Company, Bucher; S. A. Walton and Son, Fairview; and Harlan Tomlinson, park superintendent, Roman Nose State Park. William E. Ham field-checked the final map and gave helpful suggestions. Carl C. Branson and Alex. Nicholson edited the final manuscript.

STRATIGRAPHY

Introduction

The geologic section of Blaine County consists of 1,200 feet of Permian redbeds, of the Leonardian and Guadalupean Series, overlain by a thin veneer of unconsolidated Pleistocene deposits generally less than 100 feet thick (pl. I). The Permian rocks dip about 14 feet per mile to the southwest and strike north-northwest in the northern part of the county and west-northwest in the southern part of the county (pl. III).

The lowest and oldest formation in the section is the Cedar Hills Member of the Hennessey Shale of the Leonardian Series, the upper part of which crops out in northeastern Blaine County in the topographically low part of the county. This formation is overlain by the Flowerpot Shale, Blaine Formation, and Dog Creek Shale (ascending) of the El Reno Group of the Guadalupean Series. The Dog Creek Shale is overlain by the Marlow and Rush Springs Sandstones (ascending) of the Whitehorse Group. The topographically highest portion of Blaine County is formed by an outlier of the Cloud Chief Formation above the Rush Springs Sandstone in northwestern Blaine County, the top of the Cloud Chief being absent due to erosion.

The Pleistocene sediments were deposited by the Canadian, North Canadian, and Cimarron Rivers, upon older uplands of pre-Pleistocene escarpments of the Cloud Chief, Whitehorse, and Blaine rocks (pl. IV). Each river system has its own set of deposits with a general southeastward trend to each and similar terrace levels on each. Gravel deposits are present on the northeastern sides of the rivers, and silt and clay deposits are found on the southwestern sides. The high-level gravels of each river system contain volcanic ash of the Pearlette type (Late Kansan), thus providing a correlatable datum. Rocks of Pliocene to Mesozoic age have not been recognized in Blaine County, and they may not have been deposited in the region.

Permian System

In Blaine County, the pre-Pleistocene rocks exposed at the surface belong to the Leonardian and Guadalupean Series of the Permian System, are 1,200 feet thick, and dip about 14 feet per mile to the southwest. They are on the northeast flank of the Anadarko basin. Most of the formations consist of reddish-brown shales, siltstones, and sandstones, interbedded with thin persistent beds of dolomite and gypsum. There is apparently a northern and southern origin for many of the clastics in some formations, as shown by Fay (1961). All formations are thinner than normal where traced northward from Blaine County into Kansas, the area of breakover between the northern platform on the north and the Anadarko basin to the south being in the southern Woods-northern Major County region. Traced southward, many formations grade into a deltaic facies, with the margin of the delta probably near the Stephens County area and with the feather-edge located at various places northward, depending upon diverse environmental conditions of deposition. This delta has been termed the Tussey delta by Green (1937, p. 1524).

As defined in this report, the Cedar Hills Member of the Hennessey Shale is placed at the top of the Leonardian Series. The overlying Flowerpot Shale grades southward into the Duncan Sandstone, which is considered the equivalent of the San Angelo-Glorieta Sandstone of Texas, considered, on the basis of fossil evidence in the Midland basin, to be Guadalupean in age. The exposed upper part of the Cedar Hills in Blaine County is 105 feet thick.

The Guadalupean Series includes the El Reno and Whitehorse Groups. The El Reno Group is 700 feet thick and comprises the Flowerpot Shale (450 feet thick, with middle Chickasha wedge 115 feet thick), the Blaine Formation (100 feet of dolomite, gypsum, and shale), and the overlying Dog Creek Shale (160-190 feet thick). Overlying the El Reno Group is the Whitehorse Group (300 feet thick) and the Cloud Chief Formation at top (100 feet thick, top not present).

LEONARDIAN SERIES

Cedar Hills Member of Hennessey Shale

In northwestern Oklahoma the Hennessey Shale contains thin sandstone and siltstone layers in the upper part; these were collectively designated the Cedar Hills Sandstone Member by Miser (1954). The remainder of the Hennessey Shale of Oklahoma is undivided, and names used in Kansas for rocks equivalent to this portion are not used in Oklahoma.

Name—Cragin (1896, p. 24) first used the name Cedar Hills Sandstone, which he applied to strata below the Flowerpot Shale and above the Salt Plain measures in Cedar Hills, Barber County, Kansas. Norton (1939, p. 1789-1791) restricted the name to 180 feet of beds above the Salt Plain Formation and below the Flowerpot Shale. The concept of the Cedar Hills Sandstone as used by Norton in Kansas has been followed by subsequent workers.

Type locality—The type locality is the Cedar Hills region, east-central Barber County, Kansas, in E½ T. 33 S., R. 11 W., and W½ T. 33 S., R. 10 W.

Type section—A type section has not been designated, but a section was figured by Norton (1939, p. 1762) for T. 34 S. in south-central Barber County, Kansas.

Description in type area—The description of the Cedar Hills in the type region is different from that of Blaine County and adjacent areas south of the Cimarron River. The best stratigraphic description for the type area is that of Norton (1939, p. 1789):

> Above the Salt Plain formation lie 180 feet of red sandstone, named Cedar Hills sandstone by Cragin, including a prominent white sandstone at the base and top, the latter containing "snow-balls" of concretionary white gypsum. Softer, more shaly, red siltstones separate the more massive sandy beds and serve to break the formation into recognizable layers. These soft sandstones are readily carved into canyon topography by the streams, the more resistant beds holding up the hills and ridges and weathering to rounded forms. Two beds in particular are more readily identified than others, save the top and basal beds: the first, 127 feet below the top, weathers into forms compared with haystacks, and the second, 100 feet below the top, weathers to more smoothly rounded outcrops and benches of lighter-colored appearance which makes possible its correlation over considerable distances. The latter bed has been called the "Peace Treaty" bed, P. W. Anderson (personal communication) naming it

> for outcrops in the State Park 2 miles east of Medicine Lodge, which commemorates a peace treaty, signed at a natural amphitheater in these rocks in 1867 . . . The formation itself is confined to a belt trending northeast and southwest across Barber County and western Harper County.

Swineford (1955, p. 60) stated that in the type region most of the formation consists of brownish-red fine-grained sandstones and sandy siltstones separated by beds of silty shale and argillaceous siltstone.

Description in Blaine County—In Blaine County, the Cedar Hills is principally reddish-brown silty shale with several prominent light greenish-gray siltstones in the upper 105 feet, which is all that is exposed in the county. The siltstones are quartzose with a few fine-grained sand-size particles, but none of the units of the Cedar Hills is a sandstone in this region. It is for this reason that the name Cedar Hills Member is used in preference to the name Cedar Hills Sandstone Member. The section north of the Cimarron River in Major County is much like that in Kansas, so that a large part of the area in which the facies changes take place has been eroded away by the Cimarron River. It is in this area that

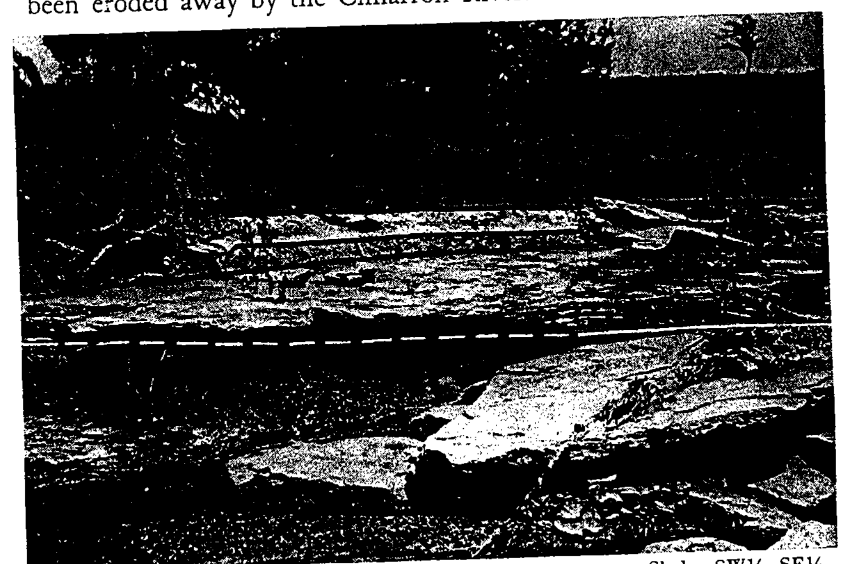


Figure 2. Siltstone bed 1, Cedar Hills Member of Hennessey Shale, SW¼ SE¼ SE¼ sec. 2, T. 19 N., R. 10 W. The light-colored siltstone unit, approximately 14 feet thick, is divided into a lower, middle, and upper part, each separated by thin shale. The middle indurated portion makes a bench in the stream channel and the loosely consolidated upper portion crops out in the stream bank. This is a typical occurrence of siltstone in the Cedar Hills.

the Cimarron River crosses the strike of the beds, following this line of weakness as it flows southeastward. For this reason it is difficult to correlate units within the Cedar Hills Member north and south of the river.

The light-colored siltstones are a few inches to a foot or more thick and are useful markers for correlation into adjacent counties. It is possible that some of these beds may extend for considerable distances. An attempt was made to trace the uppermost 2-foot bed, designated number 5 on the geologic map (pl. I), from Blaine County to Kansas; it is probable that this is the same bed as that used by Norton to define the top of the Cedar Hills Sandstone in Kansas. This bed is tentatively designated as the top unit of the Cedar Hills Member, conformably separating the Cedar Hills from the overlying Flowerpot Shale.

The other light-colored siltstones of the Cedar Hills are designated by numbers 1 through 4 (ascending), the bases of these being approximately 84, 65, 47, and 14 feet below the top of the Cedar Hills, respectively (fig. 3). Bed 1 is a composite of several beds and is approximately 14 feet thick (fig. 2). The thickness and the intervals between beds of the upper part of the Cedar Hills Member

Figure 3. Siltstone bed 4 and underlying siltstones, Cedar Hills Member of Hennessey Shale, near C north line NW¼ sec. 15, T18 N., R. 10 W. The orange-brown siltstone unit, one foot thick, just above the hammer, is well indurated and forms a prominent ledge above the less indurated silty shales and argillaceous siltstones in the Cedar Hills.

are almost uniform throughout Blaine County. An attempt to trace these units southward into Canadian County proved successful to a degree, especially for Kingfisher County and northern Canadian County.

Schweer (1937, p. 1553; 1939, p. 40) proposed the names Piedmont Sandstone and Reeding Sandstone for the light-colored units at the top and bottom of the Cedar Hills, respectively, with the type localities near the Canadian County towns of the same names. The name Piedmont is preoccupied and must be discarded. In figure 4 the section for Blaine County is given on the right and that of Schweer (1939, p. 40) on the left. Detailed information

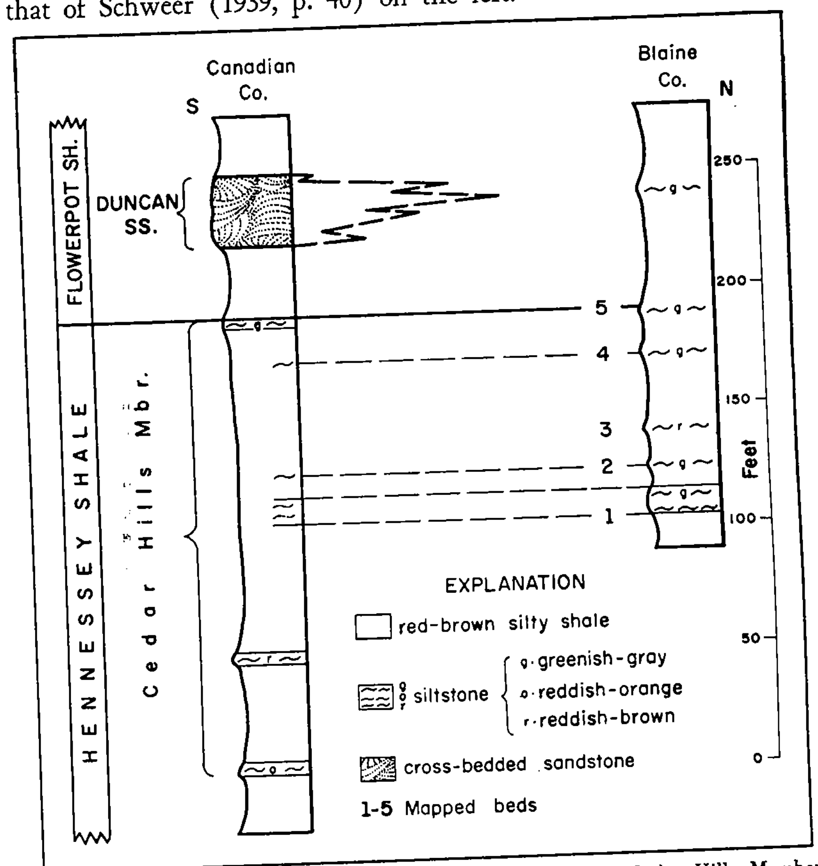


Figure 4. Stratigraphic diagram showing relationships of the Cedar Hills Member of the Hennessey Shale to the Flowerpot Shale and Duncan Sandstone in Blaine and Canadian Counties, Oklahoma. Although these units are primarily red-brown shale, many thin light-colored siltstone units can be correlated over long distances.

is given in the measured sections in the appendix. The base of the Cedar Hills was not studied because it does not crop out in Blaine County.

Direct comparison of the above sections (fig. 4) with that of the type region to the north shows that the sand of the Cedar Hills Member could not have been derived from the southeast and that the Tussey delta was probably not receiving predominately coarse clastics at that time.

DISTRIBUTION—The Cedar Hills Member extends from eastern Canadian County, Oklahoma, to Harper and Barber Counties, Kansas, passing through the northeastern corner of Blaine County.

THICKNESS—The Cedar Hills Member is approximately 180 feet thick in Kansas and 190 feet thick in Canadian County, Oklahoma (fig. 4). Only the upper 105 feet is exposed in Blaine County.

TOPOGRAPHY—The Cedar Hills Member is more resistant than are the underlying Hennessey Shale and overlying Flowerpot Shale, so that the surface expression of the Cedar Hills is one of gently rolling hills. Traced northward, the hills become more prominent because of the increase in the sandstone content.

STRUCTURE—Structure contours (pl. III), based upon elevations at the top of the Cedar Hills Member, indicate that the beds dip from 10 to 14 feet per mile to the southwest and that the dip is conformable with those of the Blaine Formation above the Flowerpot Shale.

STRATIGRAPHIC RELATIONSHIPS—The Cedar Hills is conformable with units above and below, and it grades laterally southward into the Hennessey Shale. The siltstone and shale units to the south in Oklahoma become sandstone and siltstone units northward in Kansas. In the Oklahoma City area, north of the North Canadian River, the Duncan Sandstone forms a northward-thinning wedge in the Flowerpot Shale, with about 30 feet of Flowerpot Shale between the Duncan Sandstone above and the Cedar Hills Member below (fig. 4). South of the North Canadian River, in Cleveland County, the Duncan Sandstone rests directly upon what is supposed to be the Hennessey Shale, the Flowerpot and the Cedar Hills supposedly not being recognized in this region. At this critical area of facies changes between the resistant Duncan Sandstone and overlying Chickasha Conglomerate to the south and the weakly resistant Flowerpot Shale to the north, the section is

almost entirely covered by alluvium of the North Canadian and Canadian Rivers. In this area, these rivers flow eastward across the strike of the beds, apparently following lines of least resistance, due to facies changes. Despite this difficulty, it can be demonstrated that the Duncan Sandstone is above the top of the Cedar Hills Member and that the two are not equivalent.

AGE AND CORRELATION—The Cedar Hills Member is correlated with part of the Hennessey Shale of central and southwestern Oklahoma and with the Clear Fork Group (in part) of Texas. In Texas, the Clear Fork contains fossils of Leonardian age, according to Plummer and Scott (1937). Tentatively the Cedar Hills Member is here regarded as belonging to the upper part of the Leonardian Series.

GUADALUPEAN SERIES

EL RENO GROUP

In Blaine County the El Reno Group consists mainly of reddish-brown shale and evaporite beds of gypsum, anhydrite, and dolomite, divided into the Flowerpot Shale with the Chickasha Tongue in the middle, the Blaine Formation, and the Dog Creek Shale (ascending). The upper and lower contacts are here considered to be conformable and the total thickness is approximately 700 feet.

All units within the El Reno Group (both formations and members) thin northward into Kansas, so that the total thickness in Kansas is approximately 250 feet (Fay, 1961). The clastic elements in Kansas appear to have a separate origin from those in central Blaine County, Oklahoma, and from those to the south of Blaine County. The general region of change from the northern platform to the Anadarko basin is in the southern Woods-central Major County area.

Traced southward from Blaine County, the El Reno Group grades into the Duncan Sandstone and overlying Chickasha Formation, these units being interpreted as deltaic deposits of southeastern origin (Fay, 1961). The northernmost extension of this delta, represented as a wedge in the middle of the Flowerpot Shale, is in the Blaine County area. Southward in Canadian County, this Chickasha conglomerate wedge, or tongue, gradually interfingers higher and higher in the section until the upper part of the Flowerpot and the entire Blaine Formation are represented by the conglomerate. In northern Grady County, the Dog Creek Shale has many Chickasha wedges, and a few miles to the south the entire Dog Creek has graded into the Chickasha Formation.

The name is that of the town of El Reno, Canadian County, Oklahoma. It was first applied as the El Reno Formation by Becker (1930, p. 55) to strata between the Hennessey Shale below and the Whitehorse Group above. This rank was changed to group by Schweer (1937, p. 1553), a usage followed by subsequent workers.

Flowerpot Shale Formation and Chickasha Tongue

Name—Cragin (1896, p. 24) first used the name "Flower-pot shales" for layers of reddish-brown gypsiferous shale between the Medicine Lodge Gypsum above and the Cedar Hills Sandstone below, in Flower-pot Mound, Barber County, Kansas. Norton (1939, p. 1792) reported a variation in thickness of 173 to 190 feet in the type region, using the term "Flowerpot shales" for the rocks between the dolomite at the base of the Medicine Lodge Gypsum and the white sandstone at the top of his Cedar Hills Sandstone, as redefined. This usage has been followed by subsequent writers. The form of the name has been changed to Flowerpot Shale (Swineford, 1955, p. 64; Moore and others, 1951, p. 39).

Type locality—The type locality for the Flowerpot Shale is Flower-pot Mound, at the divide between East Cedar Creek and West Cedar Creek, near the center of SW¼ sec. 26, T. 32 S., R. 13 W., 8 miles southwest of Medicine Lodge, Barber County, Kansas.

Type section—A type section has not been designated. A generalized section was given by Norton (1939, p. 1762, fig. 2) for T. 34 S., southern Barber County.

Description in type area—Cragin (1896, p. 24-27) presented the original description:

> Next in order above the Cedar Hills sandstones, but entirely eroded from the summit of the Cedar Hills, while seen in full thickness a little farther west in the escarpment of the Gypsum Hills, southwest of Medicine Lodge, and taking their name from the well-known Flower-pot mound which has been carved out of them by erosion at the point of the divide between East Cedar and West Cedar creeks, are the Flower-pot shales. These, for the most part, are highly gypsiferous clays . . . The thickness of the Flower-pot shales on the Salt Fork, southeast of Aetna, is in the neighborhood of 150 feet.

The best detailed lithologic description of the Flowerpot Shale is that of Swineford (1955, p. 64-67). She stated that the Flowerpot consists of reddish-brown gypsiferous shale and silty shale with a few thin beds of sandstone and siltstone. The sandstones are all fine grained, and the siltstones are arenaceous. Most of the shale is gypsiferous clay shale, being slightly silty in some layers. Some of the prominent sandstone benches are 40 feet above the base, 75 feet below the top, and within the upper 40 feet of the Flowerpot Shale. The section in Blaine County is slightly different.

Description in Blaine County—In Blaine County the Flowerpot Shale is 437 to 465 feet thick and may be divided into several distinct lithologic units (figs. 5, 6). The lower 180 feet consists of relatively pure reddish-brown silty clay shale with a few thin light greenish-gray siltstone beds. The next overlying 160 feet of beds is alternating reddish-brown gypsiferous shales and light greenish-gray siltstones, the lower 115 feet of which grades southward

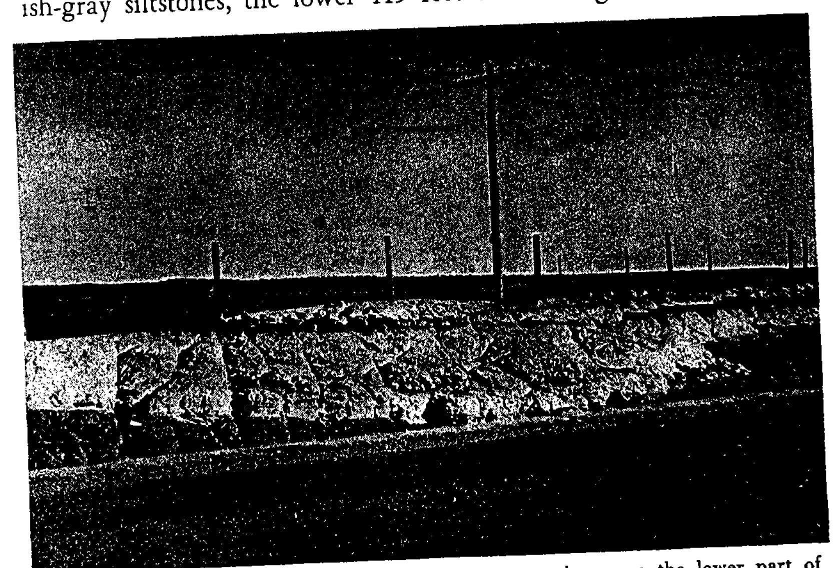


Figure 5. Siltstone bed 1, basal Chickasha Tongue resting upon the lower part of the Flowerpot Shale, near C west line NW¼ sec. 31, T. 18 N., R. 10 W., along State Highway 8. The cross-bedded channel-like nature of this unit is typical of the Chickasha Tongue. This and other similar units grade southward into mudstone conglomerate and northward into shale. Note the dark-colored shale beds in the upper part.

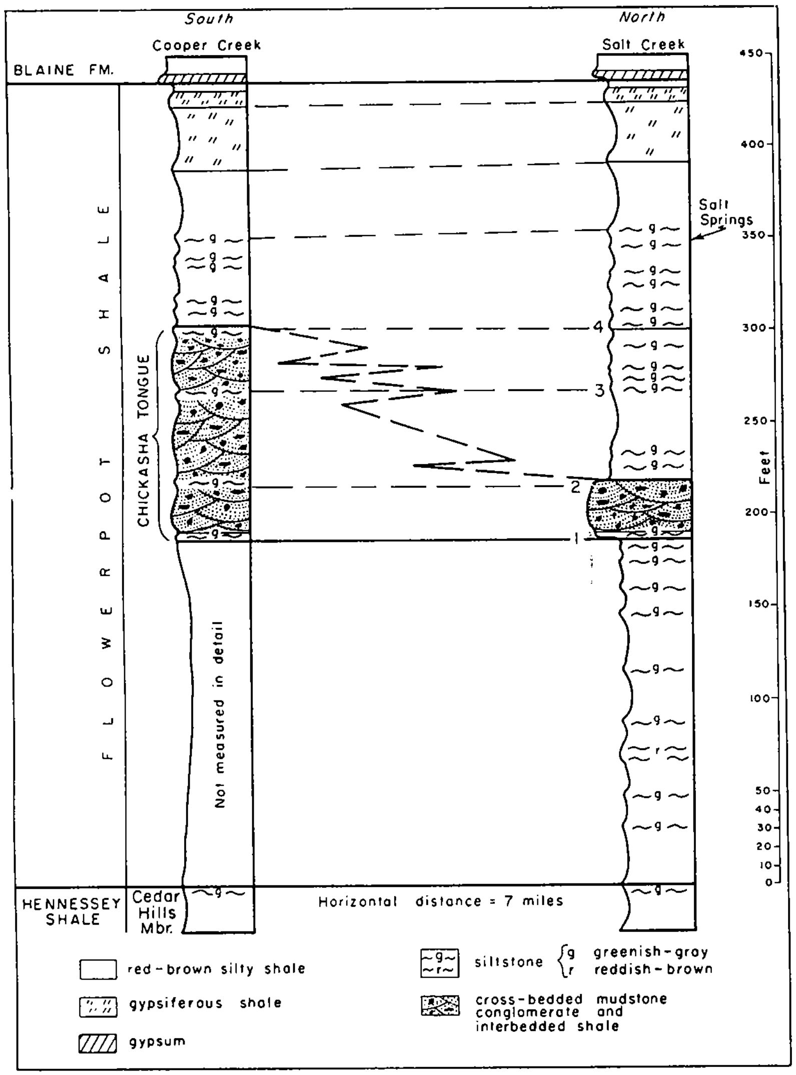


Figure 6. Stratigraphic diagram showing relationships of the Flowerpot Shale to the Chickasha Tongue in Blaine County, Oklahoma. The mapped units, numbered 1, 2, 3, and 4, are light-colored siltstones or indurated mudstone-conglomerates that can be traced locally for a few miles. These units grade into shale northward and grade into thick siltstones and mudstone conglomerates southward, forming a thick wedge in the middle of the Flowerpot Shale. Farther south, in central Canadian County, almost all of the Flowerpot is represented by the Duncan Sandstone and overlying Chickasha Formation.

into the Chickasha Formation and is termed the Chickasha Tongue, consisting of mudstone conglomerate, sandstones, quartzose sandstones, siltstones, and interbedded, lenticular silty clay shales. The next overlying 40 feet is relatively pure silty clay shale with little or no gypsum, dolomite, or siltstone veins or layers. The upper 50 feet contains several different types of impure gypsum beds, dolomites, and a siltstone, some of which can be traced into adjacent counties (frontispiece).

The basal 180 feet of the Flowerpot Shale in Blaine County consists of reddish-brown silty clay shale with a few thin light greenish-gray siltstones and some veins of selenite. Northward in Kansas, rocks equivalent to this unit contain some sandstone; thus a separate origin for the sandstone in Kansas, distinct from a southern origin, is indicated. It is possible that some of the siltstones in Blaine County may have been derived from the north, but it is more probable that they are related to deposits of the Tussey delta to the south.

The overlying 160 feet of beds consists of alternating thick reddish-brown silty clay shales and thin light greenish-gray siltstones, the lower 115 feet of which grades southward into coarse clastics including conglomerate. In the Salt Creek area of northeastern Blaine County, 18 light greenish-gray siltstones were locally mapped; four of these are here used to delineate the exact manner in which interfingering takes place. These beds are numbered 1 through 4 (ascending) on the geologic map (pl. I), being approximately 180, 210, 260, and 295 feet above the base of the Flowerpot Shale. In the Salt Creek area, the conglomerate and coarse clastics are present mainly between beds 1 and 2; and just one mile north this unit is principally silty clay shale and siltstone, showing that coarse clastics are not present in this part of the Flowerpot Shale from this point northward in Blaine County. In Kansas, sandstones in the equivalent rocks indicate that there is a separate origin for the Kansas coarse clastics, distinct from those of the Blaine County region.

South of Salt Creek, in Blaine County, conglomerate and sandstone are present between beds 1 through 3; and a few more miles south, east of Hitchcock, these coarse clastics are present up to and including bed 4. From here southward to the Blaine County line, in this unit, the coarse clastics increase in thickness and the shales decrease, making correlations progressively more difficult to the south. These clastics are reddish-brown cross-bedded lenticular mudstone conglomerates and mudstone sandstones, interbedded with quartzose sandstones, siltstones, and silty clay shales. The conglomerate, which grades into sandstone, consists of pebbles, granules, and grains of reddish-brown mudstone and siltstone cemented in a matrix of reddish-brown to greenish-gray siltstone and silty clay shale. The quartzose sandstone is fine grained, micaceous, cross-bedded, moderately to well indurated, and has subangular to subrounded grains. The siltstones are light greenish-gray to reddish-brown, quartzose, and micaceous, some of the light-colored ones being useful stratigraphic markers. The reddish-brown silty clay shale is subordinate to the conglomerate and sandstone.

These predominantly coarse clastics in this area were designated as a part of the Duncan Sandstone Formation by Becker (1930, p. 52, fig. 5) and Green (1936, p. 1456, 1466). Considering the fact that these clastics are primarily mudstone conglomerate and mudstone sandstone, that they occur more than 140 feet above the base of the Flowerpot Shale, and that they resemble the Chickasha conglomerates instead of the Duncan Sandstone, the name Chickasha Tongue is here applied to beds of the above type. For discussion and history of these formations, as used in the type region in Grady County, Oklahoma, some 60 to 70 miles to the south, see Davis (1955, p. 42-57). In northern Grady County, almost all of the Flowerpot Shale has graded into coarse clastics of the Duncan Sandstone and the lower part of the overlying Chickasha Formation. From these relationships, it can be seen that the Chickasha Tongue in Blaine County represents the lower part of the Chickasha Formation and the northernmost extension of the Chickasha Formation exposed at the surface in Oklahoma. Thus it is concluded that the featheredge of the Tussey delta was being deposited progressively northward while the lower part of the Flowerpot Shale was being deposited. The delta reached its maximum extent northward in Blaine County while the middle portion of the Flowerpot Shale was being deposited. In late Flowerpot time the deltaic featheredge was receding southward, and in Blaine time the delta was present in the central Canadian County

area. During Dog Creek time it finally receded southward to central Grady County (Fay, 1961).

The next overlying 40 feet of shales in Blaine County is relatively free of gypsum, dolomite, and siltstone, containing many vertical greenish-gray silty clay shale seams in many places.

The upper 50 feet of the Flowerpot Shale can be subdivided into several distinct units that have an important bearing on the original designation of the names Blaine Formation and Ferguson Gypsum Member. Throughout Blaine County the uppermost 6 feet of the Flowerpot Shale is reddish-brown silty clay shale, with a thin light greenish-gray band at the top, several inches thick. This 6-foot shale unit is underlain by a resistant ledge, 7 to 8 feet thick, consisting of many thin wavy layers of satin spar and silty clay shale, with a local impure 2- to 3-inch dolomite near the top that may be stained with a greenish copper mineral. Near the top of this ledge, a thin hematitic band is present in some places. Traced northward into central Major County (SW¼, sec. 5, T. 21 N., R. 13 W.), the upper 3 feet of this ledge becomes a massive well-indurated gypsum, the overlying shale unit thins to about 1.5 feet and becomes dolomitic, and the basal Blaine dolomite (Cedar Springs) is 1.5 feet thick. In southern and central Blaine County, the next underlying 30 to 40 feet of section below the 8-foot ledge consists of reddish-brown blocky, silty clay shale with much satin spar and selenite and with several prominent layers of concretions of white gypsum in the basal 5 feet. This bottom zone is persistent throughout Blaine County and extends northward into Major County. In northern Blaine County (from sec. 10, T. 19 N., R. 12 W., northward) a thin gray dense dolomite is found 22.4 feet below the top of the Flowerpot Shale, with a prominent greenish-gray 2-foot siltstone about 12 feet below the dolomite, and the persistent concretionary gypsum zone is approximately 20 feet below the siltstone. The siltstone and dolomite are absent farther south in central Blaine County. Traced northward into Major County, along Sand Creek (N½ sec. 20, T. 20 N., R. 12 W.) the dolomite is in two beds, 6 inches thick, and the underlying siltstone is 6 feet thick, with a 1-foot-thick gypsum bed in the middle. The interval between these beds and the top of the Flowerpot Shale is the same as that in Blaine County, and the base of the concretionary gypsum zone is about 10 feet lower in the section in Major County. In this area southwest of Fairview, Gould (1902, p. 42, 47; 1905, p. 44, 46) stated that the Ferguson Gypsum disappears where traced northward. The above 1-foot gypsum in the gypsiferous siltstone forms an escarpment in this area, and, without the aid of aerial photographs, one could easily mistake this bed for the thin Ferguson Gypsum of Gould. Many gypsum beds are deeply leached, and it is highly probable that this stray 1-foot gypsum bed in the upper part of the Flowerpot Shale is the northward-thinning wedge of the Ferguson Gypsum of Gould. Actually the Ferguson is the Medicine Lodge Gypsum. Gould proposed the name Blaine Formation to include beds from the Shimer Gypsum through the Ferguson Gypsum, supposedly including the Cave Creek Formation of Cragin plus the Ferguson and overlying beds. Evans (1931, p. 409) pointed out the probable equivalence of the Ferguson and Medicine Lodge Gypsums, and of the Blaine and Cave Creek Formations. The above-mentioned siltstone, with its contained 1-foot gypsum, grades northward into a sandy siltstone in Woodward County (SE¼ NE¼ sec. 10, T. 23 N., R. 17 W.); is about 15 feet below the top of the Flowerpot, with the thin dolomite about five feet above it; and it may be correlated into Kansas, where it is a fine-grained sandstone (Fay, 1961). Apparently the sand was derived from the northeast.

In Blaine County and adjacent areas, the Flowerpot Shale is conformable with beds above and below, and all units thin northward from the Anadarko basin to the northern platform, the breakover area being in southern to central Woods County, Oklahoma.

Figure 6 shows the relationships of various units of the Flowerpot Shale from the Salt Creek area at the north (T. 18 N., R. 10, 11, and 12 W.) to the Cooper Creek area at the south (T. 17 N., R. 10 W.).

Distribution—The Flowerpot Shale is present in Barber County and in the eastern part of Comanche County, Kansas. It extends southeastward through eastern Blaine County and ends in southern Canadian County, Oklahoma, where it grades into the Chickasha Formation and underlying Duncan Sandstone. It occurs around the flanks of the Wichita Mountains of southwestern Oklahoma, where it is much thinner.

Thickness—In the type region in Kansas the Flowerpot Shale is approximately 180 feet thick, whereas in Blaine County it is 450 feet thick. This divergence is explained by the fact that in Woods County, Oklahoma, and in Kansas deposition took place on the northern platform; whereas in Major County and the area to the south, the deposits were formed in the Anadarko basin, grading southeastward into thick clastic deposits of the Tussey delta. All of the Flowerpot Shale of Blaine County is here regarded as having been deposited simultaneously with 140 feet of the Duncan Sandstone and the overlying 300 feet of the lower portion of the Chickasha Formation in the Grady and Stephens County area, Oklahoma.

Topography—From Salt Creek southeastward through Blaine County, the eroded Chickasha Tongue forms a low ridge of hills similar to those formed farther east by the Cedar Hills Member of the Hennessey Shale. Otherwise, the Flowerpot Shale forms a low valley of badlands country.

Structure—Structure contours based upon elevations taken at the base of the Flowerpot Shale (northeastern part of pl. III) indicate that the beds dip about 14 feet per mile to the southwest, with some local variations. These variations are best seen in the structure contours based upon elevations of the Altona Dolomite in the overlying Blaine Formation (central part of pl. III). Here it will be seen that the beds strike north-northwest in the northern part of the county and west-northwest in the southeastern part of the county, with several local flexures between the two areas. These flexures probably represent broadly plunging noses of structures with axes at right angles to the axis of the Anadarko basin.

Stratigraphic relationships—All of the 180 feet of the Flowerpot Shale at the type area in Kansas is represented in the 450 feet of rocks in Blaine County, the breakover between the northern platform and the Anadarko basin being in Woods County, Oklahoma. Southward into Grady County, Oklahoma, there is a facies change between all of the Flowerpot Shale to the north and the Duncan Sandstone and 300 feet of the overlying Chickasha Formation of the Tussey delta to the south. The upper and lower contacts of the Flowerpot Shale are conformable, respectively, with the overlying Cedar Springs Dolomite Bed of the Blaine

Formation and the underlying greenish-gray siltstone at the top of the Cedar Hills Member of the Hennessey Shale.

PALEONTOLOGY—An amphibian and three kinds of reptiles have been found in the Chickasha Tongue, approximately 52 feet above the base of the tongue in Kingfisher County (Olson, 1962). It was near the Blaine County-Kingfisher County line, in NW¼ NW¼ NW¼ NW¼ sec. 19, T. 17 N., R. 9 W., in the ditch at the southeast corner of the intersection. Some spores have also been found in the Flowerpot Shale in southwestern Oklahoma (Wilson, 1962).

AGE AND CORRELATION—The lower part of the Flowerpot Shale grades into the Duncan Sandstone. The Duncan Sandstone of Oklahoma is considered to be the same as the San Angelo Sandstone of central Texas, according to Gould (1926, p. 152). The San Angelo Sandstone of the eastern shelf area of central Texas is correlated across the Midland basin with the Glorieta Sandstone that is found in the northwestern shelf area north of the Midland basin and in the Central Basin platform west of the Midland basin, according to King (1942, p. 695, pl. II). The Glorieta Sandstone is overlain by limestone with *Parafusulina* in the Midland basin and the Central Basin platform, the species of *Parafusulina* (*rothi, sellardsi, lineata, maleyi* var. *referta*) being "found only in the Guadalupe series" in outcrops to the west (King, 1942, p. 701-702). Accordingly, the Flowerpot Shale is here considered to be the equivalent of rocks at the base of the Guadalupean Series.

BLAINE FORMATION

The Blaine Formation in Blaine County consists of 75 to 100 feet of evaporites and interbedded shales. There are four gypsum ledges, three of which have a basal thin dolomite, separated by reddish-brown silty clay shales. The Blaine Formation is conformable with the underlying Flowerpot Shale and with the overlying Dog Creek Shale. The sequence in Blaine County is (ascending) Cedar Springs Dolomite Bed* at base overlain immediately by Medicine Lodge Gypsum Member, shale, Kingfisher Creek Gypsum Bed, shale, Magpie Dolomite Bed overlain immediately by Nescatunga Gypsum Member, shale, and Altona Dolomite Bed overlain immediately by Shimer Gypsum Member at the top.

* When plate I, the geologic map of Blaine County, was published, the Cedar Springs, Kingfisher Creek, Magpie, and Altona Beds were designated as members. Subsequently it was deemed that their proper nomenclatorial rank should be that of beds.

NAME—The name "Blaine division" was first used by Gould (1902, p. 47) for a sequence of gypsums and interbedded shales below the Dog Creek Shale and above the lower part of the Flowerpot Shale, thought to be interbedded northward in Kansas with the upper 40 feet of the Flowerpot Shale. Gould (1905, p. 44) changed the name to Blaine Formation. Gould probably miscorrelated the lowermost gypsum unit northward into Kansas, thus causing confusion in nomenclature and in correlation of members of the Blaine Formation. Much of this confusion can be corrected by one simple statement: the Ferguson Gypsum of Gould (1902) is the same as the Medicine Lodge Gypsum of Cragin (1896) (fig. 7, pl. II). The upper 40 feet of the Flowerpot Shale in Kansas is not equivalent to any portion of the Blaine Formation in Oklahoma.

The name Cave Creek Formation was first used by Cragin (1896, p. 27) for rocks in Comanche and Barber Counties, Kansas, between the Flowerpot Shale below and the Dog Creek Shale above. Although the name Cave Creek had definite priority over that of Blaine Formation, the name Cave Creek fell into disuse because most geologists thought that the Blaine Formation included rocks equivalent to all of the Cave Creek plus 40 feet of the Flowerpot Shale.

It was not until 1931, when Evans demonstrated the equivalence of the Medicine Lodge and Ferguson Gypsums, and in 1939, when Norton restudied type sections in Kansas, finding a gypsum missed by Cragin, that the equivalence of the Blaine Formation with the Cave Creek Formation became established. All authors subsequent to Norton have followed his usage for named members of the Blaine Formation in Kansas and northern Oklahoma (Fay, 1961). Figure 7 shows the relationships between named units of the Blaine Formation extending from Kansas to Canadian County, Oklahoma. The name Blaine Formation is used in this report because it has been extensively used in the literature.

TYPE LOCALITY—The type locality for the Blaine Formation is the area of Roman Nose and Salt Creek Canyons (frontispiece) in central to north-central Blaine County, Oklahoma. The type

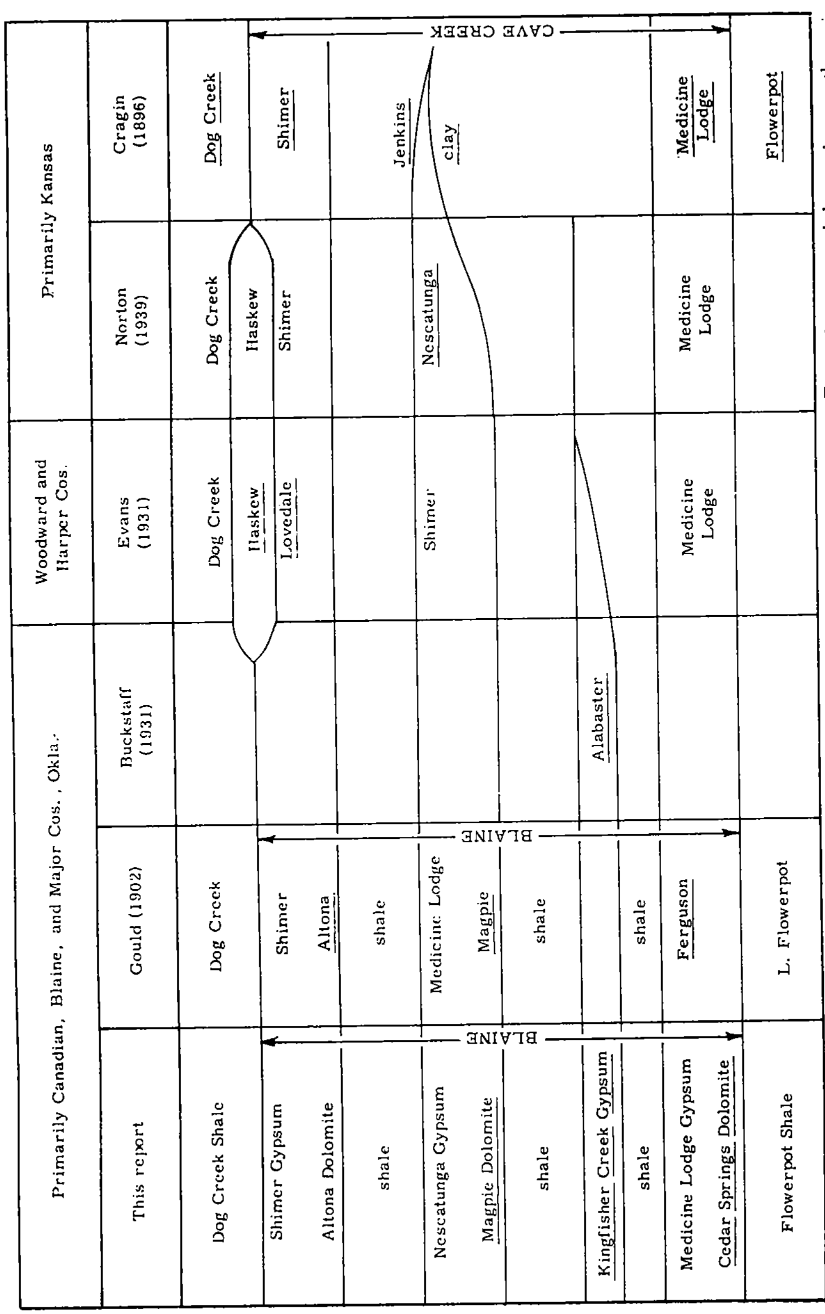


Figure 7. Nomenclature diagram showing relationships of the named members of the Blaine Formation as used by various authors in Kansas and northwestern Oklahoma. No implication of thickness is intended by the spacing between units. New names introduced by authors are underlined.

locality for the Cave Creek Formation is the Cave Creek area of the old Shimer Township, Tps. 33, 34, 35 S., R. 17 W., Comanche County, Kansas.

TYPE SECTION—The type section for the Blaine Formation is here designated as the rocks exposed along State Highway 33, about 7 miles east of Watonga, Blaine County, Oklahoma, in the southern part of sec. 19 and northern part of sec. 30, and SW¼ sec. 20, T. 16 N., R. 10 W., where the entire formation is exposed. There is no type section for the Cave Creek Formation at present, but the one at Comanche Cave, Comanche County, Kansas, would be suitable (Fay, 1961). The nature of the Blaine Formation at the type section, compared with that at Cave Creek, Kansas, is shown in figure 8.

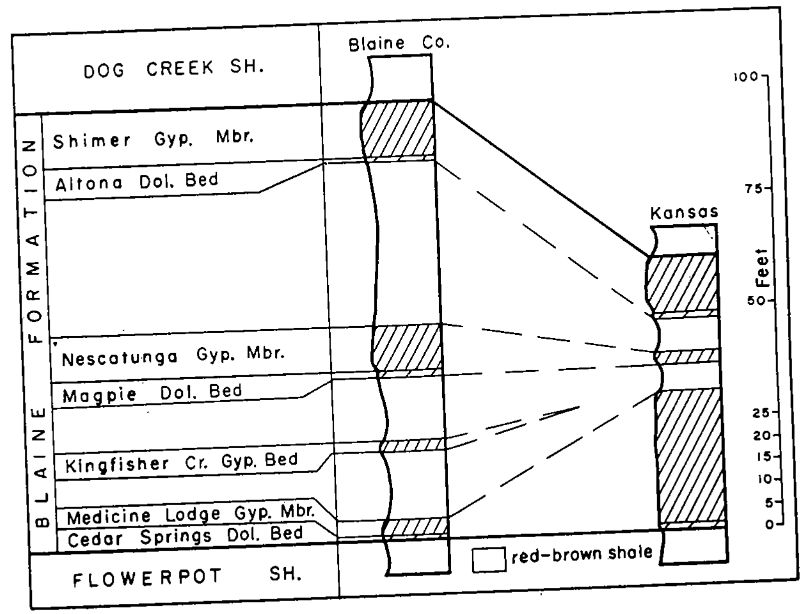


Figure 8. Stratigraphic diagram showing relationships of the members of the Blaine Formation at the type section on State Highway 33, Blaine County, Oklahoma, to those at Cave Creek, Comanche County, Kansas. The shale units are markedly thinner northward. The Medicine Lodge Gypsum is thinner south of Blaine County and grades into shale in central Canadian County, Oklahoma. The Kingfisher Creek Gypsum attains a maximum thickness in southern Blaine County and grades into shale southward and northward in central Canadian and southern Major Counties respectively. The Nescatunga Gypsum is thinner northward in Comanche County, Kansas, and is absent in Barber County, Kansas. The Shimer Gypsum grades into shale southward in central Canadian County, Oklahoma, but has about the same thickness northward in Kansas.

Description of the Blaine Formation—Beginning with the Cedar Springs Dolomite Bed at the base and proceeding upward, the Blaine Formation is as follows.

Cedar Springs Dolomite Bed

Name—The Cedar Springs Dolomite Bed* of the Blaine Formation is the name here given to the dolomite at the base of the Blaine Formation, conformably overlying the Flowerpot Shale and grading upward into the Medicine Lodge Gypsum. The name is that of the town of Cedar Springs, in the north-central part of T. 20 N., R. 13 W., southern Major County, Oklahoma.

Type locality—Southern Major County, Oklahoma, in T. 20 N., R. 12 W., especially along Sand Creek, is the type locality.

Type section—The section exposed in the high bluff along the east bank of Sand Creek in NW¼ sec. 20, T. 20 N., R. 12 W., southern Major County, Oklahoma, is here designated as the type section (fig. 9).

Description in type area—The Cedar Springs Dolomite is approximately 9 inches thick at the type section, is light gray, fine grained, oölitic, and massive, and has a few compact portions that are non-oölitic.

Description in Blaine County—In Blaine County, the Cedar Springs is the same as it is in the type area except that it is 1 to 2 inches thick or is missing in places and that at several places in southern Blaine County it contains stains of a green copper mineral. Traced southward into Canadian County, the Cedar Springs grades laterally into a calcareous siltstone of the Chickasha Formation. Traced northward, in central Major County (SW¼ sec. 5, T. 21 N., R. 13 W.), this unit thickens to almost 3 feet, the lower 1.5 feet being argillaceous, with a 3-foot-thick impure massive gypsum beneath it included in the Flowerpot Shale. In Kansas, Norton (1939, p. 1795) reported this dolomite to be 0.5 to 1 foot thick and ripple-marked.

Medicine Lodge Gypsum Member

Name—The name Medicine Lodge Gypsum was first used by Cragin (1896, p. 28) for the thick massive gypsum above the Flowerpot Shale, named for the river and town of Medicine Lodge, Barber County, Kansas. The name, as used by Gould (1902) in the Blaine County area, refers to the next gypsum ledge above the Medicine Lodge Gypsum. The Ferguson Gypsum of Gould is the equivalent of the Medicine Lodge Gypsum of Cragin. Both authors included the basal dolomite with the overlying gypsum in their nomenclature, but, as used here, the basal dolomite is termed the Cedar Springs Dolomite Bed and the overlying gypsum is termed the Medicine Lodge Gypsum Member.

* Labeled member on plate I. See footnote, page 30.

Type locality—The type locality of the Medicine Lodge Gypsum is northern Barber County, Kansas, along the Medicine Lodge River valley and the area southwest of Medicine Lodge.

Type section—No type section has been designated.

Description in type area—The best published description of the structure and microscopic character of the Medicine Lodge Gypsum is that of Kulstad and others (1956, p. 41-45) who stated that:

> The Medicine Lodge gypsum member . . . crops out in Barber County, Kansas, and extends westward into Comanche County and southward into Oklahoma. The gypsum ranges in thickness from 10 to 30 feet, the maximum thickness being exposed in the Pioneer mine, Sun City. In the mine, lenses of anhydrite occur within the gypsum about 10 feet above the base of the gypsum . . . The regional dip is about 11 feet per mile to the southwest . . . Anhydrite is not present in the lower or upper parts of the gypsum.

Description in Blaine County—In Blaine County, the Medicine Lodge ranges in thickness from about 7 feet at the north to 4 feet at the south. It contains no visible anhydrite and has many reddish-brown clay shale seams in its upper portion, giving the appearance of the reddish-brown mottled gypsum on the outcrop. Traced northward into central Major County (NE¼ sec. 7, T. 22 N., R. 14 W.), this unit thickens to 15 feet and has a 6-inch-thick bed of anhydrite in the middle. In the Salt Creek Canyon area of Blaine County, Muir (1934, p. 1304) reported the presence of small irregular cubes and aggregates of anhydrite in the middle portion of the Medicine Lodge Gypsum and minor amounts of anhydrite in the upper portion. The Medicine Lodge is a white, compact to porous, fine- to coarse-crystalline banded gypsum. It is mottled moderate reddish brown to pale pink and forms a pinkish-gray ledge. It grades into the underlying Cedar Springs Dolomite (fig. 9) and is conformably overlain by reddish-brown silty clay shale with greenish-gray streaks.

The overlying shale is 15 feet thick in southern Blaine County and extends upward to the Kingfisher Creek Gypsum. In northern Blaine County the shale is 7 feet thick and contains many layers of greenish-gray clay shale and gypsum; and the Kingfisher Creek is there represented by an impure thin greenish-gray argillaceous gypsum that appears like the thin beds below (pl. II, and appendix). These beds contain increasing amounts of gypsum to the north and appear to grade into the Medicine Lodge Gypsum in central Major County, Oklahoma, accounting for the increase in thickness of the Medicine Lodge Gypsum from southern to central Major County.

Kingfisher Creek Gypsum Bed

Name—The name Alabaster Gypsum was first used by Buckstaff (1931, p. 435) for a thin gypsum bed in the shale unit between the Medicine Lodge Gypsum below and the Nescatunga Gypsum above of the Blaine County area. No type locality was designated,

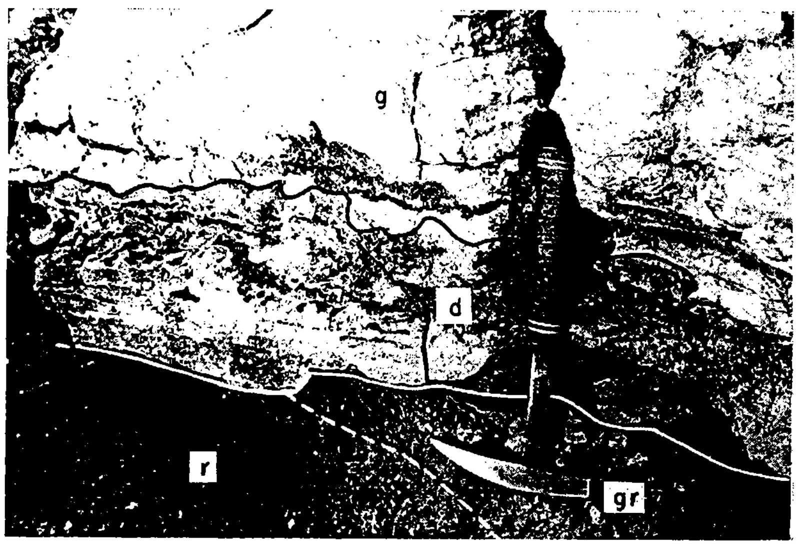


Figure 9. Cedar Springs Dolomite Bed of the Blaine Formation, at the type section, overlain by the Medicine Lodge Gypsum Member, SW¼ SW¼ NE¼ sec. 20, T. 20 N., R. 12 W., top of bluff on Sand Creek, southern Major County, Oklahoma. The light gray, oölitic dolomite (d), nine inches thick, grades upward into gypsum (g). Note the thin light greenish-grey shale (gr) below the dolomite at hammer head, below which is the typical red-brown shale (r).

the name being that of a rock type. This gypsum is here named the Kingfisher Creek Gypsum Bed* for Kingfisher Creek, which has its headwaters in eastern Blaine County.

Type locality—Southeastern Blaine County, especially Tps. 15 and 16 N., R. 10 W., is here designated the type locality.

Type section—The type section, here designated, is on State Highway 33 and outcrops just north and south of the road, especially in SE¼ SE¼ sec. 19, T. 16 N., R. 10 W., Blaine County, Oklahoma (fig. 10). This is included in the type section of the Blaine Formation.

Description in type area—At the type section the Kingfisher Creek Gypsum is approximately 2.5 feet thick, ranging from 1 to 3 feet from central Blaine County to northwestern Canadian County. It is thickest near the Blaine County-Canadian County line and grades southward into greenish-gray and reddish-brown silty clay shale. North of T. 17 N., the Kingfisher Creek grades into several thinner greenish-gray clay shale and gypsum units, one of which is more indurated than the others. These beds, in addition to the 7

* Labeled member on plate I. See footnote, page 30.

Figure 10. Kingfisher Creek Gypsum Bed of Blaine Formation at type section, SE¼ SE¼ SE¼ sec. 19, T. 16 N., R. 10 W., north of State Highway 33. The ledge of fine-grained well-indurated white gypsum ledge, two feet thick, is underlain by red-brown shale with many thin white seams and veins of satin spar. This ledge forms a prominent escarpment in southern Blaine County.

feet of shale below, gradually become more gypsiferous northward into southern Major County.

In Blaine County the Kingfisher Creek is a white fine-crystalline well-indurated alabaster-like gypsum, mottled greenish gray and pale pink to pale red, with many thin clay shale and selenite seams, forming a white to greenish-gray ledge.

In southern Blaine County, the Kingfisher Creek Gypsum is 15 feet above the top of the Medicine Lodge Gypsum and 16 feet below the base of the Magpie Dolomite. In northern Blaine County the Kingfisher Creek is 7 feet above the top of the Medicine Lodge and 9 feet below the base of the Magpie. Southward in Canadian County where the Kingfisher Creek is missing, the reddish-brown silty clay shale unit between the Medicine Lodge and the Magpie is approximately 30 to 35 feet thick. Northward in central Major County, the interval between the top of the Medicine Lodge and the base of the Magpie is only 7 to 11 feet. The Kingfisher Creek Gypsum Bed is conformable with beds above and below.

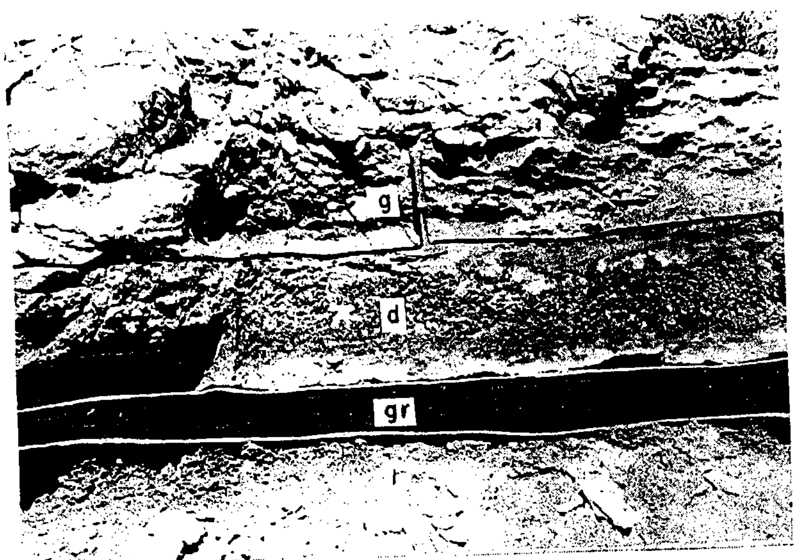


Figure 11. Magpie Dolomite Bed of Blaine Formation, overlain by the Nescatunga Gypsum Member, at type section, SW¼ SE¼ SE¼ sec. 19, T. 16 N., R. 10 W., north side of State Highway 33. The Magpie Dolomite (d) in center of picture is 1.5 feet thick, grading upward into the Nescatunga Gypsum (g). Note the light greenish-gray shale (gr), approximately eight inches thick, below the Magpie and the red-brown shale (r) at bottom of photograph. On the right side, at the base of the gypsum, is a large filled cavity, showing typical leaching effect of ground water.

Magpie Dolomite Bed

Name—Magpie Dolomite was the name given by Gould (1902, p. 48) to the thin dolomite at the base of the Nescatunga Gypsum (Medicine Lodge of Gould). The name is that of the permanent camp of the Arapahoe chief, Magpie, on Bitter Creek, just below the Nescatunga ledge in Roman Nose State Park, Blaine County, Oklahoma. The Magpie residence is south of the park area just south of the center of SW¼ SE¼ sec. 30, T. 17 N., R. 11 W., west of State Highway 8A.

Type locality—The type locality of the Magpie Dolomite is Roman Nose State Park, sec. 24, T. 17 N., R. 12 W., Blaine County, Oklahoma.

Type section—The type section, here designated, is on State Highway 33, about seven miles east of Watonga, in the southern part of sec. 19 and northern part of sec. 30, T. 16 N., R. 10 W., Blaine County, Oklahoma (fig. 11). This is the same area as the type section for the Blaine Formation.

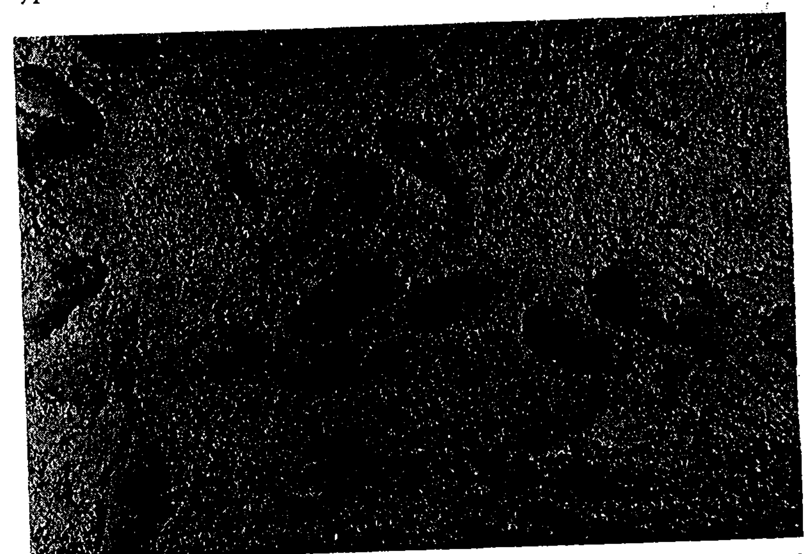


Figure 12. Hand specimen of Magpie Dolomite (x1.3) with abundant fossils (*Permophorus*) from Universal Atlas quarry, SW¼ NE¼ SW¼ sec. 27, T. 17 N., R. 11 W. Note the oölitic texture of the rock and the abundant molds of the one species, *Permophorus albequus* (Beede). These fossils are most abundant in this area, decreasing in number northward and southward. In Kingfisher County they have not been found in the Magpie; and in Woods County, to the north, they are apparently absent.

Description in type area—In Blaine County and adjacent counties to the north and south, the Magpie Dolomite Bed* ranges from 0.5 to 1.5 feet in thickness. It is a light-gray to yellowish-gray fine-crystalline oölitic fossiliferous dolomite with a dense fine-crystalline non-oölitic portion at the base. It is interlayered with the oölitic portions higher up. The common fossil is the clam *Permophorus,* which occurs as molds (fig. 12).

The Magpie is conformably underlain by a thin light greenish-gray silty clay shale and grades upward into the overlying Nescatunga Gypsum. The presence of small dolomite crystals in gypsum in the lower Nescatunga of the Salt Creek Canyon area was reported by Muir (1934, p. 1305). He also reported small dolomite aggregates in anhydrite of the middle Nescatunga.

Traced southward into central Canadian County, the Magpie grades into a light greenish-gray calcareous siltstone. It is absent in Kansas.

* Labeled member on plate I. See footnote, page 30.

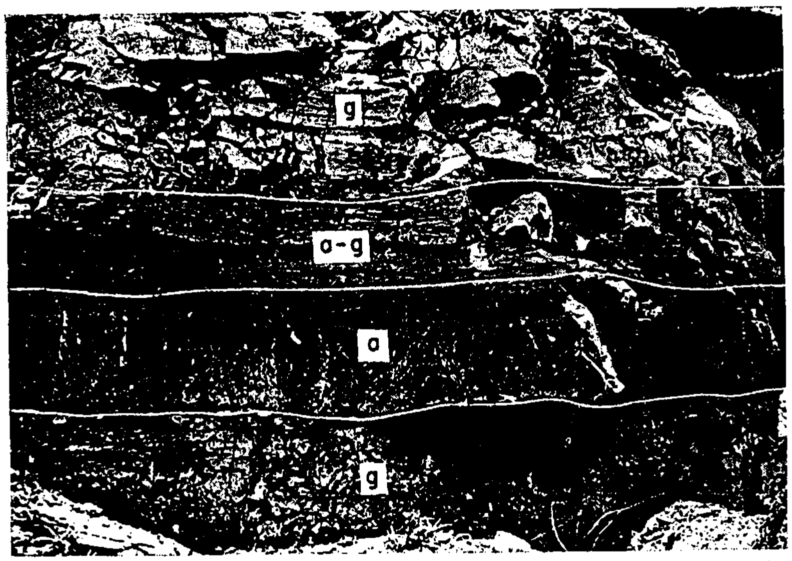


Figure 13. Nescatunga Gypsum Member of Blaine Formation, in old Universal Atlas quarry, SE¼ NE¼ SW¼ sec. 27, T. 17 N., R. 11 W. The quarry face is approximately 15 feet high, with a central dark-colored anhydrite bed (a), two feet thick, grading upward into gypsum (a-g) for about two feet, overlain by white finely granular gypsum (g), approximately five feet thick, and underlain by finely granular gypsum (g), approximately five feet thick. At this place, more than 15 feet of overburden is present, showing the relationship between hydration and amount of overburden.

Nescatunga Gypsum Member

Name—The name Nescatunga was the Comanche Indian name for Salt Fork River, Comanche County, Kansas. Norton (1939, p. 1794-1795) used the name Nescatunga for the 3- to 9-foot-thick gypsum bed that occurs 7 to 10 feet above the Medicine Lodge Gypsum and about the same interval below the Shimer Gypsum along Nescatunga River and adjacent areas, Comanche County, Kansas. Because of miscorrelations by Gould (1902) and Evans (1931), this bed was correlated as the Medicine Lodge and Shimer, respectively, by them. In Oklahoma, Norton included the dolomite at the base with this member, but it is here separated and the name Nescatunga Gypsum Member is applied only to the gypsum and anhydrite parts above the Magpie Dolomite Bed.

Type locality—The type locality is the lower reaches of Nescatunga Creek, T. 34 S., R. 17 W., southeastern Comanche County, Kansas.

Type section—No type section has been designated.

Description in type area—Norton (1939, p. 1797) wrote:

> The Nescatunga gypsum bed is well exposed along the lower reaches of Nescatunga Creek where it is 8 feet thick and separated from the overlying and underlying gypsums by red shale beds of nearly the same thickness. Two miles west, near Liberty School, the member has thinned to 2 feet although protected by several feet of cover. In this area no dolomite occurs at the base of the bed although it is reported present in Oklahoma.

The basal dolomite is present from central Woods County southward to central Canadian County, Oklahoma (Fay, 1961).

Description in Blaine County—In Blaine County the Nescatunga is divisible into three units, an upper and lower gypsum portion separated by a middle bed of anhydrite (fig. 13). The thickness ranges from 12 to 15 feet in northern Blaine County to 7 feet in southern Blaine County. The anhydrite portion is approximately 9 feet thick in the Salt Creek Canyon area and 4 feet thick in northern Blaine County. Traced southward, the Nescatunga grades into reddish-brown and greenish-gray silty clay shales, in central Canadian County, Oklahoma. Traced northward into central Major County, the Nescatunga is 21 to 22 feet thick but has little anhydrite developed in the middle. The Nescatunga thins northward into Kansas, where no anhydrite is reported.

The lower gypsum unit is a white, fine-grained to coarsely granular gypsum with coarse crystals of satin spar and selenite. According to Muir (1934, p. 1305), small cubes of anhydrite and fine-grained dolomite are surrounded by gypsum in this portion of the Nescatunga in the Salt Creek Canyon area. At no place is there anhydrite next to the dolomite, except where solution of this lower gypsum has taken place, and even here a thin, leached clay shale is present between the two.

The middle anhydrite unit is principally a light-gray compact fibrous anhydrite that weathers bright white, forming a bright-white ledge throughout the county. The anhydrite is associated with white compact fine-granular gypsum, some of which clearly cuts through anhydrite crystals that maintain optical continuity (Muir, 1934, p. 1306). The anhydrite occurs as radial aggregates, with some gypsum and microscopic amounts of dolomite present in between and with gypsum replacing some of the anhydrite. The lower contact is gradational through a distance of five millimeters with the underlying gypsum. In some places this unit is roughly banded.

The upper gypsum unit is a white fine-crystalline compact massive alabaster-like gypsum that is roughly banded with slightly darker bands in places. It contains microscopic amounts of anhydrite (Muir, 1934, p. 1307). In most places it is overlain conformably by a thin greenish-gray layer of clay shale and gypsum.

Where weathered, all the above units have coarsely crystalline selenite on their surfaces. The Nescatunga forms an escarpment throughout Blaine County and adjacent areas and is identified by its white ribbon-like pattern, produced especially by weathering of the middle anhydrite. This anhydrite becomes so pronounced in the Salt Creek Canyon area that it has been called the Salt Creek marble locality (Suffel, 1930, p. 69).

The overlying shale unit up to the base of the Altona Dolomite Bed is approximately 36 feet thick in southern Blaine County and 20 feet thick in the northern part of the county. It consists of moderate to dark reddish-brown blocky ferruginous clay shale, with many one-quarter to two millimeter greenish-gray round spots. It contains several thin greenish-gray clay shale layers, two of which appear to be persistent, and it has small selenite and satin spar particles. The above-mentioned two shale layers are each

about one foot thick, separated by about 5 feet of reddish-brown shale, the bottom one occurring about 16 feet above the base of the shale unit in southern Blaine County and 8 feet above the base in northern Blaine County (pl. II). A thin persistent greenish-gray zone of shale is found at the top of this unit just beneath the Altona Dolomite Bed, and at the base of this unit overlying the Nescatunga Gypsum. In Kansas, this shale unit is approximately 8 feet thick. In central Canadian County, Oklahoma, this unit is approximately 40 feet thick, the Nescatunga Gypsum being absent.

Altona Dolomite Bed

Name—The Altona Dolomite was named by Gould (1902, p. 48) for the dolomite at the base of the Shimer Gypsum, for Altona, in southwestern Kingfisher County, Oklahoma. As used by Cragin (1896), Norton (1939), and others, the Shimer included the dolomite at the base. In this report, the Altona Dolomite

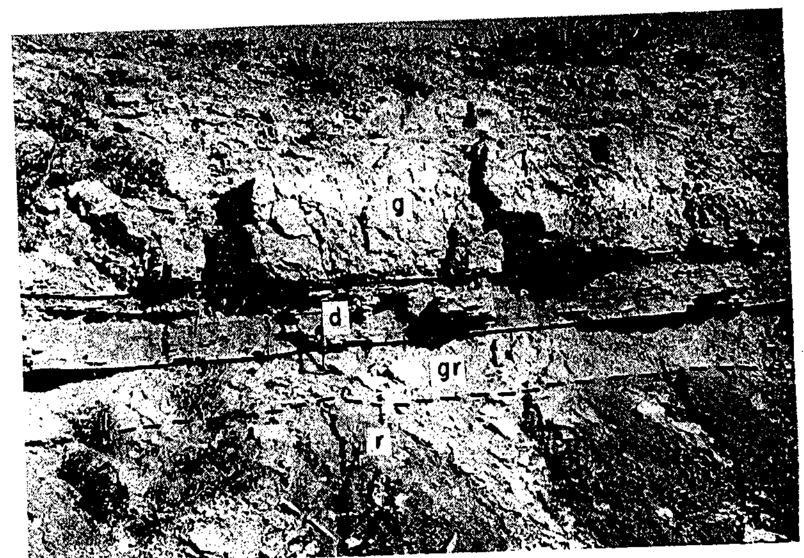


Figure 14. Altona Dolomite Bed of Blaine Formation, at the type section, overlain by the Shimer Gypsum Member, SW¼ SW¼ SW¼ sec. 19, T. 16 N., R. 10 W., on north side of State Highway 33. Altona Dolomite (d), one foot thick, is in center of picture, grading upward into the Shimer Gypsum (g), 12 feet thick, and underlain by light greenish-gray shale (gr), approximately one foot thick, with red-brown shale (r) below.

Bed* is separated from the immediately overlying gypsum, which is termed the Shimer Gypsum Member.

Type locality—Southwestern Kingfisher County and southeastern Blaine County, Oklahoma, especially southwest of Altona in the Gypsum Hills escarpment, is the type locality.

Type section—The section on State Highway 33, seven miles east of Watonga, Oklahoma, southern part of sec. 19 and northern part of sec. 30, T. 16 N., R. 10 W., Blaine County, Oklahoma, is here designated as the type section (fig. 14). This is the same section as that of the type Blaine Formation.

Description in type area—In Blaine County the Altona Dolomite Bed is approximately one foot thick and is similar to the Magpie Dolomite. It is a light-gray to yellowish-gray fine-crystalline oölitic dolomite, with molds of *Permophorus* and other fossils (fig. 15). In the lower part and in thin layers throughout occurs a dense fine-crystalline portion that is non-oölitic. The Altona is conformable with the thin greenish-gray clay shale unit below and grades upward into the overlying Shimer Gypsum. Traced

* Labeled member on plate I. See footnote, page 30.

Figure 15. An orthocratite cephalopod (x4.7) in Altona Dolomite Bed of Blaine Formation, SE¼ sec. 16, T. 19 N., R. 12 W., just west of road. The presence of this type of fossil in the Altona Dolomite shows that this and similar beds are of marine origin.

southward into northern Grady County, Oklahoma, the Altona grades into a calcareous light greenish-gray siltstone, and the underlying shale grades into a massive sandstone and into cross-bedded lenticular mudstone-siltstone conglomerates of the Chickasha Formation. In Kansas, the Altona is 0.5 to 1.5 feet thick.

The Altona erodes commonly into what is termed box-works. The dolomite is jointed and secondary calcite fills these seams, giving a box-work appearance where weathered. The Magpie has this characteristic to some degree. Both the Altona and Magpie form similar-appearing weathered escarpments.

In southeastern Blaine County, the Altona has a light greenish-gray dolomitic shale in the upper part just below the gypsum, the total thickness of the dolomite and the shale being almost 3 feet. In this same area and in adjacent Kingfisher County, the fossil *Permophorus* is so abundant that one might describe certain parts of the dolomite as coquina. This fossil character persists in the Altona southward to the area just west of El Reno, central Canadian County, Oklahoma, and is useful for correlation in this region. About 4 miles south of El Reno the fossils have not been found. Northward in Blaine County, the number of these fossils diminishes rapidly in T. 15 N., R. 10 W., so that most of the Altona in Blaine County appears like the Magpie Dolomite.

Shimer Gypsum Member

Name—Cragin (1896, p. 27) first used the name Shimer Gypsum for the uppermost gypsum and underlying dolomite of the Cave Creek Formation, named for Shimer Township, Comanche County, Kansas. Gould (1902, p. 48) gave the name Shimer to the gypsum portion only and named the underlying dolomite the Altona Dolomite, stating that the Shimer Gypsum marked the top of the Blaine division. In the present paper, the name Shimer Gypsum Member is used to designate the gypsum above the Altona Dolomite Bed, forming the topmost unit of the Blaine Formation, conformably overlain by the Dog Creek Shale. Evans (1931, p. 410-411) proposed the name Lovedale Gypsum for what he considered a higher unit in the Blaine Formation of Harper County, Oklahoma, but later work by Norton (1939, p. 1794-1795) and Myers (1959, p. 30-32) showed that the Lovedale is the same as the Shimer.

Type locality—Shimer Township, through which Cave Creek flows, now Tps. 33, 34, 35 S., R. 17 W., Comanche County, Kansas, is the type locality.

Type section—No type section has been designated.

Description in type area—The Shimer Gypsum is 14 feet thick on Cave Creek in the type area. It is commonly much thinner due to excessive solution and erosion. It is overlain by the Dog Creek Shale and underlain by the Altona Dolomite. Traced northeastward, it grades into the Dog Creek Shale of Barber County, Kansas.

Description in Blaine County—In Blaine County the Shimer Gypsum is approximately 6 feet thick to the south and 16 to 21 feet thick to the north. Locally, in T. 17 N., Rs. 11, 12 W., in the Hitchcock-Roman Nose area, a thin 9-inch-thick bed of anhydrite is present near the middle of the Shimer. In the quarries at Southard, T. 18 N., R. 12 W., anhydrite is present in the middle of the Shimer wherever 30 to 33 feet or more of natural overburden is present (fig. 16). Otherwise anhydrite is absent in the quarries and it has nowhere been observed on the outcrops in that area. Muir (1934, p.

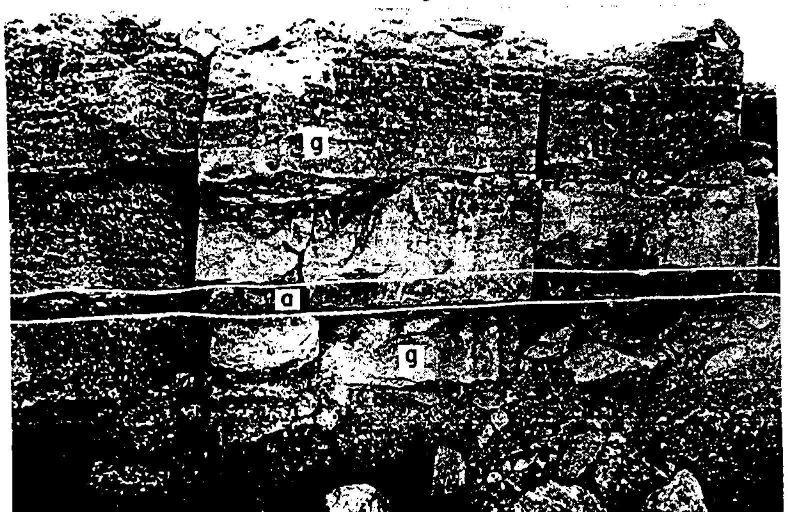


Figure 16. Shimer Gypsum Member of Blaine Formation, west face of old quarry of U. S. Gypsum Company, SW¼ SW¼ SW¼ sec. 14, T. 18 N., R. 12 W. The quarry face is approximately 14 feet high, with a thin dark-colored anhydrite bed (a), nine inches thick, near the center, overlain by seven feet of gypsum (g) and underlain by six feet of gypsum (g). Anhydrite crops out at few places in the Shimer Gypsum, although it is commonly present in the middle of the Shimer and can be seen in artificial cuts.

1308) reported that a few irregular crystal fragments of anhydrite were present in the Shimer Gypsum of the Salt Creek Canyon area.

The Shimer is a white fine- to coarse-crystalline dense to porous massive gypsum that forms a massive white ledge covered with coarse-crystalline selenite. It grades into the underlying Altona Dolomite. The upper surface of the Shimer is wavy bedded with about one foot of relief and is everywhere conformable with the overlying Dog Creek Shale. The lower 20 to 35 feet of the Dog Creek Shale contains a considerable number of thick wavy bedded satin spar layers, suggesting that sporadic deposition of gypsum continued for some time after the Shimer was deposited. Thus it is not strange that the presence of thin massive lenticular gypsums is reported in the Dog Creek Shale. In northern Canadian County, Oklahoma, a 2-foot-thick unnamed gypsum occurs about 25 feet above the Altona Dolomite (SW¼ SW¼ sec. 20, T. 14 N., R. 8 W.); and in Harper and Woodward Counties, Oklahoma, a 4-foot-thick gypsum, named the Haskew Gypsum by Evans (1931, p. 411), occurs about 4 feet above the top of the Shimer.

Southward in northern Canadian County, the Shimer is about 4 feet thick, and in central Canadian County it grades into reddish-brown silty clay shale. Traced northward into Kansas, the Shimer maintains its thickness, or becomes slightly thicker, and then grades northward into the type Dog Creek Shale of Barber County, Kansas.

Distribution—The Blaine Formation is present in central Canadian County, Oklahoma. It extends northwest through central Blaine County, Major County, northeastern Woodward County, eastern Harper County, and central Woods County, and ends in Comanche and Barber Counties, Kansas.

In southwestern Oklahoma, the Blaine is present from Kiowa to Beckham to Jackson Counties and continues southward into Texas to Coke and Tom Green Counties. The upper and lower limits of the Blaine Formation in this area are not the same as are those at the type locality in Blaine County, Oklahoma.

Thickness—The Blaine Formation of Blaine County is approximately 90 feet thick in the southern part, 100 feet thick in the central part, and 75 feet thick in the northern part. All gypsum units, except the Kingfisher Creek, thicken northward and all shale units thicken southward. In Kansas the Blaine Formation is approximately 60 feet thick on Cave Creek, Comanche County, but only about 15 feet of this section is shale (Norton, 1939, p. 1796). See plate II for details in Blaine County. In central Canadian County, the Blaine Formation is approximately 85 feet thick and is almost all red-brown silty shale between the Altona Dolomite above and the Cedar Springs Dolomite below.

Topography—The gypsum units of the Blaine Formation form distinctive ledges that are resistant to weathering. These ledges extend the length of the outcrop of the Blaine Formation and form the Gypsum Hills of northwestern Oklahoma (fig. 17). The non-resistant Flowerpot Shale erodes more rapidly than the gypsum, leaving an escarpment that is several hundred feet high in places such as Salt Creek Canyon (frontispiece). The top of this escarpment is almost 300 feet higher than the Cimarron River to the east, and, if the overlying Dog Creek Shale with its resistant

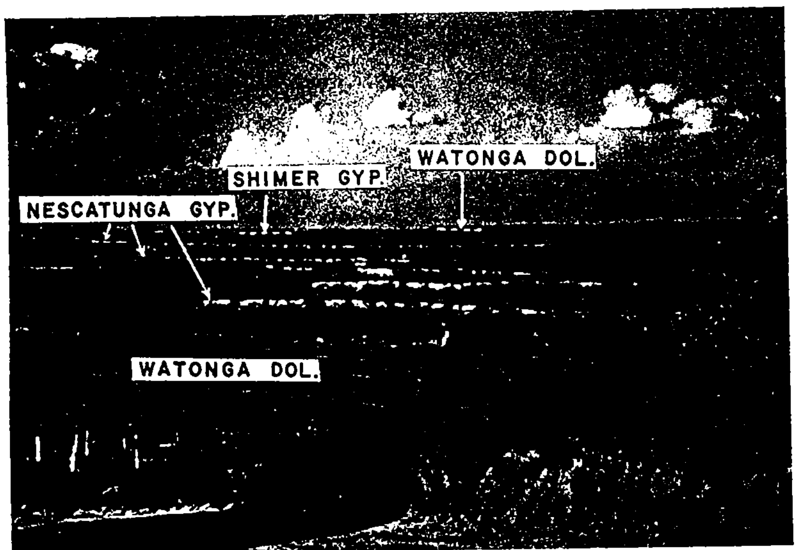


Figure 17. Blaine and Dog Creek escarpments along Roman Nose Canyon, looking northeast through sec. 24, T. 17 N., R. 12 W. The prominent white band in the middle of the picture is the Nescatunga Gypsum. The thin Medicine Lodge Gypsum is inconspicuous; and the thick Shimer Gypsum forms a white band in the background and a rounded escarpment on the right. The isolated buttes and flat grass prairies above the Shimer and in the foreground blow the fence are formed in the Watonga Dolomite. The light-colored Pleistocene sand and gravel of the North Canadian River deposits, seen in the foreground, rest upon the Dog Creek Shale and support thick vegetation, including many oak trees.
(Photograph by William E. Ham)

dolomite members is included, the escarpment is 400 feet higher than the Cimarron.

Many salt and gypsum springs flow from this escarpment, the water probably coming from the gravel and sand of the overlying North Canadian River deposits, and the gypsum and salt being supplied by the Dog Creek, Blaine, and Flowerpot Formations.

Many isolated buttes capped by gypsum are present in this area, some of them being named, such as Henquenet's Butte in Salt Creek Canyon. The Glass Mountains of central Major County are particularly noticeable because they are close to the Cimarron River, and because the basal gypsum is thick at this locality. In wide areas such as Woods County, many of the gypsum units are thin or missing due to solution, but in most places underlying dolomite is present. In Blaine County, slumping and solution work are not as common as in the counties to the north. A rule-of-thumb used in the Southard area of Blaine County is that if there is 5 feet or more of original overburden above a gypsum, the underlying gypsum is probably present in its entire thickness. If there is less than five feet of original overburden, the gypsum may be cavernous and unworkable. This applies only to the Southard area and it is hazardous to apply it elsewhere.

Structure—Structure contours, based upon elevations at the base of the Altona Dolomite Bed, indicate that the Blaine Formation dips about 14 feet per mile to the southwest and that the strike changes from north-northwest in northern Blaine County to west-northwest in southern Blaine County (pl. III). Minor irregularities indicate the presence of broadly plunging noses with axes at right angles to the main trend of the Anadarko basin.

Stratigraphic relationships—Traced southward into Canadian County, Oklahoma, the gypsum units grade into reddish-brown and greenish-gray silty clay shales, and the dolomites grade into calcareous siltstones, the uppermost Altona Dolomite Bed being the most persistent unit. These give way to sandstones and siltstone-mudstone conglomerates of the Chickasha Formation (middle part) in southern Canadian County and northern Grady County, Oklahoma.

In central and western Major County, Oklahoma, the gypsum units are thick and the interbedded shale units are thin. This region is here interpreted as the breakover area between the northern platform and the Anadarko basin to the south. In Barber County, Kansas, at the type locality for the Dog Creek Formation, the Medicine Lodge Gypsum and underlying dolomite are present in addition to the Altona Dolomite, but the remainder of the Blaine Formation has here graded into the reddish-brown shale of the Dog Creek (Norton, 1939, p. 1796).

PALEONTOLOGY—Fossils have been reported from the Magpie and Altona Dolomite Beds. *Permophorus albequus* (Beede) is the common clam in both dolomites. A specimen of an orthoceratite cephalopod (fig. 15) was collected from the Altona Dolomite just west of the road in SE¼ sec. 16, T. 19 N., R. 12 W., northern Blaine County.

Clifton (1942, p. 688) listed names of some fossils which he collected from the Blaine Formation in Kingfisher and Blaine Counties, Oklahoma, stating that they were collected from his "Acme Member," which in Blaine County would probably be the Nescatunga Gypsum and underlying Magpie Dolomite. Clifton had two collecting localities in this area: (1) SE¼ sec. 33, T. 15 N., R. 9 W., Kingfisher County, and (2) common line secs. 19 and 30, T. 16 N., R. 10 W., Blaine County. Clifton's description of the Acme as "fossiliferous enough that the trace of its surface expression is an attenuated series of fossil-bearing limestone outcrops" does not fit that of the Magpie for locality (1) but does fit with that of the Altona Dolomite. Both the Altona and the Magpie crop out at his locality (2) where all gypsum units are present, and his Acme here may be the same as the Nescatunga and the underlying Magpie. Clifton also stated that fossils occur in the gypsum but did not specify in which of his 14 collecting localities in Texas and Oklahoma he had found them. The fossils listed by Clifton, with collecting localities after each, are: *Wilkingia rothi* (Newell) (1, 2), *Schizodus oklahomensis*? Beede (1, 2), *Permophorus albequus* (Beede) (1, 2), *Perrinites hilli* (Smith) (1, 2), and *Permophorus mexicanus* (Girty) (2).

As previously noted, the Altona Dolomite is almost a coquina in southeastern Blaine, southwestern Kingfisher, and northwestern Canadian Counties, Oklahoma.

AGE AND CORRELATION — The cephalopod *Perrinites hilli* (Smith), long used as a marker for Leonardian strata, has been collected from the Word Formation, Glass Mountains, West Texas (Miller and Furnish, 1957, p. 1052). Equivalent members of the Blaine Formation in central Texas appear to grade into a limestone and dolomite sequence in the Midland basin to the west, and these carbonates contain fusulinids restricted to Guadalupean rocks. Accordingly, the Blaine Formation is here considered to belong to the Guadalupean Series.

In southwestern Oklahoma, the lower part of the Van Vacter Gypsum may be the same as the Shimer, the Mangum the same as the Altona, the Collingsworth and underlying Creta the same as the Nescatunga and underlying Magpie, the Cedartop the same as the Kingfisher Creek, the upper Haystack and underlying dolomite the same as the Medicine Lodge and Cedar Springs, and the lower Haystack the same as the upper gypsiferous ledge of the Flowerpot Shale of the Blaine County area (Scott and Ham, 1957, p. 19, fig. 4).

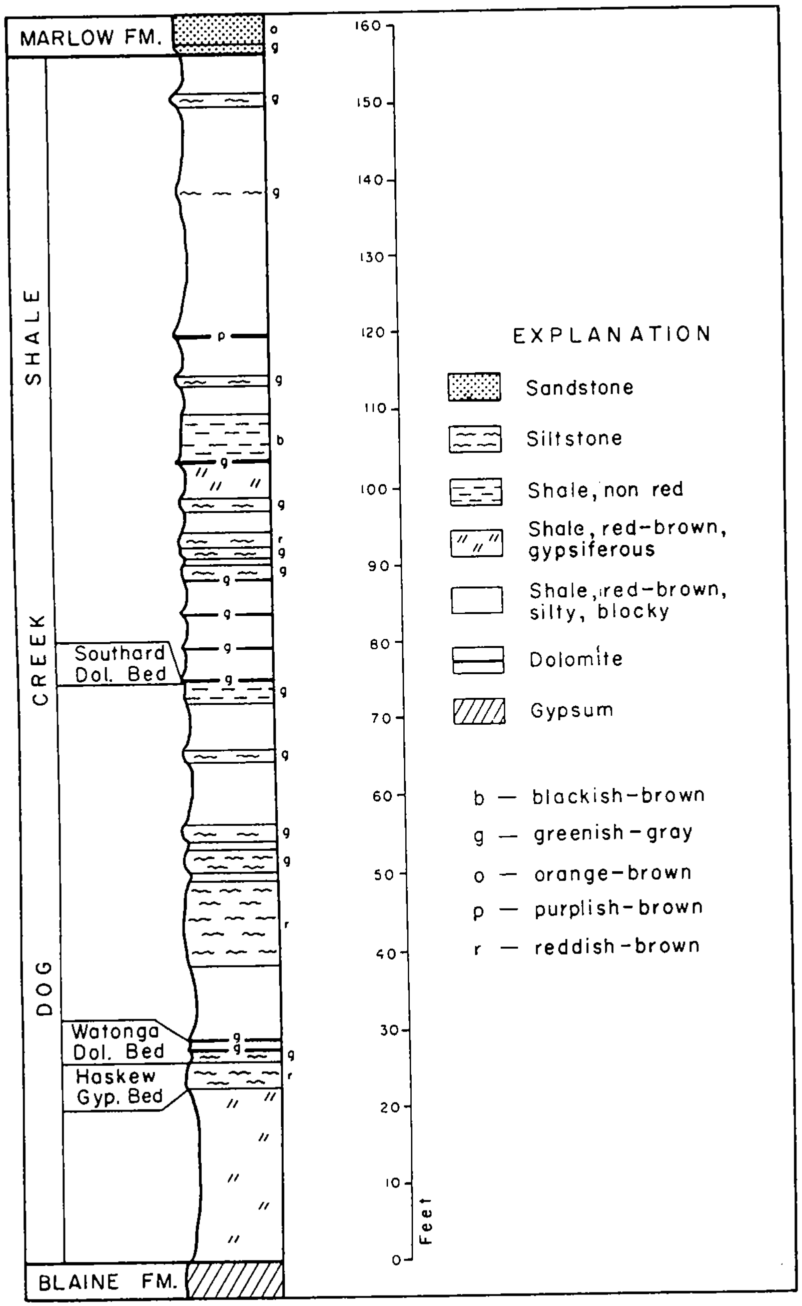
DOG CREEK SHALE FORMATION

The Dog Creek Shale conformably overlies the Shimer Gypsum Member of the Blaine Formation and is overlain, probably conformably (Fay, 1961), by the Marlow Formation. The Dog Creek is principally a reddish-brown blocky clay shale with an average thickness of 190 feet in southern Blaine County and 157 feet in the northern part (fig. 18, pl. II). In Blaine County, two thin dolomite beds, the Watonga and the Southard, occur about 30 and 80 feet, respectively, above the base.

NAME—The name Dog Creek shales was first used by Cragin (1896, p. 39-40) for a series of shales and dolomites between the Cave Creek (now Blaine) Formation below and the Red Bluff beds (now Whitehorse Sandstone) above. The formation was named for Dog Creek, northwestern Barber County, Kansas.

TYPE LOCALITY—The type locality is south of Lake City, Barber County, Kansas, in secs. 4 and 9, T. 32 S., R. 14 W.

TYPE SECTION—No type section has been designated, but that on State Highway 160, in N½ N½ sec. 9, T. 32 S., R. 14 W., in Barber County, Kansas, measured by Swineford (1955, p. 71-72) and again by Fay (1961) along the Dog Creek valley, is here selected as the type section.



Description in type area—The Dog Creek Shale is 31 feet thick in the type section, extending from the Altona Dolomite at the base to the Marlow Sandstone at the top. The Watonga dolomitic siltstone is about 3 feet thick, and is 5 feet above the base. The Southard argillaceous and dolomitic siltstone is about 22 feet above the base. A prominent arenaceous siltstone separates these two beds, and several other siltstones are present near the top of the formation. Mineralogically these and other fine-grained sandstones lower in the section (Blaine and Flowerpot) are similar to the Marlow Sandstone and probably originated from the east and northeast (Fay, 1961).

According to Swineford (1955, p. 71-73), "there is no indisputable evidence in Kansas of an unconformity separating it from the overlying Whitehorse sandstone," an observation that may be applied throughout Oklahoma as well (Fay, 1961). Westward from Dog Creek, on Cave Creek in Comanche County, Kansas, a reddish-brown and white-banded gypsum, 5 feet thick, occurs at the base of and interbedded with the Marlow Sandstone, marking the top of the Dog Creek Shale in that area. At this locality the Blaine Formation is typically developed, and the Dog Creek is 25 feet thick, extending from the top of the Shimer Gypsum Member of the Blaine Formation to the basal gypsum of the Marlow Formation.

Description in Blaine County—In Blaine County, the reddish-brown blocky clay shale of the Dog Creek is divisible into several distinct mappable units. Each unit is thicker to the south where the total Dog Creek is at least 190 feet thick (240 feet in the subsurface) and thinner to the north where the total thickness is approximately 157 feet. Two thin dolomites in the lower 80 feet of the Dog Creek are named the Watonga Dolomite Bed (30 to

Figure 18. Composite stratigraphic diagram of the Dog Creek Shale in southern Major County, secs. 11 and 14, T. 20 N., R. 13 W., east of Cedar Springs. The total thickness of the Dog Creek is approximately 157 feet. The Haskew, Watonga, and Southard Beds can be traced from central or southern Blaine County northward into Woods County, Oklahoma. The Haskew horizon in Blaine County is represented by a gypsiferous siltstone, but in western Major County it grades into an argillaceous gypsum. The Watonga Dolomite is thickest in central Blaine County, grading southward into shale in central Canadian County and northward into a thin ripple-marked dolomitic siltstone in Kansas. The Southard is about 3 inches thick everywhere exposed. The Dog Creek is about 200-240 feet thick in southern Blaine County, and 30 feet thick or less in Kansas, but the named beds appear to persist between the two areas.

35 feet above the base) and the Southard Dolomite Bed (approximately 80 feet above the base).* Several other thin persistent beds of dolomite, siltstone, and greenish-gray clay shale can be correlated within the Dog Creek sequence. One of these, the Haskew Bed, is a gypsiferous siltstone just below the Watonga Dolomite (pl. II). This unit consists of gypsiferous grains and some quartzose grains in a gypsum cement and, together with the overlying Watonga Dolomite, forms a resistant mappable escarpment throughout Blaine County. It is not named on the geologic map or stratigraphic diagram (pls. I, II) but is classed with the lower part of the Watonga Dolomite, as shown on the map.

The lower part of the Dog Creek Shale, below the base of the Watonga Dolomite, is divisible into two contrasting units, a lower gypsiferous reddish-brown shale and an upper thin light-brown gypsiferous siltstone (Haskew Bed) that is well indurated. The lower shale unit is characterized by the presence of numerous thin to thick wavy bedded satin spar layers throughout and an occasional thin greenish-gray clay shale or calcareous siltstone bed. A 1-foot-thick bed of greenish-gray silty dolomitic gypsum and clay shale forms a resistant ledge several feet above the base at places. The lower part of the Dog Creek is approximately 36 feet thick in southern Blaine County and 23 feet thick in the northern part of the the county.

Haskew Bed

Name—The name Haskew is that of a township in northwestern Woodward County, Oklahoma. The name was applied by Evans (1931, p. 411), in Harper and Woodward Counties, to a thin gypsum, shale, and gypsiferous siltstone unit that is 4 feet thick and is approximately 4 feet above the top of the Shimer Gypsum.

Type locality—The type locality is Haskew Township and surrounding areas in T. 25 N., Rs. 18-19 W., Woodward County, Oklahoma.

Type section—The type section is SW¼ SW¼ SW¼ sec. 6, T. 25 N., R. 18 W., just east of State Highway 50 in a creek bank, Woodward County, Oklahoma.

* When plate I, the geologic map of Blaine County, was published, the Watonga and Southard Dolomite Beds were designated as members. Subsequently it was deemed that their proper nomenclatorial rank should be that of beds.

Description in type area—The Haskew is divisible into 4 separate portions at the type section: a lower massive white gypsum several feet thick, overlain by a siltstone and reddish-brown shale about 1 foot thick, with a thin white gypsum above the shale and a reddish-brown gypsum at top. The uppermost gypsum is persistent southeastward into the Cheyenne Creek area of Major County, south of which the section grades into light-brown gypsiferous siltstone, about 4 feet thick. The Watonga Dolomite Bed occurs just above the Haskew as a dolomitic siltstone from Woodward County northward to Kansas. The northern limit of the Haskew is in southern to central Woods County where it grades into reddish-brown Dog Creek Shale above the Shimer Gypsum (Fay, 1961).

Description in Blaine County—In Blaine County the Haskew Bed is 4 feet thick, and is composed of several siltstone beds, in places separated by silty shale, that grade upward into the base of the Watonga Dolomite (pl. II). The light-brown gypsiferous

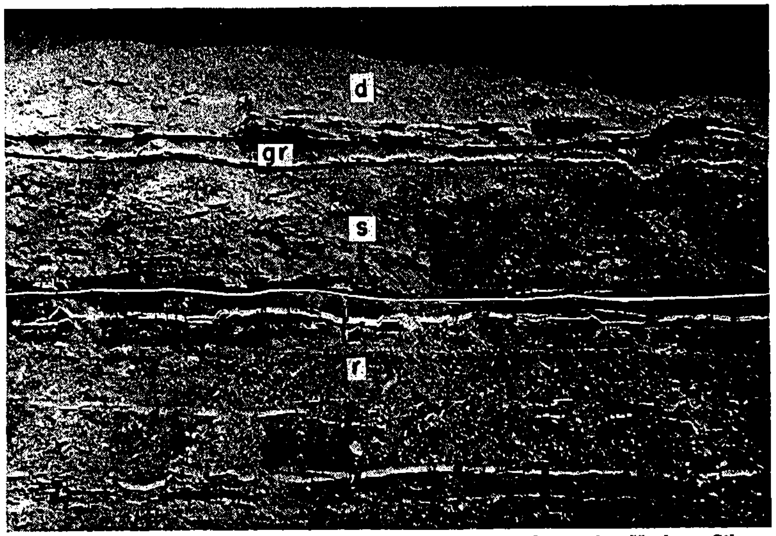


Figure 19. Watonga Dolomite at the type section, overlying the Haskew Siltstone horizon of the Dog Creek Shale, SW¼ SW¼ SW¼ sec. 19, T. 16 N., R. 10 W., north side of State Highway 33. The light greenish-gray Watonga Dolomite (d) is composed of thin silty dolomite beds interbedded with greenish-gray shale, approximately six feet thick, with greenish-gray gypsiferous shale below (gr), about one foot thick, overlying the light-brown gypsiferous siltstone of the Haskew horizon (s). The Haskew and Watonga Beds form a prominent ledge throughout Blaine County, with red-brown gypsiferous shale (r) below. Note the thick satin spar bands, characteristic of this part of the section.

siltstone is well indurated in many places and forms a prominent mappable escarpment together with the overlying Watonga Dolomite Bed, occurring 23 to 36 feet above the Shimer Gypsum Member of the Blaine Formation. The Haskew grades into shale southward into Canadian County.

In Canadian County, the interval between the Altona Dolomite and the Watonga Dolomite, where the Shimer and Haskew are absent, is approximately 50 feet. In this area a thin gypsum unit (unnamed), about 2 feet thick, overlain by a thin dolomite, is present locally about 25 feet above the base (SW¼ SW¼ sec. 20, T. 14 N., R. 8 W.). Thus it can be seen that other gypsum units similar to the Haskew may occur locally in the lower part of the Dog Creek Shale, and one may expect to find others in the subsurface rocks of this part of the Dog Creek. Apparently during early Dog Creek time much gypsum was deposited locally in northwestern Oklahoma, that in Canadian County being older than that in Woodward County.

Watonga Dolomite Bed

Name—The name Watonga Dolomite Bed* is here given to the 3- to 7-foot-thick unit of dolomite and interbedded dolomitic shales and siltstones in the lower portion of the Dog Creek Shale, about 25 to 40 feet above the top of the Shimer Gypsum. The unit is named for Watonga, Blaine County, Oklahoma, east of which are excellent exposures of the dolomite on State Highway 33. Cragin (1897, p. 353-354, 358) used the name Amphitheatre Dolomite for this unit, with Chapman's Amphitheatre, head of Salt Creek Canyon, as the type locality. The name fell into disuse because neither illustrations nor measurements were given.

Type locality—The area east and northeast of Watonga, Blaine County, Oklahoma, in T. 16 N., Rs. 10, 11 W., is here designated the type locality.

Type section—The section on State Highway 33, about 7 miles east of Watonga, in SW¼ SW¼ sec. 19, T. 16 N., R. 10 W., and SE¼ SE¼ sec. 24, T. 16 N., R. 11 W., Blaine County, Oklahoma, is here designated as the type section (fig. 19).

Description in type area—In Blaine County, the Watonga Dolomite consists of many thin beds of light bluish-gray fine-

* Labeled member on plate I. See footnote, page 54.

grained to compact dolomite, with vuggy laminae interbedded with light bluish-gray to moderate reddish-brown blocky vuggy dolomitic shale and siltstone that are poorly indurated. It forms a light bluish-gray ledge together with the underlying light-brown siltstone. The lower 2 to 3 feet of the Watonga is interbedded with shale and siltstone of the underlying Haskew, the line of demarcation being drawn at the top of the massive part of the underlying siltstone or the place where the first dolomitic shale or dolomite occurs at the base of the Watonga. The upper boundary of the Watonga is drawn at the contact with the overlying reddish-brown shale. Thin dolomites are present in the lower several feet of the overlying shale but are a different color (grayish-white to orange-brown) from that of the Watonga and are not included with the Watonga.

As defined above, the Watonga Dolomite is 3 to 7 feet thick, with more interbedded shale at its base to the south and less to the north. As traced southward into Canadian County, the Watonga is represented by a thin greenish-gray to reddish-brown argil-

Figure 20. Siltstone in middle part of Dog Creek Shale, along State Highway 51, near C NW¼ NW¼ sec. 3, T. 18 N., R. 12 W. The light orange-brown siltstone (s) is about five feet thick, overlain and underlain by dark red-brown shale. This siltstone grades southward into shale and northward into sandstone. Near the Kansas-Oklahoma line, this unit is a few feet below the base of the Marlow and is identical in lithology with the Marlow. The Watonga Dolomite occurs about 10 feet below the siltstone at this locality.

laceous dolomite, overlain by several feet of reddish-brown shale and two stray dolomites. The upper and lower contacts are conformable.

The overlying shale unit is 45 to 50 feet thick and is divisible into several zones in the northern part of Blaine County. The gross unit may be described as a moderate to dark reddish-brown blocky silty clay shale, speckled with small greenish-gray spots and thin seams, with some thin greenish-gray silty and slightly calcareous greenish-gray shale seams in the middle portion and a thin light-brown to moderate reddish-brown siltstone in the lower portion (fig. 20). In the upper portion are a few thin greenish-gray siltstone layers, mottled moderate reddish-brown, but predominantly this portion is reddish-brown silty clay shale.

The lower siltstone, about 5 feet thick in northern Blaine County, is about 7 to 8 feet above the top of the Watonga Dolomite. In central Blaine County this unit is only 1 foot thick and is about 13 feet above the top of the Watonga. It increases in thickness northward into southern Major County and grades into reddish-brown silty clay shale in southern Blaine County. About 3 to 5 feet above this siltstone is a 10-foot-thick zone of thin greenish-gray gypsiferous clay shales in reddish-brown clay shale, with 3 thin greenish-gray beds (at bottom, middle, and top) which seem to be persistent in Blaine County, grading into a reddish-brown clay shale sequence in southern Blaine County. About 5 to 8 feet above the top of this zone, is a 2-foot-thick bed of greenish-gray and reddish-brown siltstone, which is approximately 8 to 10 feet below the Southard Dolomite Bed. These beds appear to grade into thick siltstones in southern Major County where the entire thickness of this unit between the Watonga and Southard Dolomites is 42 feet. The upper and lower contacts are conformable with beds above and below, and the upper few inches just beneath the Southard Dolomite is a greenish-gray clay shale.

Southard Dolomite Bed

Name—The name Southard Dolomite Bed* is here given to a 3- to 4-inch-thick light-gray dense dolomite that occurs about 80 feet above the base of the Dog Creek Shale, or 45 feet above the Watonga Dolomite in northern and central Blaine County. It is named for the town of Southard in north-central Blaine County, south of which it crops out on State Highway 51A. Cragin (1897, p. 353-354, 358) gave the name Chapman Dolomite to this same bed plus a few higher dolomites in the same area, designating Chapman's Amphitheatre of the Salt Creek Canyon area as the type locality. The name fell into disuse because Cragin failed to give measured sections or to map or describe the unit.

Type locality—The Southard area, Tps. 18, 19 N., R. 12 W., north-central Blaine County, Oklahoma, is here designated the type locality.

Type section—The section on and near State Highway 51A in SW¼ SW¼ sec. 10, T. 18 N., R. 12 W., one mile south of Southard, northern Blaine County, Oklahoma, is here designated as the type section (fig. 21).

Description in type area—In Blaine County the Southard Dolomite is a yellowish-gray to light-gray fine-crystalline compact massive to laminated silty dolomite with some dark-black specks. It erodes into a massive yellowish-gray ledge, forming an escarpment above the Watonga Dolomite escarpment. It is 4 inches thick

* Labeled member on plate I. See footnote, page 54.

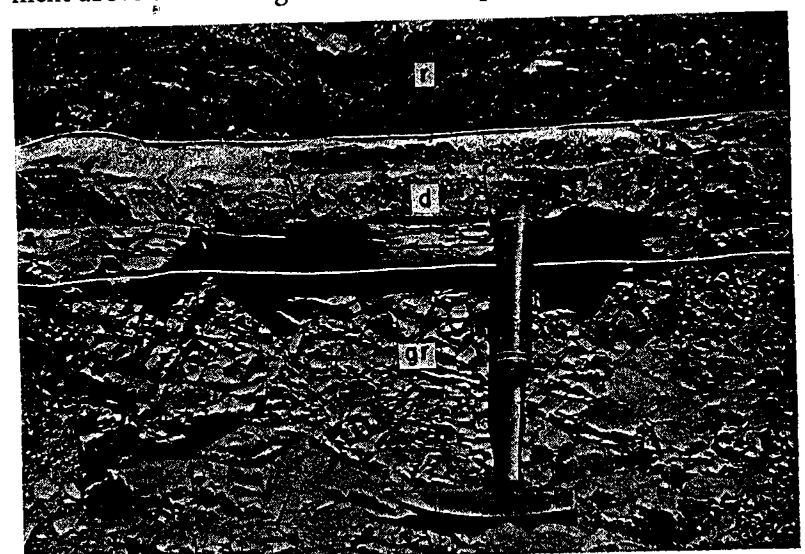


Figure 21. Southard Dolomite Bed of the Dog Creek Shale Formation, SW¼ SW¼ SW¼ sec. 10, T. 18 N., R. 12 W., at the type section south of Southard. The dolomite proper (d) is about three inches thick, overlain by red-brown shale (r), and underlain by dolomitic greenish-gray indurated shale (gr). This unit forms a mappable escarpment throughout most of Blaine County.

at the type section and is approximately this same thickness in central and northern Blaine County and southern Major County, Oklahoma. Another dolomite similar to the Southard is about 11 to 15 feet above the Southard and is almost a foot thick in places (pl. II).

Traced southward, the Southard is questionably present at and south of Greenfield, west of the North Canadian River, in sec. 4, T. 15 N., R. 11 W., south and west of State Highway 8. The base of the Marlow Formation is covered in this area, but it is stratigraphically approximately 100 feet above the Southard. An elevation on the Southard in the area is 1,472 feet and the elevation of the Relay Creek Dolomite Bed in the adjacent bluff is 1,654 feet. The Marlow is approximately 80 to 85 feet thick beneath the Relay Creek Dolomite Bed, leaving approximately 100 feet for the thickness of the upper part of the Dog Creek Shale in this area. A well drilled in NW¼ NW¼ sec. 26, T. 16 N., R. 13 W., about 10 miles to the northwest, penetrated approximately 180 feet of Dog Creek Shale, with the greenish-gray zone of the Southard about 100 feet below the top, thus confirming the relative Dog Creek thickness and the position of the Southard as about the same in the subsurface as at the surface. Samples were taken every five feet, and the well started in the Rush Springs Sandstone, ending in the Flowerpot Shale.

North and south of Greenfield, the Southard is poorly exposed and is mostly covered by Pleistocene deposits of the North Canadian River. South of Roman Nose State Park the Southard has been stripped off by erosion by the North Canadian River. The Southard forms a prominent greenish-gray ledge in Major, Woodward, Harper, and Woods Counties, Oklahoma, changing facies into a dolomitic siltstone in Kansas, where it is questionably correlated to Dog Creek, Barber County, Kansas (Fay, 1961).

The overlying reddish-brown clay shale is approximately 90 to 100 feet thick in southern Blaine County and is 80 feet thick in southern Major County, Oklahoma. In the Greenfield area and south into southern Blaine County, the upper part of the Dog Creek Shale is almost all reddish-brown clay shale. In Geary near the railroad tracks south of town, this shale was used in the manufacturing of bricks. The base of the Marlow in this area is marked

by a light greenish-gray fine- to medium-grained quartzose sandstone with a few coarse well-rounded quartz grains. A few siltstones and fine-grained quartzose sandstones similar to this bed, but without the large grains, occur in the upper 50 feet of the Dog Creek in this area. The lower 20 feet of the Marlow is interbedded reddish-brown shale and siltstone with moderate reddish-orange to reddish-brown fine-grained sandstone in the Greenfield area of central Blaine County. To the south, in northwestern Canadian County, this interval is occupied by ledge-forming gypsiferous fine-grained sandstone. To the north, near Canton in Blaine County, the lower 20 feet or more is fine-grained sandstone to the base.

The upper contact of the Dog Creek Shale is here considered conformable with the overlying Marlow Formation, there being no evidence of either an unconformity or of lateral gradation at the Marlow-Dog Creek boundary. It is here assumed that a change from mud deposition to sand deposition took place in the same body of water almost simultaneously over a large area of the Anadarko basin and surrounding areas from Dog Creek time to Marlow time. In northern Blaine County and adjacent Major County, the upper 45 to 50 feet of the Dog Creek contains many thin dolomites and gypsiferous siltstones not present in southern Blaine County, indicating that the origin for the clastics is probably east and northeast (Fay, 1961). Figure 18 shows the character of the Dog Creek Shale in southern Major County.

Distribution—The Dog Creek Shale extends from northern Grady County northward through central Blaine County, Oklahoma, into Barber and Comanche Counties, Kansas. It is present in southwestern Oklahoma north and west of the Wichita Mountains and extends into Texas.

Thickness—At the type locality in Kansas the Dog Creek is approximately 31 feet thick between the Altona Dolomite below and the Marlow Sandstone above. In southern Major County, Oklahoma, the Dog Creek is approximately 157 feet thick between the top of the Shimer Gypsum and the base of the Marlow Sandstone. In southern Blaine County, the Dog Creek is about 190 feet thick at the surface and 240 feet thick in the subsurface. From northern Grady County southward, there is an apparent progressive gradation of the Dog Creek Shale into Chickasha siltstones, sandstone, and mudstone conglomerates. In central Grady County, in the Ninnekah area, only 40 feet of shale is present below the Marlow and just south of that area the Chickasha Formation extends up to the base of the Marlow (Fay, 1961).

TOPOGRAPHY—The Watonga and Southard Dolomite Beds form prominent mappable escarpments similar to the Blaine ledges, forming the upper part of the Gypsum Hills in northwestern Oklahoma. In Kansas, Norton (1939) mentioned that a ledge (correlated as Watonga by Fay, 1961) in the middle of the Dog Creek can be used to subdivide the Dog Creek in that area because it forms a prominent light-colored bench. In Blaine County, the upper part of the Dog Creek is mostly reddish-brown blocky clay shale and is weakly resistant. The North Canadian River forms most of its valley in this part of the section.

STRUCTURE—The structure of the Dog Creek Shale is similar to that of the underlying Blaine Formation and overlying Marlow Formation, there being no evidence of an unconformity along the upper surface. In the Canton area, along the west side of the reservoir, the upper contact is wavy bedded but parallel to wavy bedding in the layers above and below. Just south of the reservoir, the contact dips about 10 degrees southeast and strikes north 25 degrees east. This structure is here interpreted as the northwest limb of a broad southwestward-plunging syncline, with the synclinal axis striking southwest through the area of Canton (pl. III).

STRATIGRAPHIC RELATIONSHIPS—The upper and lower contacts of the Dog Creek Shale are here considered conformable with beds above and below. Traced southward into Grady County, Oklahoma, the Dog Creek grades into the upper part of the Chickasha Formation. Northward in Kansas, the Dog Creek is thinner by about one-seventh of its total thickness in Blaine County, but named members and other units can be correlated within the Dog Creek between both areas. The thinning takes place within all parts of the Dog Creek, as shown by Fay (1961). The sandstones in the Dog Creek of the northern platform are mineralogically similar to the Marlow and evidently were derived from the northeast. The breakover between the northern platform and the basin during Dog Creek time was close to the latitude of west-central Major County, Oklahoma.

The best evidence for an unconformity at the base of the Marlow Formation is that given by Davis (1955, p. 53, 67) who stated that the Chickasha-Duncan complex is less than 200 feet thick in T. 2 N., R. 6 W., in Stephens County, but 600 feet thick in sec. 31, T. 5 N., R. 8 W., and thicker to the north in Grady County, Oklahoma. The interpretation by Davis is that the area was uplifted at the end of El Reno time and eroded or truncated by an advancing Marlow sea. The alternative interpretation is that the Tussey delta was formed over a topographically high area in this region and that the area in T. 2 N., R. 6 W., was close to land; thus the sediments in this region would be expected to be thin as is the case in modern deltas.

The contrast between the purple mudstone conglomerates of the Chickasha-Duncan complex and the moderate reddish-orange fine-grained sandstone of the overlying Marlow is striking and probably reflects a change from deltaic conditions to marginal marine conditions, with southward regression of the deltaic margin (Fay, 1961). The Marlow contains sand and chert grains and granules that appear to have come from older Ordovician rocks, perhaps in the Arbuckle Mountains and areas to the southeast. Obviously the fine clastics of the Chickasha-Duncan complex originated from the southeast, probably when stream competency was low. It is possible that uplift of the Ouachita complex caused stream competency to increase and that much sand and chert were transported to the Marlow sea. With this interpretation, one does not have to postulate an unconformity at the base of the Marlow Formation.

AGE AND CORRELATION—The Dog Creek Shale grades southward into the Chickasha Formation. In southwestern Oklahoma, the Dog Creek Shale grades eastward into the Chickasha Formation of Grady County, but grades westward and southwestward into an evaporite sequence of gypsums and dolomites. If the Watonga Dolomite of Blaine County is the equivalent of what is called the Acme Dolomite of southwestern Oklahoma, then the gypsiferous shales of the Dog Creek beneath the Watonga (including Haskew) and the underlying Shimer are the equivalents of the lower Van Vacter Gypsum beneath the Acme. The middle part of the Dog Creek Shale of Blaine County would then be the equivalent of the upper Van Vacter Gypsum of southwestern Oklahoma. The Southard Dolomite may correlate approximately with the Guthrie Dolomite of north-central Texas, and the upper part of the Dog Creek Shale of Blaine County may correspond to the interval between the Guthrie and the base of the Marlow of north-central Texas. In Texas the beds below the Marlow and above the San Angelo are termed members of the Blaine Formation, according to Lloyd and Thompson (1929, p. 950-952).

The Dog Creek Shale is here considered to belong to the Guadalupean Series because it probably grades into rocks of that series in the Midland basin of Texas, as discussed in sections on the Flowerpot Shale and Blaine Formation.

WHITEHORSE GROUP

In Blaine County, the Whitehorse Group consists of approximately 300 feet of fine-grained sandstone, subdivided into the Marlow Formation below (93-114 feet thick) and the Rush Springs Sandstone above (180-230 feet thick). The upper contact is present west of Blaine County and possibly in Blaine County in an isolated hill northwest of Eagle City, most of the upper part of the Rush Springs having been eroded away by the Canadian River in western and southwestern Blaine County. The upper and lower contacts of this group are here considered conformable with beds above and below.

Cragin (1896, p. 40) used the name "Red Bluff beds" for sandstones and shale between the Dog Creek Shale below and the Day Creek Dolomite above, named after the post office of Red Bluff, near Protection, western Comanche County, Kansas. The name was preoccupied; and a new name, Whitehorse Sandstone Member was proposed for this same sequence of beds by Gould (1905, p. 55). The type locality is the area of Whitehorse Springs, central Woods County, Oklahoma. Miser (1954) and Davis (1955, p. 62), following Sawyer (1929, p. 11), used the name Whitehorse Group, subdivided into the Marlow Formation below and the Rush Springs Sandstone above, to include all strata between the El Reno Group below and the base of the Cloud Chief Formation above. South of the North Canadian River the base of the Weatherford Dolomite marks the top of the Whitehorse Group. North of the North Canadian River the base of the Day Creek Dolomite marks the top of the Whitehorse. These two dolomites

may not be the same. For this reason the name Whitehorse Group as used in this report is defined to include the beds between the top of the Dog Creek Shale and the base of the Weatherford Dolomite (?), recognizing the fact that this definition may differ from that of Gould.

The area of Whitehorse Springs, central Woods County, Oklahoma, is the type locality. No type section has been designated, but in the type area only the Doe Creek Sandstone Member of the Marlow Formation is exposed, with the Day Creek Dolomite cropping out about 6 miles to the northwest.

At Whitehorse Springs the Doe Creek Sandstone is a coarse-grained sandstone and algal dolomite, 3 to 9 feet thick, above the Dog Creek Shale (Evans, 1954, p. 196).

In Blaine County, the Whitehorse Group consists of 300 feet of moderate reddish-orange to moderate reddish-brown fine-grained sandstone. The Marlow Formation is approximately 93 to 114 feet thick, with two persistent dolomites at the top, 18 to 28 feet apart, termed Emanuel and Relay Creek Dolomite Beds, the Emanuel marking the top of the Marlow Formation. The overlying Rush Springs Sandstone contains many medium-sized quartz grains that are well rounded and frosted. The Rush Springs is approximately

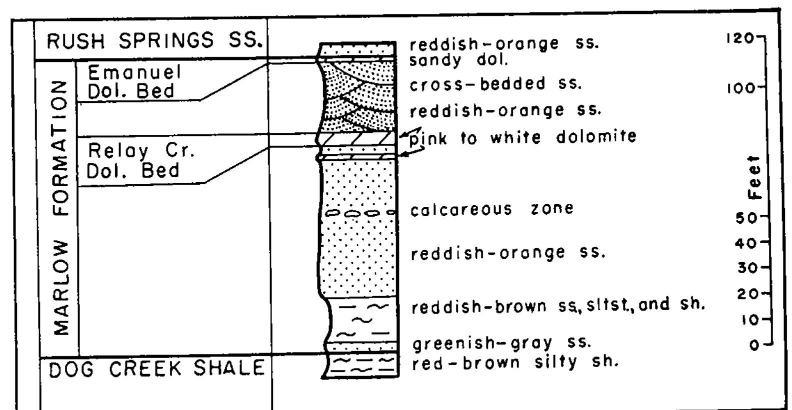


Figure 22. Stratigraphic diagram of the Marlow Formation in the Red Hills, northwest of Greenfield, secs. 29 and 30, T. 15 N., R. 11 W., and sec. 25, T. 15 N., R. 12 W., at the type section of the Emanuel and Relay Creek Dolomites. The lower 20 feet is gradational with the Dog Creek Shale, and the upper 30 feet contains three dolomites locally, the lowermost one of which is absent outside of this area. The sandstone of the Marlow is identical with that of the overlying Rush Springs; thus the Emanuel Dolomite Bed is used by geologists as a boundary marker between these two formations.

180 feet thick in northwestern Blaine County and 230 feet thick in southwestern Blaine County and in adjacent Custer County. These thicknesses are computed from differences in elevations on the Weatherford Dolomite (?) (as correlated) and on the Emanuel Dolomite (pl. III). The only place in Blaine County where a possible upper contact of the Rush Springs Sandstone can be seen is northwest of Eagle City, northwestern Blaine County, in a high hill in the SW¼ sec. 6, T. 17 N., R. 13 W. Four dolomites occur in this hill, the second one up being more like the Weatherford Dolomite than are the others and tentatively correlated with the Weatherford Dolomite in this report. This means that in northwestern Blaine County a stray dolomite is present in the Rush Springs Sandstone about 35 feet below the top.

Marlow Formation

Name—Sawyer (1924, p. 313-315) first used the name Marlow Formation for 120 feet of sandstone and shale overlying the Duncan Sandstone and underlying the Whitehorse Sandstone of Reeves (1921). It was named for the town of Marlow, northern Stephens County, Oklahoma. The Duncan of Sawyer is the same as the El Reno Group, and Sawyer also placed the Marlow above the Dog Creek Shale wherever the Duncan is missing. He did not know where to draw an upper contact and did not trace the Marlow northward to the type locality of the Whitehorse. Sawyer (1929, p. 11) separated the Whitehorse into two members, the lower Marlow Member and the upper Rush Springs Member, stating that the former was even bedded and the latter cross-bedded but that he had no other way of distinguishing the two. Evans (1931, p. 416) proposed the name Relay Creek Dolomites for three thin dolomites that are at the top of the Marlow just northwest of Greenfield, Blaine County, Okahoma (figs. 22, 23, 25, 26). The upper two were designated the Upper Relay Creek Dolomite (now Emanuel) and Lower Relay Creek Dolomite (now Relay Creek),* the lowest being unnamed because it thins rapidly and is absent outside the type area. Stephenson (1925, p. 629-630) had previously

* The Emanuel and Relay Creek Dolomites are designated Upper Relay Creek and Lower Relay Creek on plate I, the new names having been adopted subsequent to publication of the map.

used the name Greenfield Limestone for these beds but the name was preoccupied. Relay Creek is a small stream just northwest of Greenfield. Davis (1955, p. 64) placed the top of the Marlow at the top of the Emanuel Dolomite Bed and this designation is used in this report.

Type locality—The type locality is the vicinity of Marlow, Stephens County, Oklahoma.

Type section—The type section for the Marlow Formation is herein designated as that in the Red Bluffs, NW¼ sec. 29, T. 15 N., R. 11 W., extending to NE¼ sec. 25, T. 15 N., R. 12 W., Blaine County, Oklahoma.

Description in type area—Davis (1955, p. 64) stated that in Grady County the Marlow is 105 to 135 feet thick and consists of even-bedded fine-grained silty sandstones and shales that are dominantly moderate reddish brown. Several white gypsiferous layers are discernable, one of which was termed the Agawam Gypsum by Dott and others (1939, p. 15-16, 19, 24), being 2 feet thick and lying 2 feet above the Relay Creek Dolomite. The Emanuel and Relay Creek Dolomites range in thickness from paper-thin to four inches, are separated by 15 to 20 feet of sandstone and shale, with a thin pink shale 1 foot below the Emanuel Dolomite, this shale having been termed "Gracemont" by Brown (1937, p. 1543). A lower pink shale occurs about 60 feet above the base and is unnamed. The Verden Sandstone, formerly known as the Footprint Sandstone, occurs as a fossiliferous medium- to coarse-grained sandstone composed of quartz and chert cemented by calcium carbonate, between the lower pink shale and the Relay Creek Dolomite. The Verden was named by Reed and Meland (1924, p. 151). The base of the Marlow is marked by a light greenish-gray conglomerate and sandstone in many places.

Description in Blaine County—In Blaine County, the Marlow Formation is approximately 93 to 114 feet thick, the thickest part being in central Blaine County where the Emanuel and Relay Creek Dolomites are thickest (fig. 22). The Marlow is a moderate reddish-orange to moderate reddish-brown fine-grained quartzose silty sandstone. Locally the basal 20 feet contains some dark reddish-brown silty clay shale and siltstone. The base is marked by a light greenish-gray fine-grained quartzose sandstone with many medium-sized grains that are well-rounded and frosted (fig. 23). At only one locality a definite pink shale was observed, about five feet above the Relay Creek Dolomite, in NE¼ SE¼ SE¼ sec. 11, T. 16 N., R. 13 W., a few miles southeast of Eagle City, on the section-line road (fig. 24). Approximately 50 to 60 feet above the base of the Marlow is a zone that appears to be more calcareous than the rest of the formation, many calcite nodules occurring in places at this horizon. In northwestern Canadian County, just southeast of Blaine County, the lower portion of the Marlow is gypsiferous and forms indurated ledges that are resistant to weathering. The named members of the Grady County area, such as Agawam, Gracemont, and Verden, were not found in Blaine County. The base of the Marlow is conformable with the underlying Dog Creek Shale, and the top is conformable with the overlying Rush Springs Sandstone. The Emanuel and Relay Creek Dolomite Beds, marking the top of the Marlow, are named from Blaine County and can be mapped into adjacent counties with confidence. In figure 22 is shown the nature of the Marlow Formation at the type locality for the Emanuel and Relay Creek Dolo-

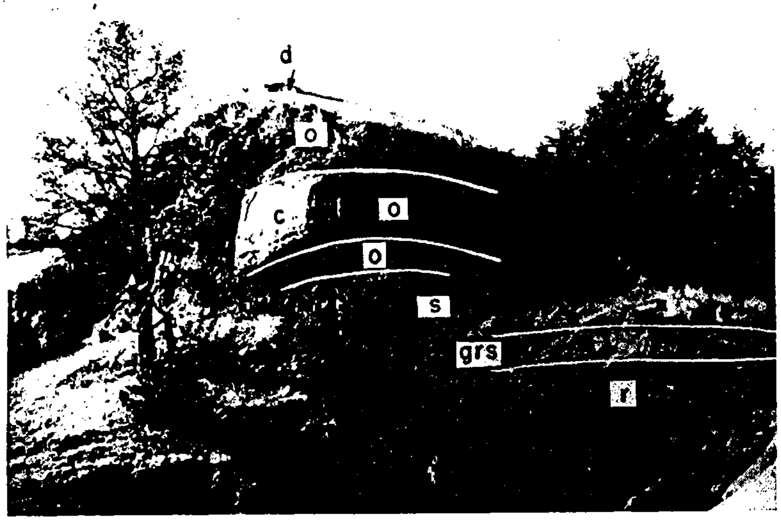


Figure 23. Marlow Formation in Red Hills, near C SE¼ sec. 19, T. 15 N., R. 11 W., looking west up steep bluff face. The light-colored greenish-gray sandstone (grs) marking the base of the Marlow is seen in the middle of the picture, overlying the red-brown Dog Creek Shale (r), and overlain by 20 feet of weakly indurated shales, siltstones, and sandstones (s), above which is about 50 feet of orange-brown sandstone (o), the middle part of which is calcareous and forms an indurated bench (c). The top of the escarpment is capped by the Relay Creek Dolomite (d).

mites, in SE¼ sec. 19, SW¼ sec. 20, NW¼ sec. 29, T. 15 N., R. 11 W., in the prominent butte two miles northwest of Greenfield where the entire Marlow and the upper 75 feet of the Dog Creek Shale are exposed.

Emanuel and Relay Creek Dolomite Beds

Name—Stephenson (1925, p. 629) applied the name Greenfield Limestone to the dolomites capping the butte northwest of Greenfield. As the name Greenfield was preoccupied, Evans (1931, p. 416) proposed the name Relay Creek Dolomites, for the creek of that name just north of the prominent butte, for the same beds. He recognized three dolomites but noticed that the basal one is absent outside the type area. He applied the names Upper Relay Creek Dolomite and Lower Relay Creek Dolomite to the upper two dolomites.* Cragin (1897, p. 360-363) thought that only one dolomite capped the hill and termed it the Day Creek Dolomite (actually Relay Creek), and he gave the name "Taloga formation" to the rocks above this dolomite as seen in exposures south of Wa-

* The Upper Relay is herein named the Emanuel Dolomite Bed, from the community of Emanuel, NE¼ NE¼ sec. 31, T. 15 N., R. 12 W., Blaine County, Oklahoma. The Lower Relay Creek is herein named the Relay Creek Dolomite Bed. The type locality and type section of the Emanuel and Relay Creek Beds are those of the Upper and Lower Relay Creek Beds, respectively. See footnote, page 66.

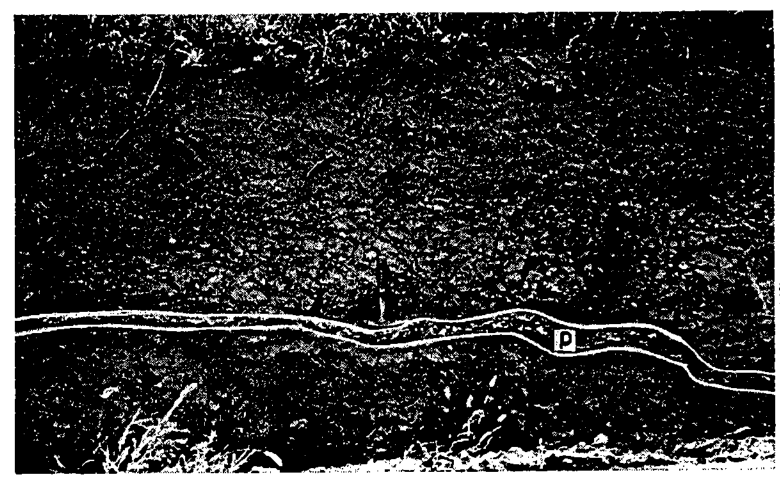


Figure 24. Pink shale (p) at head of hammer, five feet above the Relay Creek Dolomite near C east line SE¼ sec. 11, T. 16 N., R. 13 W., on west side of road. This is the only place in Blaine County where a definitely pink shale can be seen, and its position is not the same as of those described farther south.

tonga and farther northwest in the vicinity of Taloga, Dewey County, Oklahoma. Thus the "Taloga formation" includes all of the upper Marlow above the Relay Creek Dolomite, the Rush Springs Sandstone, and the Cloud Chief Formation.

Type locality—The prominent butte two miles northwest of Greenfield, Blaine County, Oklahoma, in secs. 19, 20, 29, 30, T. 15 N., R. 11 W., and secs. 24, 25, T. 15 N., R. 12 W., is designated as the type locality (figs 22, 23, 25, 26).

Type section—The section south of Relay Creek in the hill in NE¼ NE¼ sec. 25, and SE¼ SE¼ sec. 24, T. 15 N., R. 12 W., in the hill northwest of Greenfield, Blaine County, Oklahoma, is here designated as the type section.

Description in type area—At the type section, the unnamed dolomite, at the base of the three dolomites, ranges from paper-thin to 1.3 feet in thickness. It is pale pink, fine crystalline, and compact, with many thin argillaceous greenish-gray and pinkish-gray laminae that weather into vuggy openings. These openings are lined with coarse-crystalline calcite. Some parts of the dolomite are moderate reddish-orange and contain much sand and silt. The overlying five feet of sandstone is moderate reddish-brown

Figure 25. Relay Creek Dolomite Bed of the Marlow Formation, NE¼ NE¼ sec. 25, T. 15 N., R. 12 W., at the type section north of Relay Creek in the Red Hills. The Relay Creek Bed ranges from one to four feet in thickness in this region and is characterized as a compact fine-grained dolomite with vuggy layers. The vugs are formed from weathered sandstone beds within the dolomite.

TABLE 1.—CHEMICAL ANALYSIS OF THE RELAY CREEK DOLOMITE
(Sample collected by C. A. Merritt and W. E. Ham [1942], and analyzed by J. F. Eberle, Oklahoma Geological Survey)

Laboratory number	9053
Location	Hill in SE¼ 5-14N-11W
Thickness of channel sample	2.3 feet

Constituent	*Concentration (percent)*
SiO_2	0.66
Al_2O_3	0.15
Fe_2O_3	0.08
P_2O_5	0.67
CaO	31.89
MgO	19.87
CO_2	46.59
SO_3	0.11
Total	100.02
Calculated mineral components	
Dolomite $CaMg(CO_3)_2$	90.89
Calcite $CaCO_3$	7.44
Gypsum $CaSO_4 \cdot 2H_2O$	0.25

with a light greenish-gray streak in the middle. The sandstone is fine-grained, quartzose, silty to argillaceous, and poorly indurated. It has a few medium-sized subrounded to rounded frosted grains and weathers as a recess. The color of the beds is probably caused by iron oxide (hematite) stains coating the sand grains. The Relay Creek Dolomite is an alternately layered dense pinkish-gray and vuggy greenish-gray dolomite, being fine to coarse crystalline (fig. 25). It forms a vuggy pinkish-gray ledge, the vugs being aligned along the greenish-gray zones and lined with secondary calcite. A chemical analysis of the Relay Creek Dolomite is given in table 1.

The overlying sandstone is a dark reddish-brown to grayish-orange fine-grained quartzose sandstone with subangular to subrounded grains. It contains some medium-sized well-rounded frosted grains and is dolomitic, as are the sandstones above and below. In the upper several feet it is highly dolomitic and at the type section contains symmetrical ripple marks that strike N 25° E. The Emanuel Dolomite, about 28 feet above the top of the Relay

Creek Dolomite at the type section, is a 9-inch-thick grayish-pink to pale-pink coarse-crystalline dolomite with many fine laminae of fine-grained quartzose sandstone. It is well indurated and forms a ledge, as do the other two dolomites just described.

The unnamed dolomite at the base thins rapidly in the type area and wedges into sandstone. The next dolomite above, the Relay Creek Dolomite, ranges in thickness from one to three feet in the type area and thins rapidly to one inch or less just outside the type area. Only the basal part seems to be represented elsewhere in the county and in the adjoining counties, where it is a maroon-colored impure sandy dolomite with many black manganese oxide stains and secondary calcite to the extent that it may be termed a sandstone instead of a dolomite. It is crinkly bedded and in places contains a 1-inch-thick bed of pure white dolomite. It is sporadic in its occurrence and is evidently not one continuous bed of constant thickness. In some places it may not be present where expected. The Emanuel Dolomite is 9 inches thick at the type section and thins rapidly to one inch or less outside the type area. Persistently found in adjoining counties in association with the underlying Relay Creek, the Emanuel has the same appearance and the same type of sporadic occurrence as the Relay Creek. The best means of mapping these beds is to find both beds in the same outcrop and to plot their elevations on a map. The interval between these beds is about 28 feet in the type region and approximately 20 feet elsewhere, with an average dip of 17 to 18 feet per mile west-southwest in the northern part of the county, 7 feet per mile in the Greenfield area, and 16 feet per mile southwest to south in the southern and southwestern parts of the county (pl. III). Either or both dolomites can normally be found at any locality, and for this reason they are persistent. However, they are sporadic because one is apparently missing at some localities. This erratic but persistent occurrence of these beds is one of their main characters.

Distribution—The Marlow Formation extends from northern Stephens County, Oklahoma, northwestward through western Blaine County to Woods County, Oklahoma, and perhaps into Kansas. It extends westward from Stephens County, north of the Wichita Mountains, to Beckham and Harmon Counties, southwestern Oklahoma.

Thickness—The Marlow is approximately 105 to 135 feet thick in Grady and Stephens Counties and 100 feet in Blaine County.

Topography—The Marlow is resistant to weathering, forming a series of low rounded hills. Where capped by the dolomites, it forms a series of flat-topped ledges, with steep escarpments (fig. 26). These escarpments, together with those formed by the overlying Rush Springs Sandstone, form the second line of hills mentioned in older reports. This latter name originated from settlers who came westward, especially from the Kingfisher area. The first line of hills is that formed by the Blaine-Dog Creek Formations, and the next higher line of hills is that formed by the Whitehorse Group.

Structure—Structure contours based upon points of elevations on the Relay Creek Dolomite, or extrapolated from the Emanuel Bed, show that the Marlow dips uniformly with the Blaine Formation below. In the Greenfield area, the dip is more gentle and in the Canton area to the north, there is a broad synclinal nose; otherwise there are no major structures. The beds apparently are undulatory, and the dip and strike are not constant in small areas (pl. III).

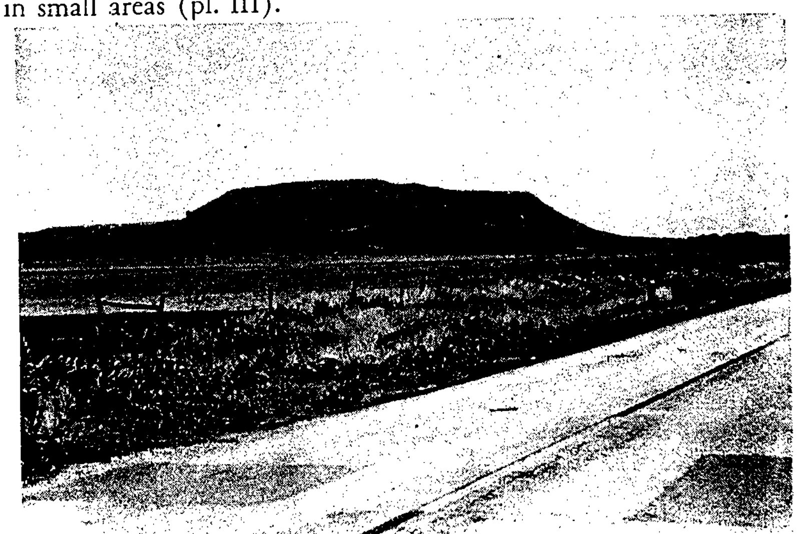


Figure 26. Red Hills northwest of Greenfield, showing the Marlow escarpment in secs. 29 and 30, T. 15 N., R. 11 W., just south of Relay Creek. The Emanuel and Relay Creek Dolomites cap this hill, and the calcareous sandstone of the lower part of the Marlow forms the projecting ledge in the face of the hill. The gentle slope at the base is formed in the Dog Creek Shale. In the background, to the left, the Emanuel Dolomite forms a small escarpment, not prominent in this view.

Stratigraphic relationships—The Marlow is conformable with beds above and below. The basal few feet are represented by conglomerate in places in Grady County, but fine-grained sandstone prevails in Blaine County, suggesting that the materials of the basal unit came from the southeast. Some of the Marlow Sandstone is composed of medium-sized quartz grains that are well rounded and frosted. The contact of the Marlow with the underlying Dog Creek is sharp in most places but is gradational in a few places. Where the contact is sharp, there is no evidence of erosion. The interval between the base and the top of the Marlow is constant over a wide area, taking into account regional northward thinning.

The Doe Creek and Verden Members are below the Relay Creek Dolomite and at various intervals above the base. The Doe Creek has a linear southwestward trend and is composed of algal dolomite and large quartz grains. It rests upon the Dog Creek Shale on the northeastern end and is 8 feet or more above the base on the southwestern end, showing that the reef was a fringing type that grew basinward throughout Marlow time. At no place is there a suggestion of an unconformity at the base of the Doe Creek Sandstone Member. The Verden is similar to the Doe Creek in its linear nature but is composed at places of large chert granules. It may have an origin similar to that of the Doe Creek Member. The fact that the Doe Creek and Verden Members contain the only known fossils of the Marlow Formation indicates that the sea water must have been close to normal salinity in order to support life in these areas.

In summary, the stratigraphic relationships of the Marlow Formation are such that the clastic part probably originated from the east and southeast, with simultaneous increase in salinity of the sea water where evaporites were deposited and with decrease in salinity where algal reefs were formed, accompanied by uplift of the Ouachita Mountains and Ozark dome. The change from deltaic deposition during Chickasha time to marine deposition during Marlow time is here considered to be due to the lowering of the southeastern margin of the Anadarko basin. The iron-stained quartz grains were probably transported by highly competent streams flowing westward from the Ouachitas and the Ozarks. The grains were probably deposited in a highly saline sea that contained strong currents, which distributed the sand evenly over a wide area. In some places, especially shallow areas near shore, marine currents of low salinity probably prevailed, allowing algae and animal life to flourish. These probably built up fringing reefs that are represented by the Doe Creek and Verden Members. At the close of Marlow time in Oklahoma and in adjacent areas of the Anadarko basin, the salinity of the sea water reached the point that the Emanuel and Relay Creek Dolomite Beds were deposited. Then brackish-water conditions probably prevailed along the eastern and southern margins of the basin during Rush Springs time, where sandstone was deposited. In the deeper parts of the basin the water was probably more saline and evaporites were deposited in the Rush Springs Sandstone.

Age and correlation—The usage of the name Marlow Formation in Kansas may not be the same as that in Oklahoma. Green (1939, p. 1817) stated that the Marlow is 65 feet thick in Kansas, but Norton (1939, p. 1803-1804) stated that the Marlow is 110 feet thick in Kansas. The latter correlation is tentatively accepted in this report, pending further investigation. In southwestern Oklahoma, the Marlow is estimated to be 120 feet thick, according to Scott and Ham (1957, p. 31), having the same character as that of the type area. In Texas, the Upper Eskota Dolomite is approximately 120 feet above the base of the Marlow Formation. In Blaine County, the Emanuel Dolomite is about 110 feet above the base of the Marlow, and on the basis of regional uniformity the Emanuel may be the same as the Upper Eskota of Texas. Lloyd and Thompson (1929, p. 948) placed the Eskota in the Whitehorse of Texas. If the above correlation is correct, it is possible that the Grayburg equivalent of Texas may be the equivalent of the Marlow of Oklahoma; and the Marlow would then be Guadalupean in age, following West Texas Geological Society nomenclature (1941, p. 48).

Rush Springs Sandstone Formation

Name—The name Rush Springs Member was proposed by Sawyer (1929, p. 11) for the reddish-brown cross-bedded sandstone between the Marlow Formation below and the Weatherford Dolomite above, the name being given for Rush Springs, Grady County, Oklahoma. Sawyer stated that this sandstone is the same as that of Reeves (1921, p. 51). Reeves did not use terms such as Marlow or Weatherford, but his descriptions leave little doubt about the upper contact and some doubt about the lower contact. When Evans (1931, p. 416) proposed the name Relay Creek Dolomites and Davis (1955, p. 64) placed the lower contact of the Rush Springs at the top of the Emanuel Dolomite, a definite mappable contact became established. As used in this report, the Rush Springs Sandstone includes beds between the top of the Emanuel Dolomite and the base of the Weatherford Dolomite.

Type locality—The river bluffs one mile north of the northeast corner of Tonkawa Township, sec. 36, T. 7 N., R. 10 W., Caddo County, Oklahoma, is the type locality.

Type section—No type section has been designated.

Description in type area—In the type region the Rush Springs is an evenly to highly cross-bedded light-brown silty sandstone about 300 feet thick. There are many well-rounded frosted sand grains, and the average diameter of the grains is 0.124 millimeter,

Figure 27. Cross-bedded Rush Springs Sandstone along east side of road in NW¼ NW¼ sec. 5, T. 17 N., R. 13 W. This type of cross-bedding (termed "current") is typical of the Marlow, Rush Springs, and Cloud Chief Formations in Blaine County, and is especially prominent in the Rush Springs Sandstone. There appears to be no preferred direction to cross-bedding over a large region.

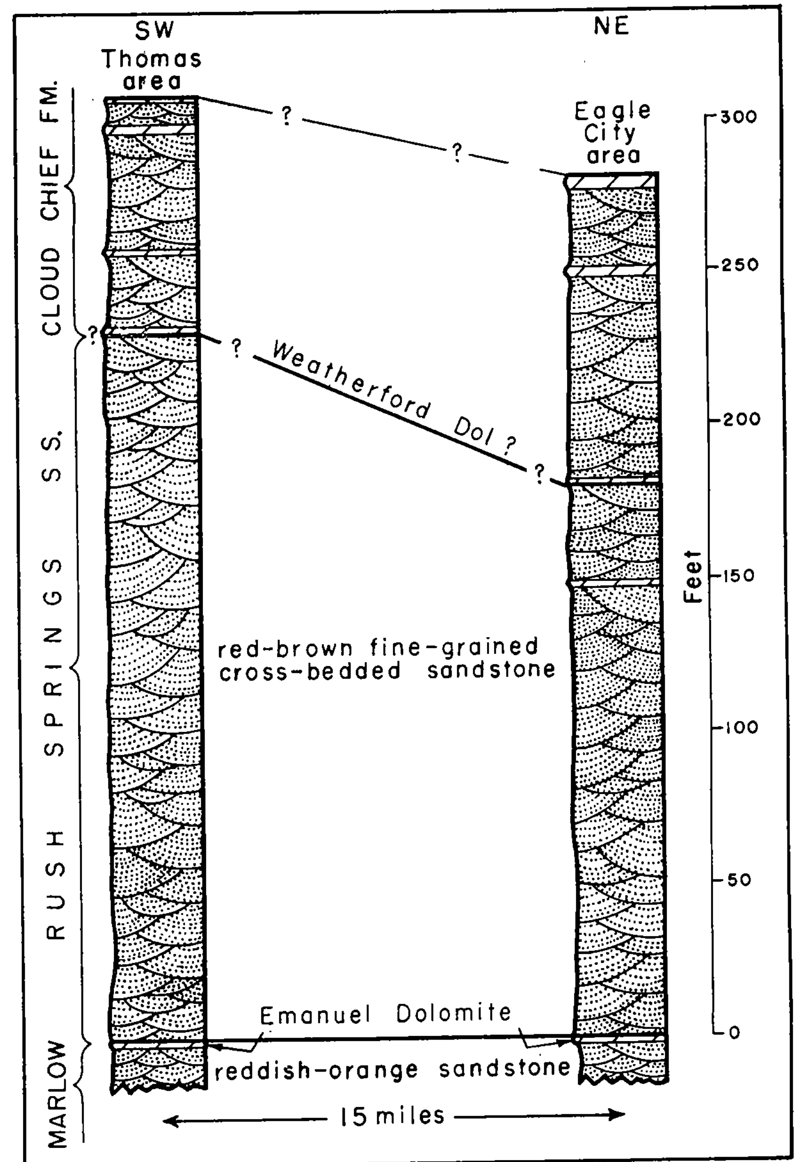


Figure 28. Correlation diagram showing inferred relationships of columnar sections of the Rush Springs and Cloud Chief Formations from the Thomas area, Custer County, to the Eagle City area, Blaine County, Oklahoma. The correlation of the Weatherford Dolomite is based mainly upon intervals taken above the Emanuel and Relay Creek Dolomites, together with lithologic similarity, and is considered a tentative correlation. The knob south of Thomas is in sec. 7, T. 14 N., R. 14 W., and the knob northwest of Eagle City is in secs. 1 and 12, T. 17 N., R. 14 W., with smaller knobs in sec. 6, T. 17 N., R. 13 W.

according to Davis (1955, p. 70). Evaporites are absent in the type area.

DESCRIPTION IN BLAINE COUNTY—In Blaine County, the Rush Springs is a moderate to dark reddish-brown fine-grained quartzose silty calcareous cross-bedded sandstone with subangular to subrounded grains that are poorly cemented together (fig. 27). There are many medium-sized and a few coarse-sized well-rounded grains. The Rush Springs is approximately 230 feet thick to the southwest and 180 feet thick to the northwest near Eagle City. Where weathered, the Rush Springs forms a moderate to dark reddish-brown escarpment of gently rolling hills covered by evergreens and dissected by deep V-shaped valleys.

In the Eagle City area, a local 9-inch-thick pinkish-gray to grayish-orange pink and white fine-crystalline well-indurated arenaceous vuggy dolomite occurs about 35 feet below the top. It grades into a dolomitic sandstone and forms a ledge in SW¼ sec. 6, T. 17 N., R. 13 W. The sandstone above this ledge is similar to that described above.

The bed tentatively correlated with the Weatherford Dolomite is different. It is light red to grayish pink and white, with many thin wavy laminations and seems to be more persistent. A similar bed occurs at the top of the hills just north of Thomas, Custer County, Oklahoma, about 15 miles to the southwest. If these two beds are the same dolomite, the thicknesses as given are correct. These relationships are shown in figure 28.

DISTRIBUTION—The Rush Springs covers a wide area of outcrop from Harper County, northwestern Oklahoma, to northern Stephens County, south-central Oklahoma, then west to Harmon County, southwestern Oklahoma. It occurs in western and southwestern Blaine County, west of the North Canadian River.

THICKNESS—If correlations are correct, the Rush Springs is 300 feet thick in south-central Oklahoma, 180 feet thick in northwestern Blaine County, and 90 feet thick or less in Kansas.

TOPOGRAPHY—The Rush Springs forms a series of sandstone hills with steep V-shaped valleys. Together with the underlying Marlow Formation and part of the overlying Cloud Chief, the escarpment formed was called the second line of hills by settlers. Curtis and Ham (1957) termed this area the Western Sandstone Hills.

STRUCTURE—Elevations on the Weatherford? Dolomite near Thomas and Eagle City indicate that the Rush Springs thins rapidly northward between the two areas. Near Thomas the Weatherford? is about 1,810 feet above sea level, and near Eagle City it is about 1,830 feet above sea level. The Emanuel Bed in the same areas is about 1,580 and 1,650 feet, respectively, above sea level. The Weatherford Dolomite apparently dips uniformly with the Emanuel and Relay Creek Dolomites, taking into account the northward thinning of the sandstone units and the undulatory nature of the Emanuel and Relay Creek Dolomites and the Weatherford? (pl. III). There is no structural evidence of an unconformity, but there is evidence of a broad southwestward-plunging syncline in the Eagle City-Canton area, as indicated.

STRATIGRAPHIC RELATIONSHIPS—The Rush Springs Sandstone is conformable with beds above and below, being delineated by thin dolomites at each contact. It thins from 300 feet in Stephens County to 90 feet or less in Kansas, where it contains much shale, leading one to believe that the sand of the Rush Springs has a southern or southeastern origin. In many places it is common to find medium-sized well-rounded frosted sand grains. In Dewey County, just west of Blaine County, several thick massive gypsums, named the "Old Crow" and "One Horse" by Cragin (1897, p. 363), are present in the Rush Springs. The Rush Springs is approximately 220 feet thick in this area if correlation of the Weatherford? is correct. The One Horse, which may be about five feet thick, is about 30 feet below the Weatherford?. The Old Crow is two to three feet thick and is underlain by 12 to 14 feet of gypsiferous sandstone, the top of the Old Crow being about 120 feet below the Weatherford? Dolomite.

Evidently the area of Dewey County in T. 16 N., R. 15 W., is the area of overlap of the brackish-water Whitehorse deposits to the east and southeast with the highly saline sea-water evaporites to the west and northwest. In northeastern Dewey County, south of Fonda, in T. 19 N., Rs. 15, 16 W., two carbonate layers, each about one foot thick, occur high in the hills, forming a prominent escarpment. These beds are approximately 32 feet apart, the upper one being tentatively correlated with the Weatherford Dolomite as used in this report and the lower one being considered the same as the stray dolomite 35 feet below the Weatherford? Dolomite in the hill northwest of Eagle City, Blaine County.

The Canadian Triangulation Station is set in the upper carbonate bed south of Seiling at an elevation of 1,991 feet above sea level. It is approximately 20 miles southeast to the Eagle City area, where the elevation on the Weatherford? is approximately 1,830 feet, the average component of dip in that direction being about 8 feet per mile. The beds near Eagle City dip westward, however, at a rate of about 17 or 18 feet per mile, making necessary the postulation of the presence of a broad syncline between the two areas in order to have proper stratigraphic relations. A steep southeast dip can be measured just south of the Canton Reservoir on the west bank of the North Canadian River at the contact of the Marlow on the Dog Creek, confirming the presence of this structure in that area. Elevations taken on the Emanuel and Relay Creek Dolomites are also helpful in delineating the structure. If the above contentions are true, the stray dolomite 30 to 35 feet below the Weatherford? of northwestern Blaine and northeastern Dewey Counties corresponds to the One Horse Gypsum (or perhaps is just at its base) of southeastern Dewey County, about 10 miles to the southwest. The fact that gypsum in Dewey County grades eastward into a dolomite-sandstone sequence and that the latter grades southward into a sandstone sequence points to a southern or southeastern origin for the coarse clastics of the Whitehorse.

Age and correlation—If the Emanuel Dolomite is the equivalent of the Upper Eskota Dolomite of north-central Texas, the Rush Springs Sandstone of Oklahoma is the equivalent of the middle several hundred feet of the Whitehorse Group of Texas. The Whitehorse of Texas grades westward into the Grayburg and the higher units of the Midland basin. These units contain much dolomite and are considered by the West Texas Geological Society Committee (1941, p. 48) to belong to the Guadalupean Series. The Weatherford Dolomite at the top of the Rush Springs Sandstone in Oklahoma may correspond to some unnamed dolomite of central Texas, and the Rush Springs of Oklahoma may be the equivalent of the Queen of New Mexico; whereas the Cloud Chief of Oklahoma may be the equivalent of the Seven Rivers of the Guadalupean Series in New Mexico.

If the Emanuel and Relay Creek Dolomites and Weatherford Dolomite of Oklahoma can ever be successfully traced northward into Kansas, much guesswork will be eliminated in trying to decide upon boundaries. For the present, the Rush Springs Sandstone of Oklahoma is here considered to be probably the equivalent of the 100 feet of even-bedded sandstone and siltstone of the Whitehorse Sandstone as used in Kansas by Norton (1939, p. 1803-1806) and later geologists. The relationship between the Day Creek Dolomite of Kansas and the Weatherford Dolomite of Oklahoma is unknown, but, according to Sherwood Buckstaff (1959, personal communication), the Day Creek is only about 30 feet above a bed equivalent to the Weatherford. If this is true, the 30-foot upper shale member of the Whitehorse Sandstone, just below the Day Creek Dolomite of Kansas, is the equivalent of the lower part of the Cloud Chief Formation in Oklahoma.

POST-WHITEHORSE ROCKS

Cloud Chief Formation

In Blaine County, the Cloud Chief Formation consists of approximately 100 feet of fine-grained moderate reddish-brown quartzose cross-bedded sandstone, with the thin pink crinkly Weatherford? Dolomite Bed at its base and two thick dolomites in the upper 30 feet. It occurs only in one small area northwest of Eagle City, Blaine County, and in the adjacent hill in Dewey County (SW¼ sec. 6, T. 17 N., R. 13 W.; SE¼ sec. 1 and NE¼ sec. 12, T. 17 N., R. 14 W.). Its top is not exposed (fig. 29).

Name—The name Cloud Chief Formation was proposed by Gould (1924, p. 337) for beds above the Weatherford Dolomite in the vicinity of Cloud Chief, Washita County, Oklahoma. Where the Weatherford Dolomite is absent, the Cloud Chief is there defined as being directly above the Whitehorse Sandstone. The upper boundary, given by Gould as the base of the Quartermaster Formation, is indefinite. Weatherford Dolomite is a name that was first proposed by Sawyer (1929, p. 11) for the dolomite at the base of the Cloud Chief exposed in the area about Weatherford, Custer County, and in the area southward in Oklahoma. Gould (1924) used the name Day Creek when defining the Cloud Chief in the Washita County area, believing that it was everywhere the same from Kansas into Oklahoma, but Sawyer and others have not accepted this correlation.

TYPE LOCALITY—The area around Cloud Chief, Washita County, Oklahoma, was designated as the type locality for the Cloud Chief. The area south of Weatherford, Custer County, Oklahoma, was designated as the type locality for the Weatherford.

TYPE SECTION—No type section has been designated either for the Cloud Chief or for the Weatherford.

DESCRIPTION IN TYPE AREA—The Cloud Chief, about 300 feet thick in the type region, consists of a lower silty shale unit about 20 feet thick above the Weatherford Dolomite, and of a 100-foot-thick gypsum-anhydrite unit above the shale, overlain by approximately 150 feet of sandstone and shale that is gradational into the overlying Doxey Shale of the Quartermaster Formation, according to Green (1936, p. 1473-1474). The gypsum unit is locally confined to the Clinton-Weatherford-Cloud Chief area, grading into sandstone and perhaps a few dolomite beds to the west, north, and southeast, where thin stringers and lenses of gypsum and dolomite are present in the sandstone sequence. The Weatherford Dolo-

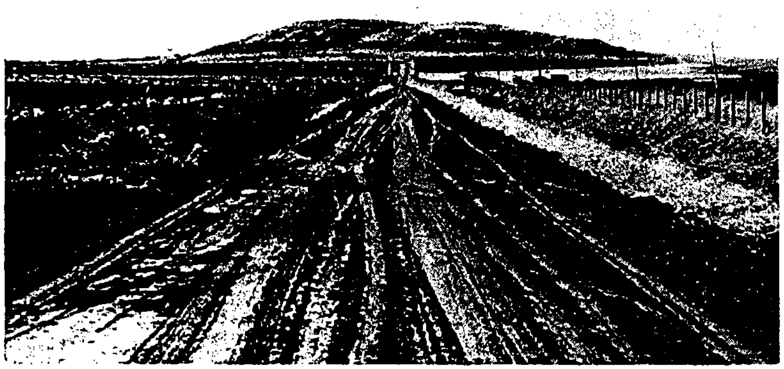


Figure 29. Cloud Chief knob northwest of Eagle City, looking west, secs. 1 and 12, T. 17 N., R. 14 W., Dewey County, Oklahoma, showing the typical knob formed in the Cloud Chief Formation where there are many dolomites in one area. The Cloud Chief is about 100 feet thick and the top of the knob is capped by a compact white dolomite almost four feet thick. The Weatherford? Dolomite is at the base of the knob.

mite is approximately one foot thick and is said to grade northward and westward into a 3- to 5-foot gypsum bed.

DESCRIPTION IN BLAINE COUNTY—In Blaine County the Cloud Chief is present only in the area northward of Eagle City, and there the top part is probably eroded away. The entire sequence is a fine-grained moderate reddish-brown quartzose calcareous cross-bedded sandstone with a few thin dolomites. The basal 6- to 9-inch dolomite is tentatively identified as the Weatherford? Dolomite. The Weatherford? is overlain by approximately 67 feet of sandstone, which in turn is overlain by a 3-foot dolomite bed (fig. 29). This dolomite is overlain by 26 feet of highly calcareous sandstone, capped at the top by a 4-foot dolomite. Suffel (1930, p. 95-99) made thin sections of various parts of these dolomites and described them in detail. The Weatherford? is a white to light-red to grayish-pink fine-crystalline arenaceous laminated wavy bedded dolomite becoming vuggy along the laminae, with occasional black manganese oxide spots. It forms a pale reddish-brown to light-brown ledge. The dolomite 67 feet higher is a white to pinkish-gray or grayish-pink to grayish orange-pink fine- to medium-crystalline compact dolomite, speckled with many black manganese oxide spots. It has many pale-red to moderate-red coarse-crystalline wavy bedded arenaceous laminae of dolomite that show definite thinning and thickening over a small area. This type of dolomite grades into a light olive-gray fine-crystalline compact dolomite, speckled with many black manganese oxide spots, giving the appearance of a salt-and-pepper texture. Many thin pinkish-gray coarse-crystalline vuggy laminae of dolomite are interbedded with the fine-crystalline type. The above dolomite forms a light-brown vuggy ledge, with calcite filling many of the vugs. The overlying sandstone is approximately the same as the underlying sandstone, except that it is more calcareous. All the sandstone is similar to the Rush Springs type, containing some medium and coarse well-rounded frosted quartzose sand grains, suggestive of a southern or southeastern origin. The upper dolomite is predominantly a white to pinkish-gray fine-crystalline compact dolomite with thin vuggy laminae filled with dolomite crystals. It weathers pinkish gray and has occasional black manganese specks. This dominant type grades into a laminated pale-pink to moderate-red and white type that is fine to medium crystalline and weathers yellowish gray to a streaked moderate red. Light-gray to white fine- to coarse-crystalline compact salt-and-pepper vuggy dolomite that weathers light gray to yellowish gray is also present. The upper two dolomites show depositional thinning on a small and large scale, indicating that these may be local accumulations. Similar dolomites are present in the knob south of Thomas, Custer County, about 15 miles southwest of the above area. A tentative correlation between the two areas is indicated in figure 28.

Distribution—The Cloud Chief Formation extends from Caddo and Grady Counties, south-central Oklahoma, northwestward to Harper County, Oklahoma, and westward to Beckham County, southwestern Oklahoma. It may be present in northwestern Blaine County.

Thickness—The Cloud Chief Formation is approximately 300 feet thick in the type region, the upper portion perhaps being eroded off to the northwest. In Blaine County and adjacent Dewey County, only 100 feet is present.

Topography—The dolomites of the Cloud Chief form high flat-topped isolated buttes projecting above the sandstone hills. The Caddo County buttes, east of Weatherford, are composed of Cloud Chief dolomites and sandstones, the buttes being noted by travelers going west along the California Trail as one of the outstanding markers of the trail.

Structure—The Cloud Chief is apparently conformable with beds above and below, the lower contact probably present in Blaine County. A character of the Cloud Chief beds and the stray evaporites in the Rush Springs is the wavy undulatory nature of the beds. It is common to see a horizontal dolomite with an almost vertical bend of several feet in the middle to continue again at a lower level in a horizontal position. This undulatory bedding can be observed on a microscopic or megascopic scale, suggesting that it is a depositional feature. For this reason it may be impossible to place correctly a correlative bed of the Weatherford Dolomite in many areas distant from the type region, where many similar beds may occur in the sequence and where erosion has obliterated the section between the type and correlated areas. The structure of the Blaine County area is discussed under the section on the Rush Springs Sandstone.

Stratigraphic relationships—The Cloud Chief is here considered to be conformable with beds above and below. The Clinton-Weatherford-Cloud Chief area of eastern Washita and southeastern Custer Counties contains the thick 100- to 120-foot body of gypsum and anhydrite that grades northward and westward into coarse and fine clastics. The Weatherford Dolomite is said to grade northward and westward into gypsum, indicating that the highly saline part of the sea was to the northwest in the Dewey County-northern Custer County area at the time of deposition of that unit, consistent with the position of the same type of sea water during Rush Springs time. This highly saline sea water then must have been shifted southeastward to the eastern Washita County area. The large well-rounded frosted sand grains present in the Cloud Chief may have been derived from the south and southeast.

Age and correlation—If the Weatherford Dolomite is the equivalent of an unnamed dolomite above the Eskota Dolomite of Texas and if the Emanuel Bed of Oklahoma is the equivalent of the Upper Eskota of Texas, the Cloud Chief Formation of Oklahoma is the equivalent of the Seven Rivers Formation of Texas, of the Guadalupean Series. Part of the Cloud Chief may be Ochoan in age, according to some authors, pending further investigation.

The Day Creek Dolomite of Kansas may be above the Weatherford Dolomite of Oklahoma, and the Whitehorse Group in the type area of Woods County, Oklahoma, may include part of the Cloud Chief Formation.

Quaternary System

PLEISTOCENE SERIES

In Blaine County the Pleistocene Series consists of river gravels, sands, silts, and clays, with some volcanic ash, deposited by the Canadian, North Canadian, and Cimarron Rivers. Each river has its own developmental history, with a similar pattern of bedrock control, distribution of deposits, and sequence of terrace deposits. For example, the bedrock dips southwest and all three rivers flow southeast, parallel to the strike, crossing the strike only in areas where north-south facies changes occur in the underlying bedrock. On the southwestern side of each river there is a thin veneer of silt and clay with hardly any sand or gravel; whereas on the northeastern side of each river there are thick deposits of sand and gravel. At least three terrace levels are present on each river system, the upper two possibly being composite with two sublevels in each (pl. IV). The highest terrace level contains volcanic ash and has sand dunes covered with vegetation, the sand dunes being on the northeastern side of each river.

The rivers filled in the bottom portions of valleys between pre-Pleistocene escarpments formed in the Cloud Chief, Whitehorse, and Blaine Formations. For instance, the top of the Pleistocene deposits of the Cimarron and North Canadian Rivers is 100 or more feet below the top of the adjacent Blaine and Whitehorse escarpments to the southwest; and the top of the Canadian River deposits of southern Blaine County are below the Cloud Chief escarpment to the southwest in Caddo County. At present it is difficult to estimate how far these escarpments may have extended eastward; but, judging from distribution of Pleistocene deposits, they could have been eroded back only one or two miles since the beginning of the Pleistocene epoch. At the present rate of dip, this means that the escarpments were probably about 30 feet higher at the beginning of the Pleistocene Epoch than at present and that they were one to two miles east of their present positions, judging from known elevations on top of the highest terrace level of each river system.

Pre-Pleistocene history — The pre-Pleistocene escarpments probably have a long history of development, beginning just after the close of the Permian Period when the region was probably uplifted slightly above sea level. Erosion and weathering were probably very slow, and it is quite possible that westward-flowing streams from the Ozarks may have reached this region, especially during the Cretaceous Period, when an inland seaway was present west of the Blaine County area. The eastern featheredge of the Permian deposits was eroded away, and initial small escarpments probably began to form.

The Canadian, North Canadian, and Cimarron Rivers probably were initiated during the Tertiary Period when the Rocky Mountains were uplifted, causing an eastward-flowing drainage pattern to be developed. It is here hypothesized that, concurrent with uplift and erosion, small tributary streams of the Arkansas

River began working headward into the rocks of the Blaine County area, perhaps following older stream channels, carving out valleys parallel to the strike of the bedrock, and forming gentle escarpments in the Cloud Chief, Whitehorse, and Blaine Formations. These escarpments were probably about 225 feet higher than present-day ones and were 15 miles east of their present positions of continuous outcrop. These assumptions are based upon known facies changes and a regional dip of 14 feet per mile toward the southwest. For example, the dolomites of the Cloud Chief outliers east of the main outcrop are highly arenaceous in composition and erratic in occurrence, and they were probably deposited only slightly farther east of their present-day outcrops. The Verden Sandstone of the Marlow Formation is considered to be an off-shore bar, not many miles from the actual shore line. The Blaine Formation contains gypsums of a normal thickness in Blaine County, but just 15 miles southeast of Blaine County the gypsums have graded into shales, showing that it is reasonable to believe the escarpment-forming resistant beds to have been deposited not much more than 15 miles east of their present continuous outcrop. The incipient Canadian, North Canadian, and Cimarron Rivers worked their ways headward, flowing over the Cloud Chief, Whitehorse, and El Reno rocks, respectively. A hundred or so feet of bedrock was probably eroded from the area, and the escarpments were eroded back many miles westward, becoming more accentuated.

In Late Tertiary time the streams continued their westward and northwestward development beyond Blaine County, having many tributary streams that reached to the Rocky Mountains. These streams probably deposited the Pliocene deposits, such as the Ogallala Formation, and formed large alluvial fans with braided drainage. The Ogallala was probably not deposited much farther east of its present outcrop because the gradient was probably lower to the east and the source of supply was far away. The water flowing eastward beyond the Ogallala must have spent its energy upon erosion of escarpments and denudation of the land in the Blaine County area, leaving little evidence of the stream's former presence. Near the close of the Pliocene age, the position of each river in Blaine County with respect to the present-day river was: 8 to 12 miles west of the Canadian River, 8 miles east of the North Canadian River, and 10 miles west of the Cimarron River (in east-central Blaine County).

The Pleistocene rivers eroded downward, forming valleys with each period of maximum melting of ice, probably at the beginning of the regression of the ice. These valleys were then filled during a time of minimum melting, at the end of regression and beginning of advance, forming terrace levels. During the second age of the Pleistocene, termed the Kansan, stream piracy of the Canadian River and, perhaps, of the Cimarron River probably took place in the Blaine County area. During the Kansan, widespread gravel deposits were distributed over the high areas of Blaine County. From the above information it is evident that each river system must be treated separately in order to show genetic relationships of the present-day streams to their counterparts during the Pleistocene Epoch.

Canadian River

The Canadian River system of Blaine County may be grouped into two separate areas: (1) the Deer Creek region of southwestern Blaine County and adjacent Caddo, Custer, and Dewey Counties, through which Deer Creek flows and (2) the Canadian River area several miles northeast of Deer Creek (pl. IV).

Deer Creek area—The Deer Creek deposits consist of 3 to 43 feet of gravel, sand, silt, and clay, with much volcanic ash, that occur in an approximately five-mile-wide strip following the Deer Creek valley, extending from the area northwest of Putnam, Dewey County, on the northwest end, southeastward through Custer and Blaine Counties, then eastward to the Canadian River, just west of Bridgeport, northwest Caddo County, Oklahoma. In southwestern Blaine County, in sec. 31, T. 13 N., R. 13 W., there are several square miles of gravel deposits that occur about 70 feet above Deer Creek. These sediments are 5 feet thick and consist of quartzite pebbles and cobbles derived from the Rocky Mountains. To the north, northeast, and east of these deposits there is a thin veneer of silt and clay, with some coarse sand at top, and an occasional small pebble, scattered over much higher ground than the Deer Creek gravels, separating them from the Canadian River gravels that are present on the northeast side of the Canadian River.

All of the known sand and gravel pits of Dewey and Custer Counties were located and plotted on plate IV, with thicknesses and elevations noted. Contour lines drawn upon points representing the base of the gravels outline an ancient stream channel that has a southeastward trend (pl. IV). The base of the Deer Creek gravels is flat, or gently inclined, with a gradient (computed along the line of the ancient channel) of approximately 10 feet per mile southeastward. The base of these deposits is approximately 2,000 feet in elevation northwest of Putnam and approximately 1,570 feet in elevation in southwestern Blaine County, about 40 miles away. This ancient stream channel appears to connect with the present-day channel of the Canadian River in the Putnam area to the northwest and the Bridgeport area to the southeast. Deer Creek flows along the bottom of the wide valley formed by this stream, emptying into the Canadian River just west of Bridgeport. Deer Creek is here classed as an underfit stream, and it obviously did not form the valley through which it flows.

Ten known volcanic-ash pits are associated with these sand and gravel deposits in Custer and Dewey Counties. The character of these ash deposits has already been described by Ham (1949, p. 48-57) and shown to be of the Pearlette (Late Kansan) type. The Pearlette ash was first described and named by Cragin (1896, p. 53-54) for a deposit of white to brownish or greenish ash in Meade County, Kansas. The deposit is 13 feet thick and occurs sporadically from Nebraska to Oklahoma. The thickness of the ash deposits in sec. 14, T. 14 N., R. 16 W., northeast of Custer City, Custer County, is 3 to 15 feet, and one pit in NE¼ NE¼ sec. 14 is estimated to contain approximately 11,000 cubic yards of ash. At this locality the ash is overlain by 2 to 3 feet of clay and is interbedded with clay and sand, with abundant gravel deposits nearby. These ash deposits were probably laid down in small lakes or ponds, such as oxbow lakes, along the floodplain of an ancient river that once flowed southeastward through this region from the Rocky Mountains. The Pearlette had been classed as Yarmouthian by the Kansas State Geological Survey but recently it has been classed as Kansan (Frye, 1961).

In the Bridgeport area near the mouth of Deer Creek the same terrace levels are present on Deer Creek and on the Canadian River. These levels on Deer Creek gradually steepen and merge several miles northwest of Blaine County. From this point northwestward there is only one highly dissected terrace level that contains the volcanic ash. It is obvious that Deer Creek has cut through this high terrace and has become a tributary to the Canadian River after deposition and formation of this high terrace. The presence of Pearlette volcanic ash in this terrace dates it as Late Kansan. At this time the ancient Canadian River was probably beheaded in the area northwest of Putnam by some eastward-flowing stream. This same stream must have been a tributary to the ancient Canadian River before piracy, probably flowing southward into the ancient Canadian River in the Bridgeport area where terrace levels and gravels are common to both Deer Creek and the Canadian River. The small tributary stream then became the newly formed Canadian River, and the ancient Canadian River became an underfit stream, Deer Creek.

Canadian River area—The Canadian River deposits consist of 80 to 90 feet of gravel and sand, overlain by silt and clay on the northeast side of the river, with a thin veneer of silt and clay, some sand, and hardly any gravel on the southwest side of the river. The gravel is present at the base of each terrace level, surmounted

Figure 30. Pleistocene sand and gravel at base of third terrace above the Canadian River, near C NE¼ NE¼ sec. 34, T. 15 N., R. 13 W. At the base of the arroyo face are dark red-brown shale pebbles incorporated in the sand, at hammer head.

by sand and clay (figs. 30-32), with much evidence of channeling. The gravel consists mostly of quartzite cobbles and pebbles derived from the Rocky Mountains and is not associated with volcanic ash.

Approximately 100 elevations taken at the base of the gravels were plotted on a map and contour lines were drawn to show the nature of the base of these deposits. There is a gradual inclination or gradient of the Pleistocene stream channel deposits of approximately 7 to 8 feet per mile southeastward. There is an average dip of these gravel deposits of 25 to 30 feet per mile to the southwest. In the area about 6 miles northeast of Taloga, Dewey County, elevations at the base of the gravels range from 1,950 to 1,980 feet for the upper levels to approximately 1,830 feet for the lower level. In the Blaine County area, about 12 miles west of Geary, the elevations on comparable levels are 1,730 feet and 1,570 feet. The distance between the two areas is approximately 35 miles. The gravels rest upon the Cloud Chief Formation to the northwest and the underlying Whitehorse Group to the southeast, as do the Deer Creek gravels, following the regional strike with a general northwestward trend. In the Taloga area, the trend is westward, following the strike of the bedrock, the change being caused by the

Figure 31. Pleistocene gray clay resting upon coarse sand in the third terrace above the Canadian River, near C NE¼ NE¼ sec. 34, T. 15 N., R. 13 W. The head of the hammer is about one foot above the contact between the clay and the sand.

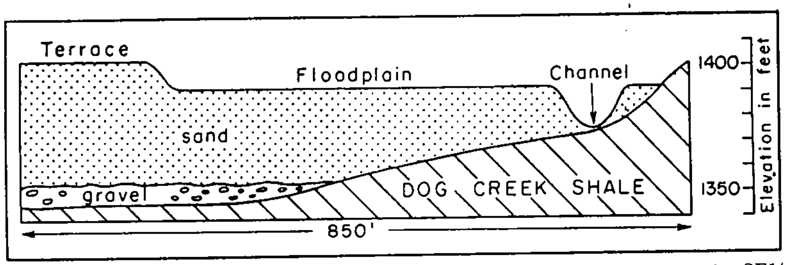


Figure 32. Schematic cross section through the Canadian River deposits in SE¼ SW¼ sec. 28, T. 13 N., R. 11 W., along the Chicago, Rock Island and Pacific Railroad bridge 5421, north of Bridgeport. Based upon core information after F. A. Luce, September 8, 1914. Note that the present channel carries sand, but that a former, deeper channel carried gravel, and that the river has been filling the old channel.

southwestward-plunging syncline in the Canton area. The bedrock in this region shows evidence of collapse or highly undulatory bedding with perhaps as much as 115 feet of relief, probably caused by solution. In this same area north of Taloga, the thick gravel deposits terminate but are present again farther south and southwest in the area northwest of Putnam, where they seem to merge with the Deer Creek gravels. This is the evidence for the belief that a large stream must have flowed northeastward from the Putnam area toward Taloga, thence eastward toward Canton and southeastward toward Geary, in Blaine County (inset map, pl. IV). The gravel deposits terminate southeastward in the area six miles west of Geary, where they have a southerly trend, following the west side of Larriat Creek, being absent along the east side. It is here assumed that the river turned southward in this region, flowing toward the area west of Bridgeport.

Approximately five terrace levels are along the Canadian River, the tops being about 50, 150, 220, 270, and 300 feet above the floodplain in central-western Blaine County. Only three terrace levels are mapped because the upper ones are mostly covered by sand dunes and the escarpments are highly dissected. The lowest terrace has marked boundaries in Permian outcrops, whereas the higher terraces have less accentuated boundaries in Pleistocene sediments. The intervals between these terrace levels and the floodplain are not constant, the change depending upon the type of bedrock over which the river flows. The 50-foot terrace is mapped separately, whereas the 150- and 220-foot levels are grouped together as are the 270- and 300-foot levels. The general southwesterly dip at the base of these terraces, with gravels on the northeastern side of the present-day river, suggests that the net shift of the channel has been from the northeast to the southwest and that the intermediate Canadian River channel had a position extending parallel to the northeasternmost edge of the gravel outcrops of the Canadian River as described above (inset, pl. IV). The river has since worked its way back and forth throughout the Pleistocene Epoch, but the net shift of its channel has been to the southwest, following the dip of the underlying bedrock, to which it is now adjusted.

Summary—The Canadian River, before stream piracy, must have been a small stream extending northeastward from the Putnam area toward Taloga, thence eastward toward Canton and southeastward toward Geary, flowing southward into the ancient Canadian River in the Bridgeport area. The stream eroded headward to the south toward the Putnam area, pirated the ancient Canadian River, changing its course northeastward and forming two large loops, in Late Kansan time or later. The beheaded ancient Canadian River then became Deer Creek, and the small tributary stream then became the intermediate Canadian River, working its way downdip to the southwest to form the present-day Canadian River (Fay, 1959, p. 3-12). A cross-section through the northern 900 feet of the river channel at the north of Bridgeport reveals that the river is now filling in an ancient channel that was cut 60 feet below the present immediate floodplain in the Dog Creek Shale. Approximately 8 to 10 feet of gravel occurs 25 feet below the base of the river channel, with 40 to 50 feet or more of sand above the gravel, carved into several levels of the floodplain (fig. 32). This deep channel was probably cut during the Wisconsinan Age when the ice was melting back, the present day being interpreted as a period of maximum retreat and alluviation during an interglacial age. The present-day Canadian River has a gradient of approximately 4 to 5 feet per mile in the Bridgeport area, being approximately half that of its Pleistocene gradient.

North Canadian River

The North Canadian River deposits consist of 40 to 100 feet of gravel, sand, silt, clay, and some volcanic ash, deposited in several terrace levels, along either side of the river in a 10-mile-wide strip. The gravel deposits are principally on the northeastern side of the river, whereas on the southwestern side of the river there is a thin veneer of silt and clay, with some gravel resting upon exposed bedrock (pl. IV).

The gravel is composed of quartzite pebbles and cobbles derived from the Rocky Mountains. One volcanic-ash pit is in NW¼ sec. 4, T. 18 N., R. 13 W., where the ash is almost 3 feet thick and is interbedded with sand and clay, with gravel beneath. This ash is also the Pearlette type and is present in the high terrace of this river system. Chemical and physical analyses of the ash are given in Burwell (1949, p. 22) and Ham (1949, table 10). Three terrace levels are mapped, but there may be as many as five, their tops being 20, 40, 50, 70, and 100 feet above the present-day floodplain. The 20-foot level, corresponding to the 50-foot level on the Canadian River, is mapped separately; whereas the 40- and 50-foot levels are combined, and the 70- and 100-foot levels are combined. The upper level includes the volcanic ash and Pleistocene sand dunes covered with vegetation and is here tentatively identified as Late Kansan or older. The intermediate terrace may be Illinoian and the low one may be Wisconsin.

The gradient at the base of the high terrace is approximately 4 to 5 feet per mile southeastward as is that of the present-day river. The gravels have an average southwesterly dip at their base of approximately 20 feet per mile. This dip shows that the river channel had once been as far as 6 or 7 miles east of its present channel and has shifted laterally southeastward with the dip of the underlying bedrock since the beginning of the Pleistocene Epoch. The present channel runs entirely upon the Dog Creek Shale; but, judging from elevations at the base of the high terrace, such as 1,630 feet in northern Blaine County and 1,450 to 1,500 feet in southern Blaine County, the old river channel probably flowed across the top of the Marlow in northwestern Blaine County and across the lower portion of the Marlow in central Blaine County. The base of the Canadian River gravel deposits is approximately 200 feet higher than the top of the adjacent North Canadian River deposits a few miles to the east, showing that there is no relationship between the two types of deposits in any direction. The intervening escarpment is composed mostly of the Whitehorse Group and must have been eroded down at least 200 feet before the beginning of the Pleistocene Epoch, the Pleistocene river cutting down another 100 feet and filling in bottom portions of the valley below the escarpment.

One feature of the drainage on the northeastern side of the river is the pattern produced by ephemeral and intermittent streams that do not reach the main rivers. Most of these streams are less than a mile long and end in a small sink or depression with a lake in the middle. Many sand dunes cover the region and account for some of this pattern, but recently formed sinkholes also contributed to the development of this pattern (Fay, 1958, p. 58-64). Many sinkholes have developed in historic time in this region, probably due to solution of the underlying Blaine Formation (fig. 33). The average modern sinkhole is about 20 or 30 feet deep and 50 to 200 feet across. The overlying gravel and sand deposits act as an aquifer, supplying water to the formations below. The water probably dissolves out the gypsum and soluble salts, flowing out eastward in the Blaine escarpment to form gypsum- and salt-water springs at lower elevations (fig. 34).

Figure 33. Recently formed sinkhole on Anna Foley farm, near C SW¼ SW¼ sec. 2, T. 16 N., R. 12 W., in the Pleistocene deposits of the North Canadian River. The hole is about 22 feet deep and 50 feet wide and was probably formed by a cave-in of the Shimer Gypsum, which is about 100 feet below the ground. My wife is standing above and Mrs. Gerald "Cowboy" Curtin, editor of the *Watonga Republican* is standing below.

Water from the terrace deposits is of good quality, with a dissolved-solids content of 400 parts per million (Dover, 1953, p. 24, 28, 43). Six wells 30 to 50 feet deep in a three-block area in Watonga have a potential yield of 5.6 million gallons per day. Analyses of fresh- and salt-water springs are given in tables 2 and 3.

Cimarron River

The Cimarron River cuts through the northeastern corner of Blaine County, but its deposits are widespread, being composed of a few feet of silt and clay, with some sand, in the northeastern part of Blaine County. In the southeastern part, in Ts. 15, 16, 17 N., R. 10 W., a gravel deposit, several feet thick, is present 120 to 190 feet above the present floodplain of the Cimarron River. It is here included in the high terrace level. There are at least three terrace levels on this river system but with minor levels in the higher ones, the tops being approximately 20, 50, 90, 140, and 190 feet above the floodplain. The high terrace level (140- to 190-foot

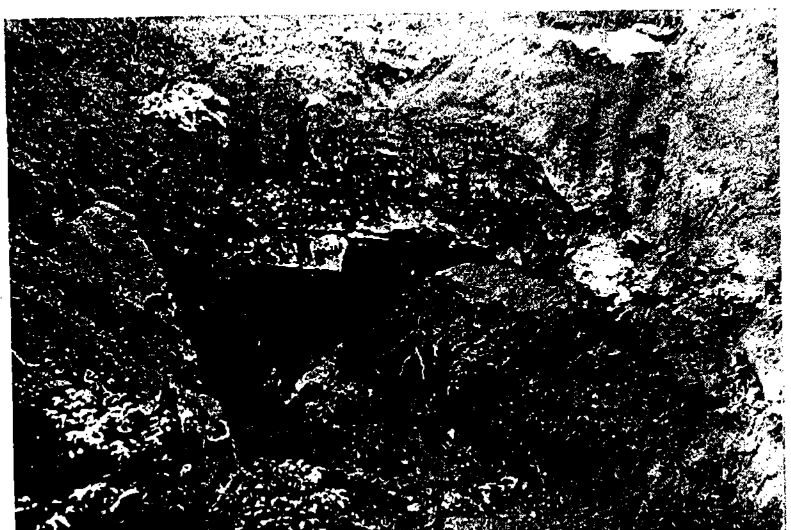


Figure 34. Big Spring, Roman Nose State Park, formed at base of Shimer Gypsum Member of Blaine Formation, W½ NE¼ SE¼ sec. 23, T. 17 N., R. 12 W. The water probably comes from the overlying North Canadian Pleistocene terrace deposits, dissolving the gypsum and forming caves. It is reported that this cave extends back almost one-fourth mile. The spring fluctuates in flow seasonally and, in July 1958, 365 gallons per minute outflow was measured.

Table 2.—Chemical Analysis of Water from Springs in Roman Nose State Park, Blaine County, Oklahoma

(All springs are in sec. 23, T. 17 N., R. 12 W. Analyst, J. A. Schleicher, Oklahoma Geological Survey.)

Spring	Little Spring	Middle Spring	Big Spring
Location	NE-SW-NE-SE	SE-NW-NE-SE	SE-NW-NESE
Laboratory number	10344	10345	10346
Flow, July 23-24, 1958*	80 gpm	175 gpm	365 gpm
Constituent	*Concentration (ppm)*		
SiO_2	19.6	21.3	18.2
Ca	589	556	523
Mg	41	34	26
K	22	21	11
Na	33	47	51
CO_3	9	4	nil
SO_4	1,523	1,475	1,347
Cl	56	43	37
HCO_3	63	78	90
R_2O_3	4	1.3	3.1
Br	nil	3	10
Total dissolved solids	2,391	2,283	2,116
Suspended load	6.4	5.8	9.6
	Theoretical combinations		
$CaCO_3$	98.5	110.2	120.0
$CaSO_4$	1,910.7	1,793.0	1,675.9
$MgSO_4$	202.9	168.6	128.8
Na_2SO_4	19.2	111.5	90.9
KBr	nil	4.8	15.5
KCl	41.8	37.3	11.2
NaCl	63.7	34.5	53.5

* Total flow, 620 gallons per minute.

levels) contains volcanic ash of the Pearlette type in Kingfisher County in sec. 27, T. 17 N., R. 9 W., dating this level as Late Kansan or older. The intermediate terrace (50- to 90-foot levels) and low terrace (20-foot level) are probably Illinoian and Wisconsinan, respectively, and probably were formed at the same time as the comparable intermediate and low terraces on the Canadian and North Canadian Rivers.

On the northeastern side of the Cimarron River, in Kingfisher and Major Counties, thick gravel and sand deposits are present, some almost 120 feet thick. Elevations at the base of these deposits

TABLE 3.—CHEMICAL ANALYSIS OF WATER FROM SALT CREEK

(Collected at SE¼ SE¼ NW¼ SW¼ sec. 24, T. 18 N., R. 12 W. Analyst J. A. Schleicher, Oklahoma Geological Survey.)

Constituent	*Concentration (ppm)*
SiO_2	4.4
Ca	1655
Mg	427
K	82
Na	37,661
CO_3	10
SO_4	3,429
Cl	56,600
HCO_3	40.4
R_2O_3	8.4
Br	230
Total dissolved solids	100,744
Suspended load	62.8
Theoretical combinations	
$CaCO_3$	70.01
$CaSO_4$	4,858.84
$CaCl_2$	566.66
$MgCl_2$	1,672.41
KBr	171.37
KCl	49.21
NaCl	93,173.55

Rate of flow July 23, 1958: 200 gallons per minute based on 6 inches of rise over a 90 degree weir, remaining steady for at least ½ hour.

show a gradual southwesterly dip, ranging from 1,220 feet to 1,060 feet in a line 9 miles long through Lacey, Kingfisher County, according to Reed and others (1952, pl. I). In southeastern Blaine County, elevations at the base of the gravels range from 1,280 feet on the western edge to 1,210 feet near the Blaine County line to the east, showing an eastward dip. It is here suggested that the Cimarron River channel was once in southeastern Blaine County and has since been pirated or has shifted approximately 12 miles eastward, probably during Late Kansan time.

The Blaine escarpment is approximately 250 feet higher than the top of the Cimarron River deposits, the base of the North Canadian gravels being on top of the Blaine escarpment just a few miles west of the Cimarron deposits, showing that there is no relationship in any direction between the North Canadian River deposits and Cimarron River deposits. The Blaine escarpment must have been cut down at least 250 feet before the beginning of the Pleistocene Epoch. The Cimarron River cut down another 200 feet and filled in the bottom of the valley east of the Blaine escarpment during the Pleistocene Epoch.

Part II.—Economic Geology and Petrology of Gypsum and Anhydrite in Blaine County

William E. Ham

INTRODUCTION

Blaine County, the center of gypsum mining in western Oklahoma, has long been recognized as a leading source of high-purity gypsum and gypsum products in the United States. Thick beds of white gypsum crop out as easily workable deposits at many localities. Even the early settlers of Indian Territory found and made use of this valuable commodity more than 70 years ago, for by simple calcination of this readily available stone it was possible to make plaster of Paris for use as an interior coating on walls and ceilings.

First recorded production was in 1894, when small plaster mills were established near railroads in Blaine County. In 1907, the year of Oklahoma statehood, 10 gypsum mills had been built in the State, and by 1913 this number had been increased to 12 (Snider, 1913, p. 72-79). The excellent quality and strong competitive position of Oklahoma gypsum became firmly established, and production increased from the annual average of 12,000 tons in 1894-1900 to the all-time record of 471,000 tons in 1960.

Three plants in Blaine County produced 96 percent of the Oklahoma total in 1960, and for many years before 1958 all the Oklahoma production was obtained from Blaine County quarries. They have consistently produced about 4 percent of the domestic tonnage of gypsum in the United States. The plant of the United States Gypsum Company at Southard has been in continuous operation since 1912.

The two principal economic gypsum beds in Blaine County are the Shimer and Nescatunga Members of the Blaine Formation, each 8 to 15 feet thick. Together they have yielded since 1908 approximately 11 million tons of gypsum of 97 to 99 percent purity, and they have a remaining reserve in the county of approximately 280 million tons.

Eleven other counties in western Oklahoma have similar or greater tonnages of high-purity gypsum, giving to this region one of the major reserves in the world.

PRODUCTION

Statistics and Historical Survey

Production of gypsum in Oklahoma for the years 1908-1960 is shown graphically in figure 35. As the principal uses of gypsum are for making plasters and wallboard, and for retarder in the manufacture of portland cement, it follows that the production of gypsum is closely related to trends in national economy and particularly to the construction of homes, buildings, and highways. The graph of figure 35 reveals peak production during the periods 1923-1929, 1943-1944, and 1948-1960, and these peaks indicate respectively the accelerated construction following World War I, the defense construction during World War II, and the period of exceptional building activity since 1948. Cumulative recorded production for the years 1908-1960 has now reached 12.09 million tons.

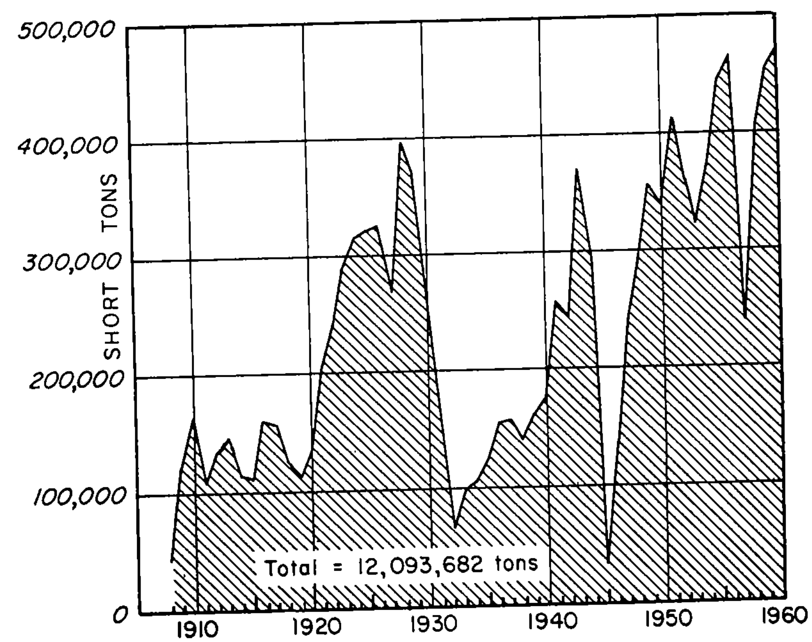


Figure 35. Gypsum production in Oklahoma, 1908-1960.

From the days of earliest production in Oklahoma, the center of the gypsum industry has been in Blaine County. The towns of Bickford, Ferguson, Southard, Homestead, Okeene, and Watonga became prominently known for gypsum mining and the manufacture of gypsum plaster. Seven gypsum mills operated within the county in the first 20-year period of production, and at the same time mills also were erected at Okarche, Alva, Rush Springs, and Eldorado, in other parts of western Oklahoma (Snider, 1913, p. 72-79).

Five of the early plants used rock gypsum exclusively; two of them used only gypsite, an unconsolidated and somewhat impure form of gypsum; and all others used both rock gypsum and gypsite. Gypsite was favored at first by some operators because it was easy to mine, it did not have to be ground for calcining, and claims were made that certain types of plaster made from gypsite were superior. The deposits themselves were erratic in distribution and were not consistently pure, however, and all the plants using gypsite were gradually forced out of business by competition with plants using the purer rock gypsum. The last gypsite deposit to be worked was that at Eldorado in southern Jackson County.

Although the number of plants decreased as the result of competition and the exhaustion of smaller gypsite deposits, production and value of gypsum steadily increased. Through 1900 the average annual production was 12,100 tons, and the annual value of gypsum products was $37,000. In 1921 the comparative figures were 209,000 tons valued at $1.29 million, and the 1923-1929 average was 327,000 tons with an annual value (crude gypsum and gypsum products) of $2.3 million. During the depression of the 1930's, production sank to less than 150,000 tons per year, and all plaster-making mills except that of the United States Gypsum Company at Southard were closed (Ham, 1958, p. 83).

The pre-depression record tonnage of 397,752 tons was produced in 1928, but the strong resurgence of building that followed the close of World War II resulted in the establishment of a new record-breaking production of 413,694 tons in 1951, of 444,874 tons in 1955, of 468,269 tons in 1956, and the all-time record of 471,065 tons in 1960. In 1951, 1955, and 1956, all Oklahoma production was from Blaine County.

From published data for the years 1953-1957, it is possible to

Table 4.—Production and Value of Crude Gypsum in Oklahoma and in the United States, 1953-1957

(All Oklahoma production during this period was from Blaine County.)

		Short tons	Average value per ton	Total value
1953	U. S.	8,292,976	$2.79	$23,175,073
	Okla.	323,451	2.76	892,720
1954	U.S.	8,995,960	3.04	27,383,515
	Okla.	373,052	2.81	1,048,130
1955	U. S.	10,683,733	3.18	33,937,560
	Okla.	444,874	2.94	1,307,930
1956	U. S.	10,316,483	3.31	34,099,445
	Okla.	468,269	2.93	1,372,030
1957	U. S.	9,194,580	3.25	29,871,446
	Okla.	237,935	3.14	746,816

Data for the United States, and for average value per ton in Oklahoma, from *Minerals Yearbook* for the indicated year. Production in Oklahoma from published Annual Reports of Mines and Mining in Oklahoma, Office of Chief Mine Inspector, Oklahoma City.

estimate the value of crude gypsum produced in Oklahoma and to compare these figures with domestic production in the United States, as given in table 4. For these years the Oklahoma production was slightly more than 4 percent of the national total. The value per ton of crude gypsum f.o.b. cars at Oklahoma plants has ranged between $2.76 and $3.14, averaging about 20 cents per ton lower than the corresponding United States average, and normally yielding a value for crude gypsum in excess of $1 million per year. The much greater total value of gypsum products made in Oklahoma is not available, as statistics on this commodity have not been published since 1930.

Probably at least 95 percent of the total Oklahoma production through 1960 has originated in Blaine County, and for the period 1940-1958 it accounted for all the production from the State. The property of the United States Gypsum Company at Southard, acquired in 1912, has since been the largest single producer in Oklahoma, and the outstanding position of Blaine County is owed directly to the successful operation of this gypsum-products plant for the last 50 years. The second largest producer in Oklahoma is the Universal Atlas Cement Company at Bucher siding, eight miles northeast of Watonga, where the company has continuously

TABLE 5.—GYPSUM PRODUCTION IN BLAINE COUNTY, 1948-1960, BY PRODUCERS
(short tons)

Year	U. S. Gyp. Company, Southard	Univ. Atlas Cement Co., Bucher	S. A. Walton and Son, Gyp.	Total Blaine Co.	Total Okla.
1948	208,326	84,189	90	292,605	same
1949	262,175	84,415	9,000	355,590	same
1950	269,027	65,419	5,300	339,746	same
1951	320,922	85,572	7,200	413,694*	same
1952	276,016	77,605	6,050	359,671	same
1953	237,648	82,097	3,706	323,451	same
1954	282,483	86,619	3,950	373,052	same
1955	331,045	104,424	9,405	444,874*	same
1956	352,766	110,453	5,050	468,269*	same
1957	127,550	101,585	8,800	237,935	same
1958	293,372	85,863	6,860	386,095	404,795
1959	320,506	98,078	8,100	426,684	454,623
1960	348,384	99,561	5,720	453,665	471,065*
Average 1948-1960	279,248	89,683	6,095	375,025	379,952

* Year of new record production.
Source: Annual Reports of Mines and Mining in Oklahoma, Office of Chief Mine Inspector, Oklahoma City.

produced crude gypsum for portland cement retarder since 1925. Substantial tonnages of crude gypsum for cement retarder and soil conditioner also have been produced since 1948 by S. A. Walton and Son. Production data by companies are available for the years 1948-1960 (table 5). They show that during the stated period the average annual production was 280,000 tons by the United Gypsum Company, 90,000 tons by the Universal Atlas Cement Company, and 6,100 tons by S. A. Walton and Son.

All the production in Blaine County is now obtained by open-face quarrying, although before 1948 the United States Gypsum Company mined the Shimer and Nescatunga ledges underground by the double-entry room-and-pillar method, and at an earlier date the Nescatunga ledge was mined underground by the Universal Atlas Company.

UNITED STATES GYPSUM COMPANY

The Southard plant of the United States Gypsum Company is part of the largest gypsum-producing organization in the world,

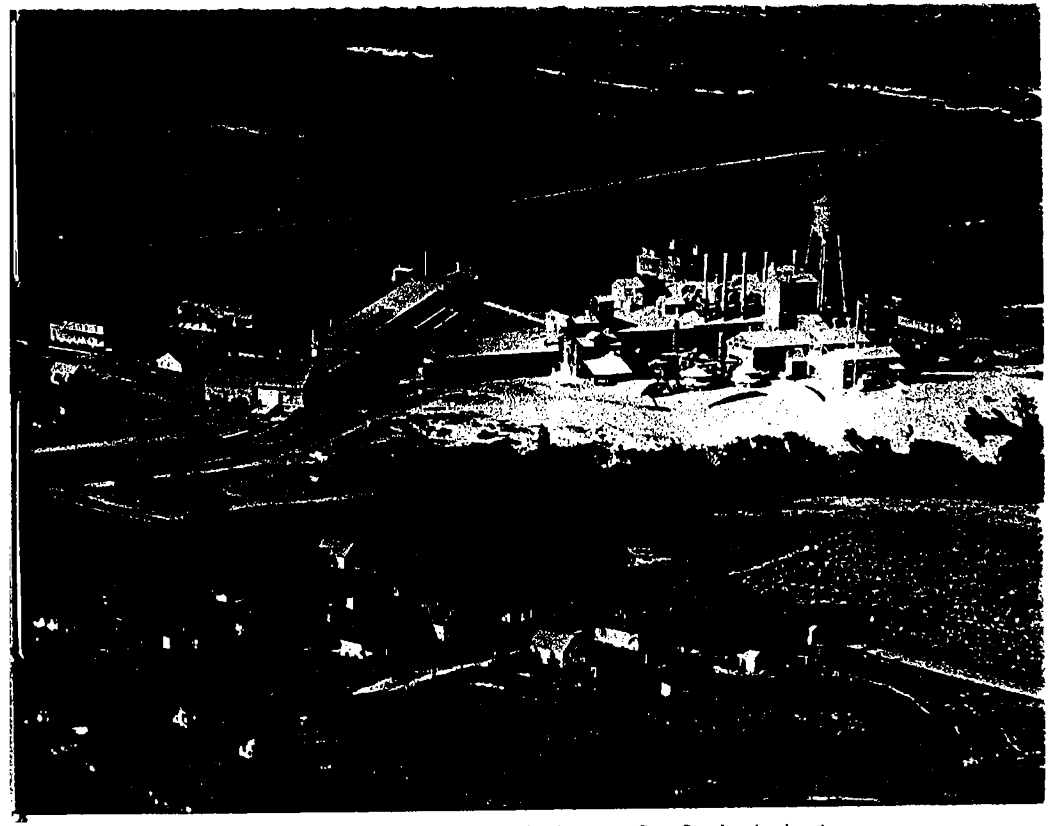


Figure 36. Aerial view of plant of U. S. Gypsum Co., Southard, showing gypsum outcrops and a few worked-out quarries at upper right. (Photograph courtesy of U. S. Gypsum Co.)

with home offices at Chicago and with 51 plants of various kinds in the United States and Canada. Organized in 1902 through consolidation of smaller companies, U. S. Gypsum in 1912 purchased the plant and property of G. H. Southard, which has since been enlarged to produce annually about one-quarter million tons of plaster and rock products, and more than a hundred million square feet of wallboard.

At Southard the gypsum is of such high purity that "Hydrocal", a U. S. Gypsum Company process for making superstrength gypsum cement by calcination in autoclaves, is produced here and at only one other company plant in the United States.

The Southard plant provides employment for about 300 people and has an annual payroll of approximately $1 million. Most of the employees live in Southard, a company town of the United

Figure 37. Aerial view of gypsum outcrops and quarry in Shimer Gypsum, the uppermost white ledge.
(Photograph courtesy of U. S. Gypsum Co.)

States Gypsum Company. More than 175 products are made at the plant (fig. 36), including various gypsum wallboards, laths, sheathing, and wall plasters. Other plasters are used for making pottery and ceramic products, for bedding plate glass during grinding and polishing, in dental laboratories, and in casting molds for nonferrous metals. Special oil-well cements are produced, and other products are used as fillers in foods, pharmaceuticals, tooth paste, paint pigments, and paper.

For permission to examine and map the quarries and outcrops at Southard and for helpful information about the United States Gypsum Company operation and history, we are indebted to the works manager, W. J. Blosser, and to the quarry superintendent, D. F. Underwood. We also gratefully acknowledge the assistance of quality-control superintendent, W. D. Reynolds, who discussed

Figure 38. Part of quarry face in Shimer Gypsum, U. S. Gypsum Co., Southard. The worked ledge is 13.5 feet thick.

with us the methods and results of chemical analyses of gypsum from company quarries. Mr. Underwood also supplied prints of aerial photographs of the plant and quarries.

Shimer Gypsum—The Shimer Gypsum (pronounced Shy'mer), the top member of the Blaine Formation, is about 15 feet thick in the Southard area and is the principal worked ledge (fig. 37). It consists of white massive gypsum that normally has a purity of 95 percent or greater. It yields about 75 percent of the company's production, being extensively used for making wallboard and common plasters. At no other locality in Oklahoma is the Shimer ledge quarried, although there are other sites where it could be worked. Probably about half the Oklahoma production of gypsum through 1960, about 6 million tons, has been obtained from the prolific Shimer ledge in the Southard area (fig. 38).

The working face is prepared by stripping off and discarding the overburden of red shale, using a diesel-powered Euclid dirt mover. The beds lie horizontally and are unfaulted, and there is no difficulty in scraping a smooth flat-lying surface at the top of the gypsum bed. After being stripped, the stone is worked by drilling vertical blast holes from the top of the ledge and horizontal blast holes near the base of the face, about one foot above the underlying Altona Dolomite. The two types of holes are shot almost simultaneously, breaking the stone in such a way that little secondary shooting is required, and leaving the unwanted dolomite undisturbed just below the quarry floor. Experienced drillers know by the behavior of the bit whether dolomite has been penetrated, and if so the hole is back-filled slightly before being loaded with explosives. Broken stone is loaded by power shovel onto 25-ton dump trucks and hauled to the crushing and calcining plant.

Prime quarry sites in the Shimer Gypsum are determined by geologic, topographic, and economic factors. One of the chief considerations is the thickness of shale overburden, which in turn strongly governs the distribution of anhydrite. Long experience in the district has shown that, where there is more than 30 feet of overburden, anhydrite is present in objectionable quantity in the gypsum below. The gypsum beds have been derived by hydration of anhydrite at or near the surface of the ground, and the hydration process is incomplete where 30 feet or more of shale protects the ledge.

Quarries in the three-mile length of Shimer Gypsum worked by the U. S. Gypsum Company have ranged in width from 100 feet to 700 feet and have averaged 350 feet. The practical width which may be stripped is that area between the outcrop edge of the Shimer Gypsum and the edge of the overlying bench capped by the Watonga Dolomite, 30 feet above the top of the gypsum

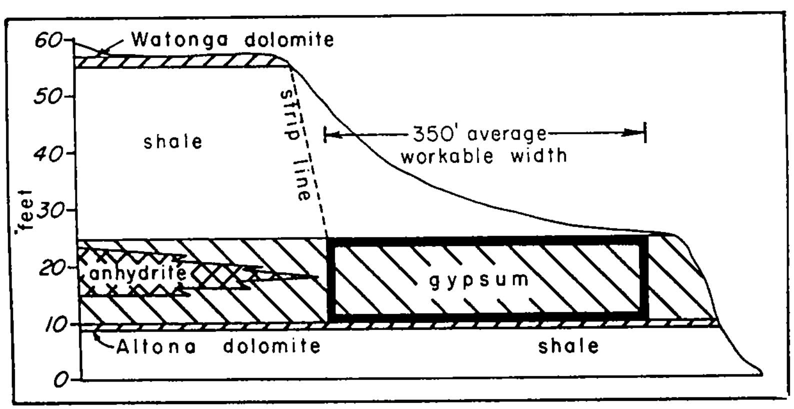


Figure 39. Diagram illustrating effects of topography on quarrying the Shimer Gypsum bed in Blaine County.

(fig. 39). The thickness of overburden within this tract thus ranges up to 30 feet and averages about 20 feet, giving a ratio of overburden to gypsum of 4:3. The eroded edge of the gypsum bed is generally too weathered and filled with clay pockets for economic recovery of the gypsum, however, and this thin outer margin is not quarried. The highest bench of the east-facing escarpment is that of the Watonga Dolomite, and the best quarry sites are in the flaring spurs, or shoulders, that project irregularly outward onto the underlying bench of the Shimer Gypsum.

The Shimer was mined underground on the Southard property for about 25 years. Underground mining was abandoned in 1948. Double-entry room-and-pillar methods were used. The rooms were 22 feet wide and 7 feet high; they were separated by 10-foot-square pillars which were robbed two feet on a side when the workings were abandoned. After being shot, the broken stone was hand loaded and hauled out by mules. In later stages, machine mining was introduced and 30-foot rooms were cut.

Nescatunga Gypsum—The second gypsum ledge worked by the U. S. Gypsum Company at Southard is the Nescatunga (pronounced Nes kah tun′ gah). It is the first gypsum bed below the Shimer and is separated from it by 30 feet of shale. Like the Shimer, it crops out as a curving bench in the dissected escarpment, grading into anhydritic gypsum where there is more than 30 feet of overburden. For these reasons the Nascatunga is stripped in exactly the same way as the Shimer, except that the Nescatunga at Southard is thinner, of slightly higher purity, and is used for the production of Keene's cement and special high-grade plasters and fillers. Exceptional care is taken to protect the purity of the gypsum. The top foot of the gypsum is scraped off, along with the overlying shale, to prevent contamination by gritty quartz silt or sand; and, after shooting, the broken stone is carefully sorted and hand loaded for trucking to the plant. The bed in the Nescatunga quarry has always been called the Keene's ledge, in allusion to its use in making Keene's cement.

In the 1920's and 1930's, the Nescatunga bed was worked underground by the room-and-pillar method, but owing probably to the thinness of the gypsum, the method was abandoned in favor of open-face quarrying.

In outcrops of central and northern Blaine County the Nescatunga Member of the Blaine Formation consists of (a) an upper gypsum sequence normally 8 feet thick and (b) a lower bed of anhydrite about 7 feet thick. The basal foot or two of the anhydrite commonly is gypsified. Only the 8-foot gypsum is quarried at the present time. It is worked down to the top of the anhydrite, which is kept as the quarry floor and which may be used at a later date if there is a demand for anhydrite. As the top foot of gypsum is not used, the ratio of overburden to recovered gypsum is approximately 20 feet to 7 feet, or about 3:1 (fig. 40).

The Nescatunga is among the purest commercially worked gypsum deposits in the world. A channel sample of the working face taken in July 1958 showed on complete chemical analysis a theoretical gypsum content of 98.68 percent, with only 0.3 percent silica, 0.12 percent alumina, and 0.57 percent calcium and magnesium carbonates (table 7, lab. no. 10337).

UNIVERSAL ATLAS CEMENT COMPANY

Universal Atlas Cement Division, United States Steel Corporation, since 1925 has operated a quarry and crushing plant for the

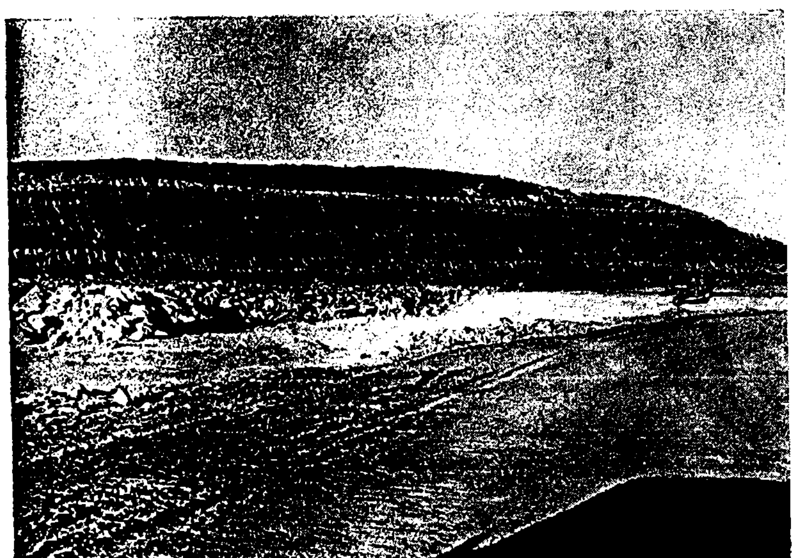


Figure 40. Part of quarry face in Nescatunga Gypsum, U. S. Gypsum Co., Southard. The horizontal gypsum ledge is 8 feet thick and is underlain by 7 feet of anhydrite, just below the quarry floor. Stripped overburden in background is shale overlain by Altona Dolomite (white band near top) and highly weathered Shimer Gypsum, of which only a few residual white blocks can be seen.

production of crude gypsum at Bucher, a siding on the Chicago, Rock Island, and Pacific Railway, 8 miles northeast of Watonga (fig. 42). The Nescatunga Gypsum Member of the Blaine Formation is extensively worked in the central part of sec. 27, T. 17 N., R. 11 W., on property adjoining the crushing and shipping plant. The worked bed is 15 feet thick and consists of white medium-crystalline to fine-grained high-purity gypsum. A layer of coarse-crystalline anhydrite as much as 4.5 feet thick, in the middle part of the gypsum bed, is exposed in the quarry walls where thick overburden has been removed. Most of the quarry is free from anhydrite and is characterized chemically by the channel sample cut from the active face in July 1958 (table 7, lab. no. 10339), which contains 98.25 percent gypsum.

Perry E. Gorby, quarry superintendent, P. O. Box 407, Watonga, gave permission to examine the quarries and supplied much helpful information about the company operation. The company has achieved a notable record for safety, having operated without a lost-time accident for 22 years of the 23-year period ending in 1958. In recent years the plant production of crude gypsum has averaged 90,000 tons annually (table 5).

Figure 41. Part of quarry face in Nescatunga Gypsum, Universal Atlas quarry. The ledge is 15 feet thick and consists of high-purity white gypsum. It is underlain by Magpie Dolomite, one foot thick, which forms the quarry floor and is exposed in drainage ditch at lower right.

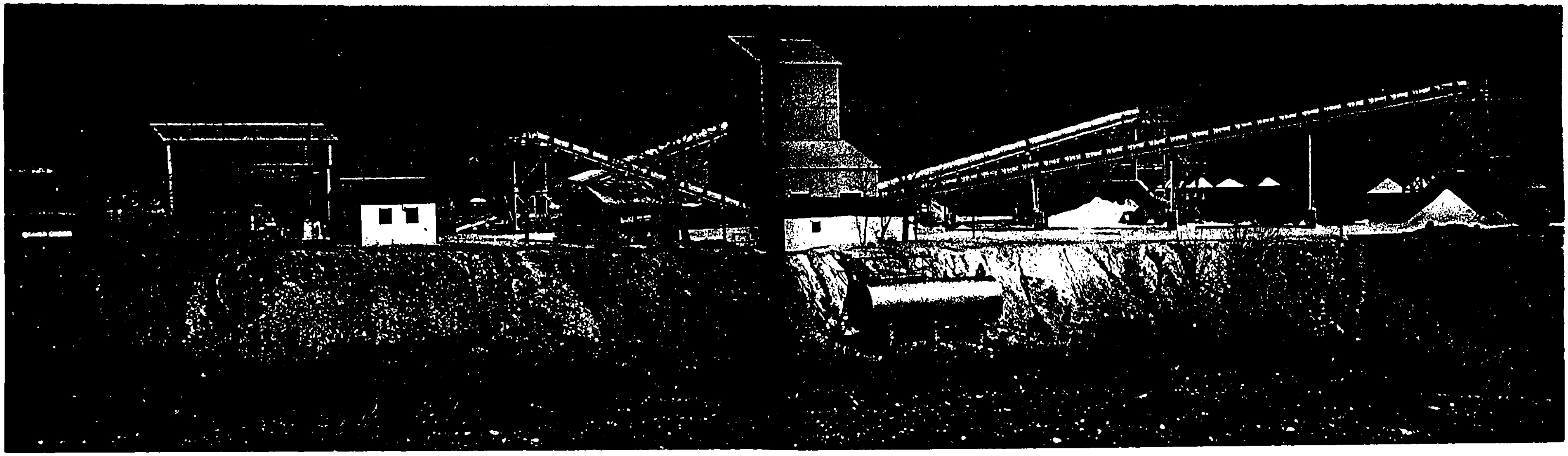


Figure 42. Plant of Universal Atlas Cement Co. at Bucher siding

The gypsum bed lies flat and is worked by open-face methods (fig. 41). After shale overburden is stripped and discarded, the face is shot from vertical blast holes, drilled to a depth one foot above the basal Magpie Dolomite. Broken stone from the face is hauled by dump trucks to the crusher plant where it is reduced to —1½-inch size through two roll crushers and loaded into open gondolas for rail shipment (fig. 42). All the stone is used as retarder in the manufacture of portland cement by 15 Universal Atlas Cement plants in the south-central part of the United States. The small amount of anhydrite locally present is worked with the gypsum as mill-run feed, for it is not sufficiently abundant to be objectionable for use of the gypsum as retarder.

As much as 10 acres of overburden is stripped in advance of the working face (fig. 43), and approximately 100,000 tons of stone is shot at one time. The thickness of shale overlying the gypsum is as much as 38 feet, up to the Southard Dolomite, but in practice not more than 25 feet is removed because here, just as in the Southard area, the percentage of anhydrite increases excessively in the worked ledge where the overburden is thicker. Underground mining was practiced at an early date but was abandoned in 1938.

Gypsum outcrops in the Blaine Formation at Bucher on the Frisco Railway have been worked for 50 years. The Monarch Plaster Company operated a gypsum-products mill at Watonga in 1913 (Snider, 1913, p. 74), shipping stone to the mill from the same deposits in sec. 27, T. 17 N., R. 11 W. that are now worked by Universal Atlas. Production was doubtless small, and the plant did not survive into the 1920's. The property was acquired in 1925 by Universal Atlas and since then has been continuously active, yielding the second largest production in Oklahoma.

S. A. Walton and Son

The partnership of S. A. Walton and Son, 805 N. 8th St., Fairview, Oklahoma, has produced crude gypsum since 1947 from properties in the central part of sec. 35, T. 19 N., R. 12 W. Located two miles northeast of Southard, at Gyp siding of the St. Louis and San Francisco Railway, the plant also is close to State Highway 51 and has excellent transportation facilities for the sale and distribution of crushed gypsum for use as retarder in the manufacture of portland cement and of ground gypsum for soil conditioner. Most of the gypsum for cement retarder is sold to the plant of the Dewey Portland Cement Company, Dewey, Washington County, Oklahoma.

From the opening of the plant in April 1948, through 1956, the Medicine Lodge Gypsum was worked by open-face methods from the bench surrounding a small butte in NW¼ SE¼ sec. 35.

The worked face was 4 feet high, and from this quarry 49,700 tons of gypsum was produced. A channel sample of this gypsum showed on chemical analysis a theoretical gypsum content of 97.34 percent (table 7, lab. no. 10341). The quality is therefore high, but the Medicine Lodge ledge in Blaine County is too thin for extensive working, and the figure recorded above probably is the maximum tonnage produced from the Medicine Lodge Gypsum at any locality in Oklahoma.

Beginning in 1948 and continuing to the present, the Nescatunga ledge has been worked in S½ SE¼ NW¼ sec. 35. In this area the Nescatunga crops out as a widely distributed bench from which much of the original shale overburden has been eroded away, with the result that not more than 10 feet of shale is removed by stripping. The Nescatunga ledge here is 15 feet thick and consists, as it does in the Southard area, of an upper sequence of pure gypsum 7 to 8 feet thick, underlain by anhydrite 7 feet thick. The contact between gypsum and anhydrite is sharply defined. On the stripped gypsum surface vertical blast holes are drilled to the top of the anhydrite, the point of penetration being immediately recognized by the driller from the much slower drilling rate. The holes

Figure 43. Upper surface of Nescatunga Gypsum at Universal Atlas quarry, stripped of shale overburden and ready for quarrying.

are shot and the broken gypsum is loaded into dump trucks by a front-end-lift tractor for transportation to the crusher. A jaw crusher reduces the gypsum to —2-inch size, and a ¼-inch vibrating screen separates out the fines. The ¼- to 2-inch product is sold for cement retarder, whereas the fines are sold for soil conditioner. Excellent high-purity products are obtained. A channel sample of gypsum from the active quarry face contained 98.92 percent theoretical gypsum, and a sample of the agricultural gypsum stockpile contained 98.54 gypsum (table 7, lab. nos. 10340, 10342).

The anhydrite floor normally is not worked, for lack of market, but some is produced intermittently for rip-rap. A large area is readily available for production, particularly in the SW¼ sec. 35 where overburden of shale and gypsum already has been removed from the anhydrite during early periods of quarrying. About 500,000 tons of anhydrite, one of the largest available reserves on the surface in western Oklahoma, could easily be produced from the surface in western Oklahoma, could easily be produced from properties owned or controlled by S. A. Walton and Son.

Most of the gypsum worked in sec. 35 before 1947 was produced by the Concho Sand and Gravel Company of Oklahoma City. Between 1930 and the time when the operations were closed, about 1940, the company quarried Nescatunga Gypsum which was shipped for retarder to the Ideal Portland Cement plant at Ada, Pontotoc County, Oklahoma.

Abandoned Gypsum Workings in Blaine County

The largest number of active gypsum quarries and mills in Blaine County was in the early part of the twentieth century, and from the excellent published accounts of their operations by Snider (1913) most of the following information has been taken. R. O. Fay obtained additional data by a search of historical records.

In addition to the areas currently being worked and described above, there are four other localities where eight companies have been active. Those companies making gypsum products were particularly competitive, and it is clear that the market was insufficient to support them all.

Salt Creek Canyon area—One of the first mills established in Blaine County was that of the Rubey Stucco-Plaster Company, built in 1901, six years before Oklahoma statehood. The company purchased the N½ and SE ¼ of sec. 35, T. 18 N., R. 12 W., along the south branch of Salt Creek and about 4 miles west of the now-abandoned town of Ferguson. The quarry was in the Nescatunga Gypsum ledge near the top of Salt Creek Canyon, and the mill was at the bottom of the canyon, about 200 feet below. Four to six cars were placed on two sets of tracks, the weight of the loaded cars going down being enough to pull the empty cars up on the companion track. The company produced 150 tons of plaster every 24 hours, employing 10 to 12 men in the quarry and mill. In 1903 the company deeded its holdings to the United States Building and Manufacturing Company, which operated until 1910. The mill burned to the ground in 1915 and everything was sold for junk; and the railroad through Ferguson, on which finished products were shipped, was abandoned in 1926.

Bucher area—The American Cement Plaster Company of Lawrence, Kansas, built a gypsum mill at Watonga in 1902. The mill handled 75 tons daily and the company employed 12 to 14 men. A new mill was opened in the summer of 1912, producing about 10 tons of plaster per hour. This company had holdings in S½ NW¼ and in NE¼ sec. 34, T. 17 N., R. 11 W., about 7 miles northeast of Watonga and immediately south of the present Universal Atlas workings. The two quarries in the Nescatunga Gypsum were in SW¼ SE¼ NW¼ sec. 34 and C NW¼ NE¼ sec. 34. Rock gypsum was crushed at the quarry, loaded on gondola cars, and shipped to the plant in Watonga. Operations of this company evidently stopped in the 1920's.

A second gypsum mill at Watonga was that of the Monarch Plaster Company, which in 1913 produced Nescatunga Gypsum in NE¼ SE¼ sec. 27, T. 17 N., R. 11 W., directly at the site now worked by Universal Atlas Cement Company. Monarch also had holdings which included N½ sec. 27, SE¼ sec. 27, SW¼ SW¼ sec. 22 and SW¼ sec. 26, T. 17 N., R. 11 W. Gypsite also was worked by the company from deposits in S½ NW¼ sec. 35 of the same township, but all gypsite mining ceased in 1914 and the company went out of business a few years later.

Bickford area—The Roman Nose Gypsum Company established a mill in 1908 at Bickford (now abandoned), about 9 miles north of Watonga on the Geary-Alva branch of the Chicago, Rock

Island, and Pacific Railroad. This company owned the SE¼ sec. 18, the E½ NW¼ sec. 18, and the E½ SW¼ sec. 7, T. 17 N., R. 11 W., working two quarries in the Nescatunga Gypsum in the W½ SE¼ NW¼ sec. 18. The gypsum was hauled by wagons to the mill in the valley of Bitter Creek. Operations were evidently discontinued before the railroad was abandoned in 1926.

Prim (Ideal) area—The Oklahoma Gypsum Company opened a mill in 1913 at a site on the St. Louis and San Francisco Railway, which first was called Wilson, then Prim, then Ideal, and is now abandoned. The mill, in the east-central part of sec. 26, T. 19 N., R. 12 W., was the only one in Oklahoma at that time using the continuous calciner process. The Medicine Lodge Gypsum was mined underground for a short time, but later this bed and the Nescatunga Gypsum were quarried at the surface in NE¼ sec. 26. This company ceased operations before 1930.

About 1913 the deposits at Prim also supplied gypsum from sec. 26 to the mill of the Southwest Cement Plaster Company at Okeene, and some production of Nescatunga Gypsum was obtained from deposits near the north line of sec. 2, T. 18 N., R. 12 W.

Most of the gypsum worked at Prim, in sec. 26, T. 19 N., R. 12 W., was produced by the Concho Sand and Gravel Company of Oklahoma City. Between 1930 and the time when the operations were closed, about 1940, the company quarried Nescatunga Gypsum, which was shipped for use as a retarder to the Ideal Portland Cement plant at Ada, Pontotoc County.

The most recent activity in the Prim area was the quarrying in 1957 of anhydrite by the Steelman Construction Company for use as rip-rap to repair the abutments of the bridge across the Cimarron River on State Highway 51 between Okeene and Lacey. Damage had been caused by heavy rains and floods in the spring of 1957, and massive anhydrite from Blaine County was the best rip-rap material available. On state contract the company produced 15,000 tons of anhydrite valued at $44,000. The worked ledge was Nescatunga Anhydrite in C SW¼ NE¼ sec. 26, T. 19 N., R. 12 W. Four to five feet of coarse-crystalline gray anhydrite was worked in an old opening from which the overlying 7 feet of gypsum had been quarried in earlier days.

RESERVES

Gypsum

An enormous amount of gypsum remains to be worked from the three commercial ledges of the Blaine Formation in Blaine County. The total reserve is estimated to be slightly more than 280,000,000 tons, of which 126 million tons is readily available from the Nescatunga ledge, 108 million tons can be economically worked from the Shimer, and 47 million tons is available from the Medicine Lodge (table 6).

The total apparent supply of gypsum in the United States in 1960 was 15.1 million tons, including 9.8 million tons domestically produced and 5.3 million tons imported (McDougal and Jensen, 1961). The reserves in Blaine County could therefore supply the Nation's needs, at the present rate of consumption, for 19 years.

The ratio of worked thickness of gypsum to thickness of overburden in the reserves of Blaine County is 1:2 and in a few places it is as much as 1:3. These ratios are comparable to those in the currently worked deposits.

R. O. Fay made calculations of the workable areas of gypsum in Blaine County, using his original mapping from aerial photographs taken at a scale of 1:20,000 or approximately 3.1 inches per mile. The resulting estimates are believed to have a high order of accuracy, despite a lack of drill information. The pattern of occurrence in the district has been established over a period of 60 years by the production of more than 11 million tons from numerous quarries and mines in each of the three gypsum ledges. The strata are flat lying, and the full thickness of gypsum can be expected under the indicated shale overburden. Where overburden is thicker, the stone is anhydritic and unsuitable for the production of high-grade gypsum.

The workable area of Shimer Gypsum is taken as that curvilinear band between the outcrop trace of the base of the Shimer ledge and the outcrop trace of the overlying Watonga Dolomite, omitting a narrow band at the eroded and locally clay-filled edge of the Shimer (pl. I). For the Nescatunga workable area, the band between its outcrop and the base of the overlying Shimer Gypsum (Altona Dolomite) was used; and for the Medicine Lodge Gypsum, stereoscopic examination of the aerial photographs and a knowledge of the outcrops in the field supplied the essential information.

In all estimates of gypsum reserves made for this report, a value of 140 pounds per cubic foot, or 3,000 tons per acre-foot, has been used.

Anhydrite

No anhydrite is being worked in Blaine County at the present time, but in past years approximately 50,000 tons has been produced for use as rip-rap for bridge abutments. Deposits of durable stone, such as limestone and dolomite, are not present in workable thicknesses in most parts of west-central and northwestern Oklahoma, and anhydrite thus has potential use for construction in this region. The Research Department of the Oklahoma Department of Highways has made investigations of the use of anhydrite as crushed stone for the base course of improved highways, finding no objectionable results in a 3-mile test strip. Anhydrite perhaps will be extensively used for this purpose in future years.

Another possible use for anhydrite is in the manufacture of sulfur and sulfate chemicals. In England much anhydrite is used in the manufacture of ammonium sulfate, sulfuric acid, and portland cement; and in 1956 the consumption of English anhydrite for the manufacture of sulfuric acid alone was 690,000 tons (Groves, 1958, p. 25-27). In the United States, however, anhydrite is not used because native sulfur is available at a cheaper price from salt domes in Louisiana and Texas. When these deposits of native sulfur are exhausted, anhydrite probably will become the major source of this valuable element.

Anhydrite in Blaine County may be of great potential significance, as the reserves are large and can be mined by either surface or underground methods. The principal deposits of anhydrite available to surface mining are in four townships of the county, in a bed 4 to 5 feet thick that occurs in the middle or lower part of the Nescatunga ledge (table 6). The estimated outcrop reserve in this area is 42,000,000 tons. Part of the calculated reserve could be worked in quarries from which the overlying gypsum already has been removed. Both the United States Gypsum Company at Southard and S. A. Walton and Son at Gyp siding have substantial properties of this kind.

TABLE 6.—ESTIMATED RESERVES OF GYPSUM AND ANHYDRITE IN BLAINE COUNTY

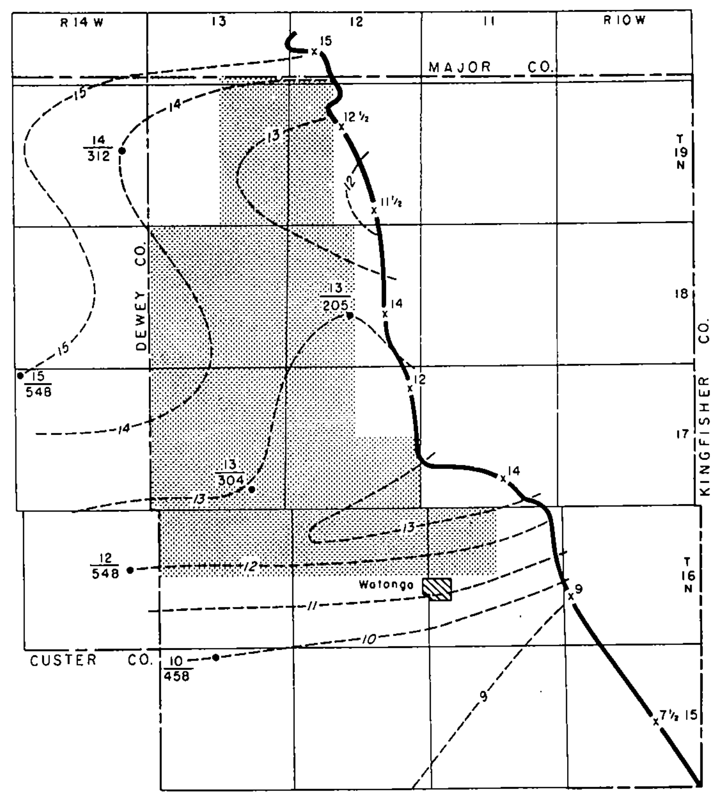
MEMBER OF BLAINE FM.	SURFACE MINING							
	TOWN-SHIP RANGE	WORKABLE THICKNESS (FEET)	SHALE OVERBURDEN (FEET)	WORKABLE AREA (ACRES)	RESERVES (THOUSAND SHORT TONS)	TOTAL GYPSUM (1,000 TONS)	TOTAL ANHYDRITE (1,000 TONS)
Shimer Gypsum	20N—12W	14	0-30, av. 20	15	630		
	19N—12W	14	0-30, av. 20	725	30,450		
	18N—12W	14	0-30, av. 20	500	21,000		
	17N—12W	13*	0-30, av. 20	630	24,570		
	17N—11W	13*	0-30, av. 20	385	15,015		
	16N—10, 11W	11*	0-30, av. 20	490	16,170		
	15N—10W	5*	0-30, av. 20	(625)	(9,375)		
						107,835	
Nescatunga Upper Gypsum	20N—12W	6	0-30, av. 20	40	720		
	19N—12W	6	0-30, av. 20	1,220	21,960		
	18N—12W	6	0-30, av. 20	1,000	18,000		
	17N—12W	5	0-30, av. 20	500	7,500		
						48,180	
Middle Anhydrite	20N—12W	4	—	40	560		
	19N—12W	4	—	1,220	17,080		
	18N—12W	5	—	1,000	17,500		
	17N—12W	4	—	500	7,000		
							42,140
Lower Gypsum	20N—12W	3	—	(40)	(360)		
	19N—12W	3	—	(1,220)	(10,180)		
	18N—12W	2	—	(1,000)	(6,000)		
	17N—12W	4	—	(500)	(6,000)		
						(22,540)	
Massive Gypsum Bed	17N—11W	14†	0-25, av. 18	830	35,000		
	16N—10, 11W	10	0-25, av. 18	850	25,500		
	15N—10W	9	0-25, av. 18	650	17,500		
						78,000	
Medicine Lodge Gypsum	20N—12W	5	0-15, av. 10	85	1,275		
	19N—12W	5	0-15, av. 10	1,060	15,900		
	18N—12W	5	0-15, av. 10	650	9,750		
	17N—12W	5	0-15, av. 10	90	1,350		
	17N—11W	4	0-10, av. 8	610	7,320		
	16N—10, 11W	4	0-10, av. 8	630	7,560		
	15N—10W	3	0-10, av. 8	500	4,500		
						47,655	
GRAND TOTAL						281,670	42,140

*Approximately 1 foot of anhydrite locally present in middle of gypsum bed.

†2 to 4 feet of anhydrite locally present in middle of gypsum bed.

Figures enclosed in parentheses ( ) indicate tonnage that is workable only under special conditions. They are not included in totals.

SUBSURFACE MINING, NESCATUNGA ANHYDRITE							
DISTRIBUTION			DEPTH	THICKNESS	INDICATED TOTAL RESERVES	INDICATED RECOVERABLE RESERVES
	TOWN-SHIP RANGE	SQUARE MILES				
E½	19N—13W	18				
W⅓	19N—12W	12	100	12	29,000,000	(Leaving 2-foot
	18N—13W	36	to	to	tons	roof and 40
W½	18N—12W	18	500	15	per	per cent in
	17N—13W	36	feet,	feet,	square	pillars)
SW¾	17N—12W	27	average	average	mile	15,000,000
N½	16N—13W	18	250	13		tons per
N½	16N—12W	18	feet	feet		square mile
NW¼	16N—11W	9				
Total Square Miles		192			5,500,000,000 tons	2,880,000,000 tons



SUBSURFACE DISTRIBUTION AND THICKNESS OF NESCATUNGA ANHYDRITE IN BLAINE COUNTY

--14-- Line of equal thickness of Nescatunga member; interval = 1 foot

• 13/304 Control well showing thickness in feet of Nescatunga member and drilled depth to its top

Area in which indicated reserves are calculated

x 13 Outcrop trace and measured thickness in feet of Nescatunga member

For purposes of calculation, the weight of rock anhydrite is taken as 175 pounds per cubic foot or 3,500 tons per acre-foot.

The main reserve of anhydrite is available by underground mining. It is contained chiefly in the Nescatunga bed, which in northwestern Blaine County underlies approximately 200 square miles* at a depth range of 100 to 500 feet, and has an average thickness of 13 feet (table 6). Leaving 2 feet of anhydrite in the roof and 40 percent of the remaining 11 feet in the form of pillars for roof support, the Nescatunga contains 15 million tons of recoverable anhydrite per square mile, or 2.9 billion tons in the region of northwestern Blaine County.

In the same region no estimate is made for the subsurface reserves of the Shimer bed because in general it is thinner or contains a middle shale parting, and it probably is workable only in certain areas. Drilling would be needed to show where these areas are.

The reserve of 2.9 billion tons in the Nescatunga alone is ample for any foreseeable need. Moreover, the underground mining of this bed in Blaine County appears to be entirely feasible, either by shaft or adit entry, as the indicated conditions of structural attitude, thickness of seam, depth, and chemical purity are almost identical to those observed by the writer during a visit in 1960 to the anhydrite mines in England.

* The area of Canton Lake, in the W½ T. 19 N., R. 13 W., has not been included in the reserve estimate.

CHEMICAL COMPOSITION

Through a program of outcrop sampling, it has been possible to give a chemical characterization to each of the three worked gypsum beds in Blaine County. The results are summarized in table 7.

Detailed chemical analyses were made in the geochemical laboratory of the Oklahoma Geological Survey, using standard methods of analysis* for the more abundant ions and emission spectrographic methods for the determination of trace elements. J. A. Schleicher made the trace-element studies and performed, supervised, or checked the remaining parts of all analyses. Channel samples were cut from quarries, from natural outcrops in bluff faces of good exposure, from fresh road-cut exposures, and from quarry stockpiles. About 10 to 20 pounds of stone were obtained at each locality by the continuous sampling of the indicated thickness, yielding a reliable and fully representative bulk sample. These samples were then crushed and quartered for chemical analysis.

In terms of chemical purity, samples of gypsum from the Shimer, Nescatunga, and Medicine Lodge ledges are approximately the same, all of them being of high purity and ranging from 96.20 to 98.92 percent theoretical gypsum.

The bed of greatest purity is the Nescatunga, which yields approximately half the current production of gypsum in Blaine County. Three quarry-face samples of this stone average 98.62 percent gypsum, 0.46 percent anhydrite, and 0.67 percent calcium and magnesium carbonates. The extremely low content of silica and alumina show that impurities of clay and quartz silt or sand are almost completely absent. The stone is white or very light gray. It can be calcined to make gypsum products of nearly pure-white color, and accordingly the Nescatunga ledge probably is the most valuable gypsum in Blaine County. Agricultural gypsum containing 98.54 percent $CaSO_4 \cdot 2H_2O$ also is produced from the Nescatunga by S. A. Walton and Son.

The Shimer ledge is almost as pure and is practically as valuable as the Nescatunga. Shimer Gypsum from three localities averages 97.88 percent gypsum, 0.21 percent anhydrite, and 1.45

* A revised method for determining water of crystallization in rock gypsum, described by Schleicher (1960), was used instead of the A. S. T. M. standard method.

percent calcium and magnesium carbonates. From this ledge is produced slightly more than half the Blaine County annual tonnage of gypsum, all of it from quarries of the United States Gypsum Company at Southard, where the white Shimer Gypsum is used for making plasters and wallboard.

Medicine Lodge Gypsum, although not currently worked in Blaine County because its maximum thickness is only 4 feet, has nevertheless been produced in past years in northern Blaine County by S. A. Walton and Son and at Prim. It also was produced in southern Major County by the Lopp Construction Company for rip-rap on the bridge across the Cimarron River at Orienta; and it is being actively worked for agricultural gypsum and road stone in northwestern Canadian County. Channel samples from these three quarries show that the average gypsum content is 96.91 percent and that the principal impurities are calcium and magnesium carbonates.

The detailed chemical analyses show elements in lesser abundance. They reflect the trace mineral content of the gypsum beds in Blaine County, as discussed in the following section on petrology. Strontium in particular is present as the strontium sulfate mineral celestite, in amounts averaging about 0.25 percent. Boron is present both as a minor constituent in the gypsum and as discrete borate minerals.

Chemical analyses of anhydrite from Nescatunga quarries also are given in table 7. Each of the two samples shows 13 to 18.6 percent gypsum, as would be expected from outcrop samples, but impurities such as clay, silt, and carbonates are as low in anhydrite as they are in the gypsum beds to which they have been altered by surface hydration. The subsurface reserves of anhydrite in the Nescatunga ledge, beneath 100 to 500 feet of overburden, probably contain little or no gypsum and presumably will average not less than 98 percent $CaSO_4$. The principal expectable impurities are calcium and magnesium carbonates.

Table 7.—Chemical Analyses of Gypsum and Anhydrite from the Blaine Formation

	SHIMER MEMBER			NESCATUNGA MEMBER					
	Gypsum			Gypsum				Anhydrite	
Laboratory number	10336	10365	10364	10337	10339	10340	10342	10338	10105
Sample description	Massive bed of white and gray gypsum from active quarry face.	Massive bed of fine-grained white-and-gray mottled gypsum from ledge outcrop	Massive bed of fine-grained white-and-gray mottled gypsum from road cut	Massive bed of white and gray gypsum from active quarry face	Massive bed of white to light-gray gypsum from active quarry face.	Massive bed of white to light-gray gypsum from active quarry face.	-½-inch agricultural gypsum from stockpile	Massive bed of mottled gray anhydrite, medium-to coarse-crystalline. Underlies 7.5 feet of gypsum. Inactive quarry.	Massive bed of light-gray coarse-crystalline anhydrite from inactive quarry
Locality	U. S. Gypsum Company NE¼ SE¼ NE¼ 22-18N-12W Southard, Blaine County	NW¼ SE¼ SW¼ 12-17N-12W Blaine County	North side of Okla. Hwy. 33, 7 mi. east of Watonga SW¼ SW¼ SW¼ 19-16N-10W Blaine County	Keenes quarry, U. S. Gypsum Company SW¼ SE¼ NW¼ 11-18N-12W Southard, Blaine County	Universal Atlas Company Cen. SW¼ 27-17N-11W Bucher siding, Blaine County	S. A. Walton and Son SW¼ SE¼ NW¼ 35-19N-12W Gyp siding, Blaine County	same as 10340	U. S. Gypsum Company SW¼ NW¼ NW¼ 14-18N-12W Southard, Blaine County	Old site of Prim Cen. SW¼ NE¼ 26-19N-12W Blaine County
Collector and date	Ham and Fay, 7-19-58	Ham and Fay, 10-6-59	Ham and Fay, 10-6-59	Ham and Fay, 7-19-58	Ham and Fay, 7-21-58	Ham and Fay, 7-22-58	Ham and Fay, 7-22-58	Ham and Fay, 7-19-58	W. E. Ham, 8-22-53
Thickness of channel sample (feet)	13.5	14	11	7.5	15	7	---	5	5
Analyst	J. A. Schleicher & Ralph Slate	J. A. Schleicher	J. A. Schleicher	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	T. E. Hamm & J. A. Schleicher
SiO_2	0.14	0.12	0.16	0.03	0.08	none	0.61	0.06	0.10
Al_2O_3	0.23	0.08	0.06	0.12	0.17	0.10	0.28	0.14	0.15
Fe_2O_3	0.01	0.043	0.046	0.01	trc.	none	0.03	none	0.03
CaO	32.33	32.75	32.51	32.54	32.65	32.67	32.21	40.01	39.73
SrO	0.16	0.16	0.17	0.18	0.13	0.13	0.15	0.19	0.12
BaO	none det.	none det.	none det.	none det.	none det.	none det.	none det.	0.0021	0.0027
MgO	0.34	0.30	0.16	0.13	0.20	none	0.04	0.14	trc.
SO_3	45.90	45.39	45.75	46.32	45.80	46.30	46.02	56.50	56.27
B_2O_3	<0.003	0.0037	0.0035	<0.003	0.0035	<0.003	0.0042	0.0106	0.013
CO_2	0.37	0.99	0.69	0.27	0.56	0.11	0.15	0.17	0.16
H_2O(+40° C)	20.60	20.35	20.50	20.65	20.56	20.70	20.62	2.74	3.89
Na	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cl	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Cu	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Cr	none	0.0005	0.0005	--	--	--	--	--	--
Mn	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Total	100.08	100.19	100.05	100.25	100.15	100.04	100.11	99.96	100.48
Calculated components									
$CaSO_4 \cdot 2H_2O$(gypsum)	98.44	97.25	97.96	98.68	98.25	98.92	98.54	13.09	18.59
$CaSO_4$ (anhydrite)	0.33	0.30	---	0.53	0.29	0.57	0.05	85.84	81.04
$SrSO_4$	0.28	0.30	0.30	0.32	0.23	0.23	0.27	0.34	0.21
$BaSO_4$	---	---	---	---	--	--	--	0.003	0.004
$CaCO_3$	---	1.50	1.18	0.30	0.77	0.25	0.23	0.05	0.36
$MgCO_3$	0.71	0.63	0.33	0.27	0.42	--	0.09	0.29	trc.
SiO_2	0.14	0.12	0.16	0.03	0.08	--	0.61	0.06	0.10
R_2O_3	0.24	0.12	0.11	0.13	0.17	0.10	0.31	0.14	0.18
Total	100.14	100.22	100.04	100.26	100.21	100.07	100.10	99.81	100.48

	MEDI
Laboratory number	10341
Sample description	Massive bed of white and light-gray gypsum from inactive quarry
Locality	S. A. Walton and Son Cen. N line NW¼ SE¼ 35-1 Gyp. siding, Blaine County
Collector and date	Ham and Fay, 7-22-58
Thickness of channel sample (feet)	4
Analyst	J. A. Schleicher & Ralph S
SiO_2	0.09
Al_2O_3	0.26
Fe_2O_3	0.02
CaO	32.52
SrO	0.19
BaO	none det.
MgO	0.18
SO_3	45.95
B_2O_3	<0.001
CO_2	0.46
H_2O(+40° C)	20.37
Na	<0.0005
Cl	0.0005
Cu	0.0005
Cr	---
Mn	0.0005
Total	100.04
Calculated components	
$CaSO_4 \cdot 2H_2O$(gypsum)	97.34
$CaSO_4$ (anhydrite)	1.04
$SrSO_4$	0.34
$BaSO_4$	---
$CaCO_3$	0.59
$MgCO_3$	0.38
SiO_2	0.09
R_2O_3	0.28
Total	100.06

TABLE 7. — CHEMICAL ANALYSES OF GYPSUM AND ANHYDRITE FROM THE BLAINE FORMATION

EMBER		NESCATUNGA MEMBER						MEDICINE LODGE MEMBER			
n		Gypsum				Anhydrite		Gypsum			
	10364	10337	10339	10340	10342	10338	10105	10341	10366	10367	Laboratory number
ined ypsum	Massive bed of fine-grained white-and-gray mottled gypsum from road cut	Massive bed of white and gray gypsum from active quarry face	Massive bed of white to light-gray gypsum from active quarry face.	Massive bed of white to light-gray gypsum from active quarry face.	-¼-inch agricultural gypsum from stockpile	Massive bed of mottled gray anhydrite, medium-to coarse-crystalline. Underlies 7.5 feet of gypsum. Inactive quarry.	Massive bed of light-gray coarse-crystalline anhydrite from inactive quarry	Massive bed of white and light-gray gypsum from inactive quarry	Interlayered white and gray fine-grained gypsum from inactive quarry	White-and-pink mottled alabaster from active quarry	Sample description
2W	North side of Okla. Hwy. 33, 7 mi. east of Watonga SW¼ SW¼ SW¼ 19-16N-10W Blaine County	Keenes quarry, U. S. Gypsum Company SW¼ SE¼ NW¼ 11-18N-12W Southard, Blaine County	Universal Atlas Company Cen. SW¼ 27-17N-11W Bucher siding, Blaine County	S. A. Walton and Son SW¼ SE¼ NW¼ 35-19N-12W Gyp siding, Blaine County	same as 10340	U. S. Gypsum Company SW¼ NW¼ NW¼ 14-18N-12W Southard, Blaine County	Old site of Prim Cen. SW¼ NE¼ 26-19N-12W Blaine County	S. A. Walton and Son Cen. N line NW¼ SE¼ 35-19N-12W Gyp. siding, Blaine County	Lopp Construction Company SW¼ NW¼ NW¼ 21-20N-12W Major County	S½ SW¼ SE¼ 2-14N-8W Canadian County	Locality
	Ham and Fay, 10-6-59	Ham and Fay, 7-19-58	Ham and Fay, 7-21-58	Ham and Fay, 7-22-58	Ham and Fay, 7-22-58	Ham and Fay, 7-19-58	W. E. Ham, 8-22-53	Ham and Fay, 7-22-58	Ham and Fay, 10-6-59	Ham and Fay, 10-6-59	Collector and date
	11	7.5	15	7	---	5	5	4	6	3	Thickness of channel sample (feet)
	J. A. Schleicher	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	J. A. Schleicher & Ralph Slate	T. E. Hamm & J. A. Schleicher	J. A. Schleicher & Ralph Slate	J. A. Schleicher	J. A. Schleicher	Analyst
	0.16	0.03	0.08	none	0.61	0.06	0.10	0.09	0.13	0.10	SiO_2
	0.06	0.12	0.17	0.10	0.28	0.14	0.15	0.26	0.11	0.11	Al_2O_3
	0.046	0.01	trc.	none	0.03	none	0.03	0.02	0.043	0.034	Fe_2O_3
	32.51	32.54	32.65	32.67	32.21	40.01	39.73	32.52	32.56	32.59	CaO
	0.17	0.18	0.13	0.13	0.15	0.19	0.12	0.19	0.15	0.17	SrO
	none det.	none det.	none det.	none det.	none det.	0.0021	0.0027	none det.	none det.	none det.	BaO
	0.16	0.13	0.20	none	0.04	0.14	trc.	0.18	0.16	0.36	MgO
	45.75	46.32	45.80	46.30	46.02	56.50	56.27	45.95	45.56	45.40	SO_3
	0.0035	$<$ 0.003	0.0035	$<$ 0.003	0.0042	0.0106	0.013	$<$ 0.001	0.003	$<$ 0.001	B_2O_3
	0.69	0.27	0.56	0.11	0.15	0.17	0.16	0.46	1.04	1.22	CO_2
	20.50	20.65	20.56	20.70	20.62	2.74	3.89	20.37	20.34	20.13	H_2O(+40° C)
	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	$<$ 0.0005	Na
	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	Cl
	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	Cu
	0.0005	--	--	--	--	--	--	---	0.0005	0.0005	Cr
	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	Mn
	100.05	100.25	100.15	100.04	100.11	99.96	100.46	100.04	100.09	100.11	Total
											Calculated components
	97.96	98.68	98.25	98.92	98.54	13.09	18.59	97.34	97.20	96.20	$CaSO_4 \cdot 2H_2O$(gypsum)
	---	0.53	0.29	0.57	0.05	85.84	81.04	1.04	--	0.70	$CaSO_4$ (anhydrite)
	0.30	0.32	0.23	0.23	0.27	0.34	0.21	0.34	0.28	0.31	$SrSO_4$
	---	---	--	--	--	0.003	0.004	---	--	--	$BaSO_4$
	1.18	0.30	0.77	0.25	0.23	0.05	0.36	0.59	1.98	1.89	$CaCO_3$
	0.33	0.27	0.42	--	0.09	0.29	trc.	0.38	0.33	0.75	$MgCO_3$
	0.16	0.03	0.08	--	0.61	0.06	0.10	0.09	0.13	0.10	SiO_2
	0.11	0.13	0.17	0.10	0.31	0.14	0.18	0.28	0.15	0.14	R_2O_3
	100.04	100.26	100.21	100.07	100.10	99.81	100.48	100.06	100.07	100.09	Total

PETROLOGY

The gypsum-anhydrite beds of Blaine County were originally deposited as evaporation products of desiccating Middle Permian epicontinental seas that covered the western third of Oklahoma. Studies in southwestern Oklahoma, which are applicable as well to Blaine County, show a cyclic division of the Blaine Formation into four evaporite units. They occur in the marginal parts of a much broader and longer basin that extended from Kansas through Oklahoma and Texas into southeastern New Mexico (Ham, 1960). These basin-margin evaporites grade into thicker carbonate rocks of the basin center, located in southwestern Texas and bordering parts of New Mexico. All the strata are of marine origin. The carbonate beds, and locally even the gypsum beds, contain a fauna dominated by clams and cephalopods (Clifton, 1942).

Gypsum is a normal evaporation product of marine water. It can easily be precipitated by evaporating sea water to 19 percent of its original volume (Clarke, 1924, p. 220). Common salt (NaCl) also begins to precipitate when the original volume has been reduced to 5 percent. About 0.4 foot of gypsum can be formed from 1,000 feet of sea water, and thus a bed of gypsum 15 feet thick would require a column of water 37,500 feet thick. As the water depth during Blaine time in Blaine County probably was never more than 50 to 200 feet, and as salt occurs only in traces, it follows that there was a constant reflux of waters from the open ocean in the New Mexico area, bringing in calcium sulfate and at the same time taking away salt. Reflux action of this type is a plausible mechanism to explain the origin of the Blaine County evaporites.

The petrology of the evaporite beds deals mainly with two mineral species—gypsum and anhydrite—and with their interrelations as they occur separately in massive beds, or together within the same bed. The studies to date indicate that the rock gypsum of the present-day outcrops has undergone a complex history, all of it having been derived from anhydrite, and much of it having passed through three stages of crystallization. The principal minerals of the gypsum beds are gypsum, residual anhydrite, celestite, dolomite, calcite, and certain borates. The anhydrite and dolomite are inherited from anhydrite beds, but all other minerals are of secondary or epigenetic origin.

The anhydrite itself, which occurs as widely distributed beds in subsurface, also has passed through three stages of crystallization before being transformed at the surface into gypsum. It is not at all certain that the anhydrite is a primary precipitate from sea water, and indeed it appears probable that the original precipitate was gypsum ($CaSO_4 \cdot 2H_2O$) or hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$). If so, the anhydrite is a second-cycle rock and the outcropping gypsum is a product of the third cycle; accordingly no rock seen today portrays its original character.

GYPSUM, $CaSO_4 \cdot 2\,H_2O$

The gypsum beds of the Shimer, Nescatunga, and Medicine Lodge Members are virtually identical in character and origin; and, as expected from their chemical analyses, they consist almost exclusively of the mineral gypsum. Through a study of thin sections and polished surfaces, it has been established that three growth stages are present in most beds at most localities.

Figure 44. Porphyroblastic Shimer Gypsum. Dark subcircular areas, some showing a central core of different color, are single-crystal porphyroblasts of selenite that contain abundant inclusions of anhydrite and represent the first stage in the gypsification of rock anhydrite (G-1). The main body of the rock is white fine-grained alabaster and represents stage 2 (G-2), in which no anhydrite is preserved. Dark irregular seams are subparallel to bedding; they consist of crystallized gypsum natural size.
of stage 3 (G-3). Polished specimen from quarry of U. S. Gypsum Co., Southard,

The most abundant form is a fine-grained mosaic of anhedral grains, which typifies the familiar alabaster of the quarries. Examples of polished surfaces of alabaster are shown in figures 44 and 45, respectively from the Shimer and Medicine Lodge beds, but the same type of rock is abundant as well in the Nescatunga. The alabaster is composed of crystalloblastic grains about 20 to 50 microns (0.0008 to 0.002 inch) in dimeter, as shown in plate V-A, B and plate VIII-E, F. Locally the grains have been increased by incipient recrystallization to about 150 microns in diameter (pl. V-E). Here designated as the second gypsum stage or G-2, this alabaster is in many places a direct conversion from anhydrite. It most commonly occurs near or in contact with anhydrite rock, having bypassed the stage of locally formed early selenite porphyroblasts, here called G-1.

The G-1 stage is the earliest gypsum formed from anhydrite in Blaine County. It consists of coarsely crystallized selenite that apparently sprouted from isolated centers with the first penetration of surface waters into the buried anhydrite. Selenite crystals of this stage generally occur as widely scattered porphyroblasts, 0.5

Figure 45. Porphyroblastic Medicine Lodge Gypsum. High-purity alabaster (G-2) contains non-anhydritic porphyroblasts of euhedral selenite crystals (G-3). For photomicrographs see plate V-A, B. Polished specimen from quarry of S. A. Walton and Son, x1.5.

to 1 inch in diameter. They are easily recognized by inclusions within them of numerous residual anhydrite grains (pl. VII-A, B), which evidently were preserved because the selenite crystals grew rapidly and thereby excluded further penetration by water. As now seen, these earliest porphyroblasts are surrounded by finer grained rock gypsum, and their present irregular outline is partly the result of replacement by the surrounding alabaster (fig. 44, pl. V-F). Selenite of the G-1 stage is present locally as crystal aggregates arranged in the form of rosettes (fig. 46). These porphyroblastic clusters and single crystals are as much as 2 inches (5.1 cm) in diameter, and they are embedded either in the compact alabaster of stage G-2 or in the late selenitic stage of G-3.

The writer has collected precisely the same type of single-crystal anhydrite-containing selenite porphyroblasts in Permian anhydrite at depths of 400 to 800 feet in the mines of Imperial Chemical Indistries, Ltd., at Billingham, Durham, England, and in Jurassic (Purbeckian) anhydrite at depths of 150 to 800 feet in the mines of Gypsum Mines, Ltd., at Mountfield, Sussex, England.

About half the gypsum of the Nescatunga, and considerably

EXPLANATION OF PLATE V

Pohomicrographs showing textures and fabrics of Blaine Gypsum

A. Field of euhedral selenite crystals (G-3) in fine-grained alabaster (G-2). Large crystal at left is 1.7 mm long. Medicine Codge Gypsum, Walton quarry. Plain light, thin section 973.

B. Porphyroblastic selenite crystal, 0.9 mm long, embedded in fine-grained crystalloblastic gypsum mostly 20 to 50 microns in diameter. Crossed nicols, thin section 973.

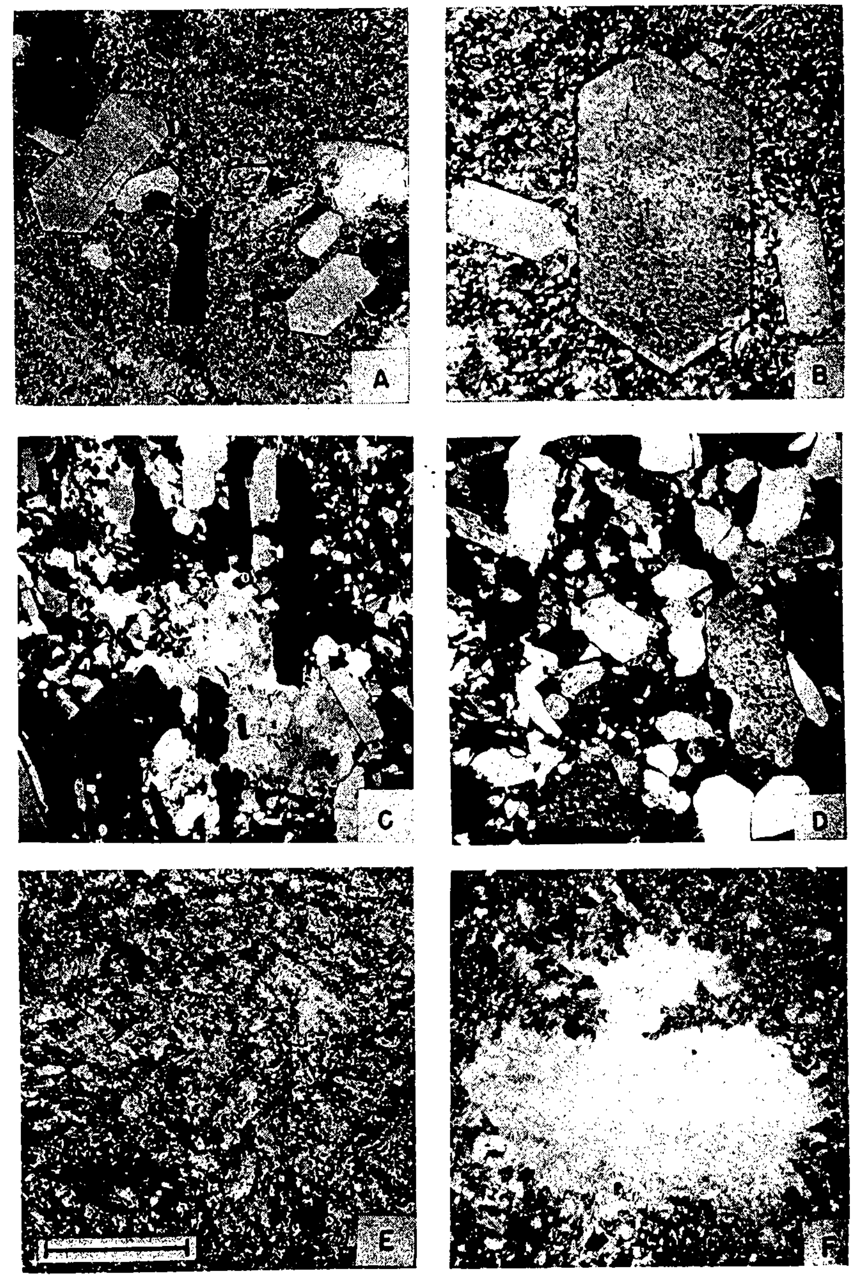
C. Fabric of recrystallized high-purity gypsum, lower part of Nescatunga, quarry of U. S. Gypsum Co. Irregular white area at lower center, with numerous small inclusions, is a single anhydritic porphyroblast of gypsum representing first stage in gypsification of anhydrite (G-1). Second stage is shown by equidimensional surrounding grains (G-2). Large subhedral crystals, with vertical orientation normal to bedding, cut across earlier fabric and represent last stage of gypsum formation (G-3). The field is 2.8 mm across. Crossed nicols, thin section 962.

D. Same, showing panidiomorphic development of gypsum grains of stage G-2. Euhedron in center is 0.15 mm long.

E. Crystalloblastic gypsum grains (G-2) about 0.15 mm in diameter, showing incipient recrystallization from anhedral mosaic. Upper part of Nescatunga, quarry of U. S. Gypsum Co. Bar scale is 1.0 mm. Crossed nicols, thin section 964.

F. Early porphyroblast of selenite (white central area) surrounded by younger fine-grained gypsum. Shimer Member, quarry of U. S. Gypsum Co. The porphyroblast represents stage G-1 and is a single crystal 4.5 mm long. It contains numerous residual anhydrite grains, which are lacking from the surrounding gypsum of stages G-2 and G-3. The porphyroblast has been partly embayed and destroyed by recrystallization. Crossed nicols, thin section 968.

Plate V



less than half of the Shimer, is made of medium-textured panidiomorphic selenite which characterizes the latest period of crystal growth. This stage is here designated G-3. Owing to its recrystallization, a broken surface of G-3 gypsum reflects pin-points of light from diversely oriented cleavage faces (fig. 47). In part the bedding is crudely defined by elongate solution pits, commonly lined with brilliant euhedral crystals of selenite; and, in part, bedding

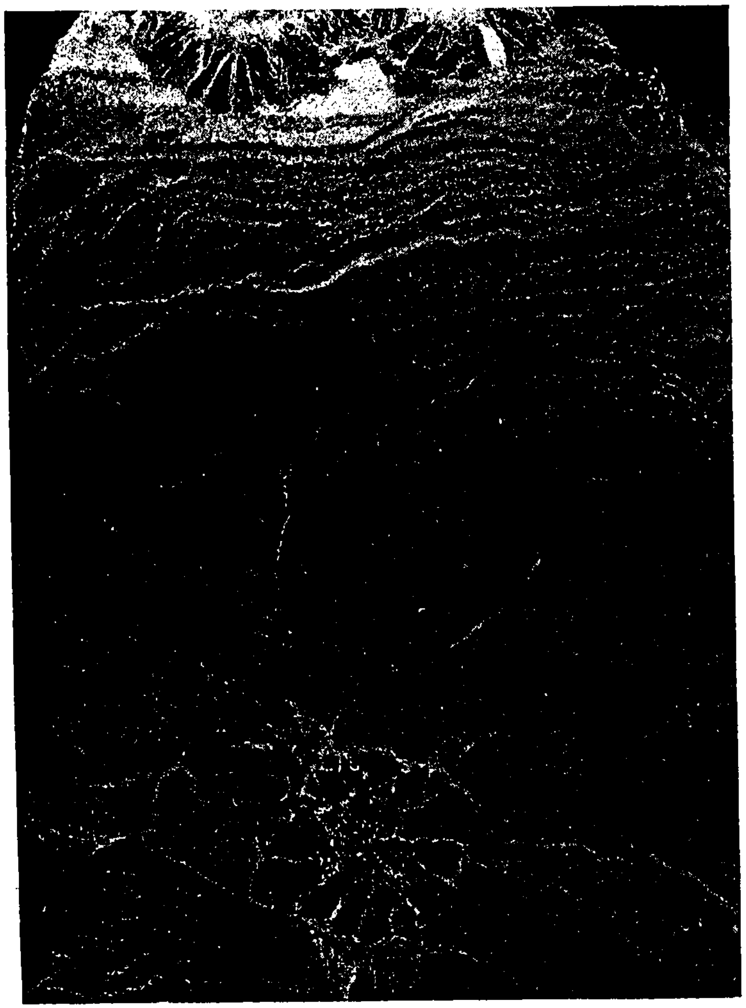


Figure 46. Crystalline-textured Nescatunga Gypsum containing selenite rosettes of an early generation. The rosettes are filled with small grains of residual anhydrite. Polished surface of specimen from U. S. Gypsum Co., natural size.

is shown by parallel alternating bands of medium-textured and fine-textured selenite (fig. 46). Generally the texture of stage G-3 is inequigranular. The earlier formed panidiomorphic grains have a diameter of 0.10 to 0.20 mm (pl. V-D) and contain younger subhedral gypsum crystals about 1 mm long, which have grown normal to bedding and have incorporated some of the panidiomorphic grains. Plate V-C shows these relations and also illustrates how the selenitic gypsum of stage G-3 replaces anhydritic porphyroblasts of G-1.

Whereas stage G-1 represents the growth of gypsum porphyroblasts in anhydrite rock, the porphyroblasts invariably showing this time-and-space relation by containing residual anhydrite inclusions, there is a corresponding but much younger growth of gypsum porphyroblasts in rock gypsum. They can be distinguished by their euhedral form and the absence within them of anhydrite inclusions, and they are most conspicuously developed in the alabaster of G-2 (pl. V-A, B). Such porphyroblasts are assigned to stage G-3,

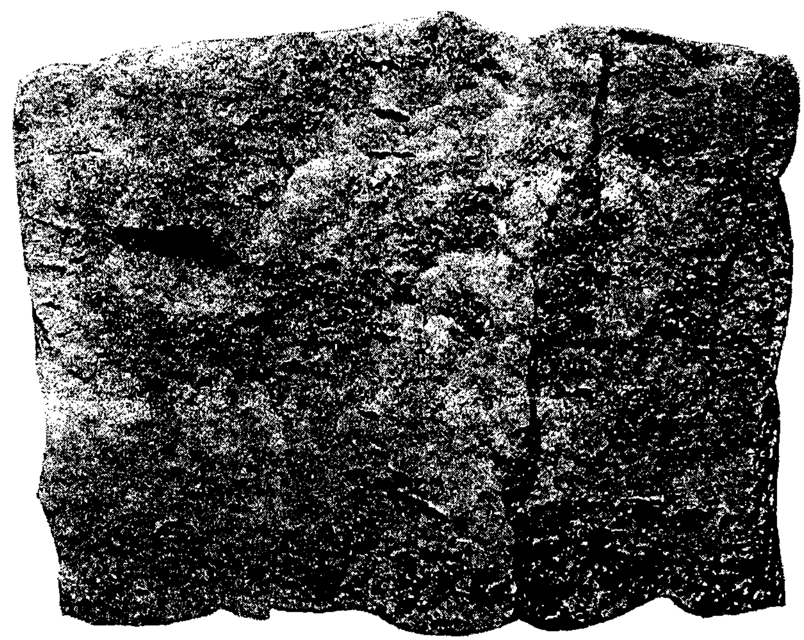


Figure 47. Coarse-textured Nescatunga Gypsum, typical of high-purity stone quarried by three companies in Blaine County. It is made up of selenite grains, as shown by photomicrographs in plate V-C, D. Elongate open cavities lie parallel to bedding. The specimen is 7 inches (18 cm) long.

as they probably originated in the alabaster beds at the same time that associated beds were being recrystallized to the G-3 stage.

The youngest gypsum in the Blaine Formation of Blaine County is that which cuts across all fabrics in the form of thin irregular seams, or occurs as transparent euhedral crystals on the walls of cavities and caves (fig. 48). Both are in process of forming at the present time, although neither form is conspicuously abundant and therefore does not play an important role in the petrology of the deposits. This type of gypsum occurrence is regarded as the last phase of stage G-3.

In many respects the textures and fabrics of Blaine County gypsum are analagous to those of certain metamorphic and igneous rocks. Euhedral selenite in alabaster is comparable to the porphyroblasts of schists; the anhedral interlocking grains of alabaster are like crystalloblastic grains in hornfels; and the panidiomorphic gypsum of the ideal G-3 stage is virtually identical to quartz-feldspar grains of aplite and alaskite dikes.

All lines of petrologic and field evidence converge at a common conclusion—that the gypsum of the outcrop has been derived by the hydration of anhydrite at shallow depth or at the ground sur-

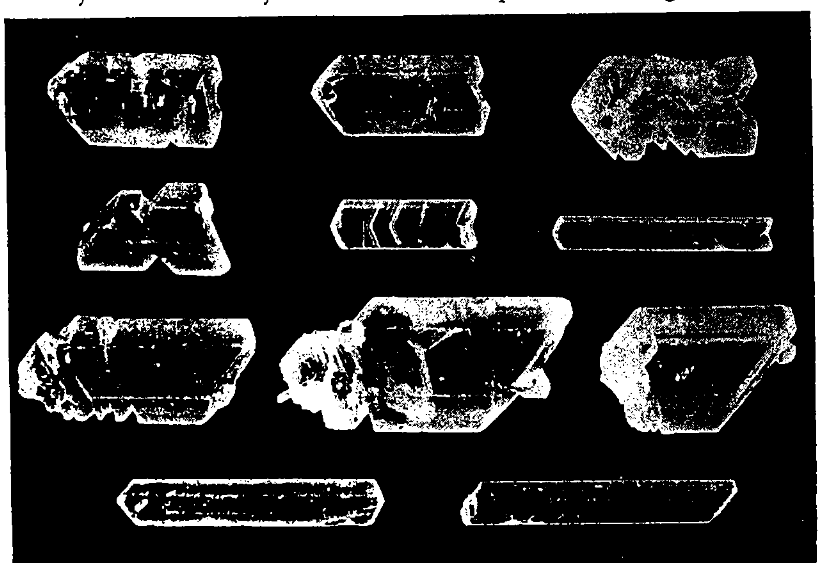


Figure 48. Euhedral selenite crystals. Swallow-tail twins are shown in upper two lines. From a cave in Shimer Gypsum encountered while working in an underground mine about 1940, U. S. Gypsum Co., Southard, x0.85.

face. First, anhydrite but not gypsum occurs at depth. Under more than just 30 feet of shale overburden, gypsum producers begin to encounter objectionable amounts of anhydrite, generally in the form of anhydrite lenses, 1 to 4 feet thick, in the middle part of the gypsum bed. The thickness of anhydrite then increases in proportion to the thickness of covering strata; and in some parts of western Oklahoma, as shown by cuttings and cores, the rock is entirely anhydrite at a depth as shallow as 40 feet. Some gypsum occurs locally at greater depth, generally in those localities where ground waters have circulated along fractures or faults, but normally at a depth of 400 feet and greater there is only anhydrite.

A few irregular lenses and thin beds of anhydrite persist even in outcrops, where they are covered by no more than a foot or two of protecting beds. Here, at the present time, anhydrite is being converted slowly into gypsum and contains 15 to 35 percent of this mineral as scattered replacement grains. A residual lens of rock anhydrite, enclosed within alabaster, is illustrated in figure 49; and a photomicrograph of the interlayered gypsum-anhydrite contact from a quarry, showing the occurrence of gypsum seams

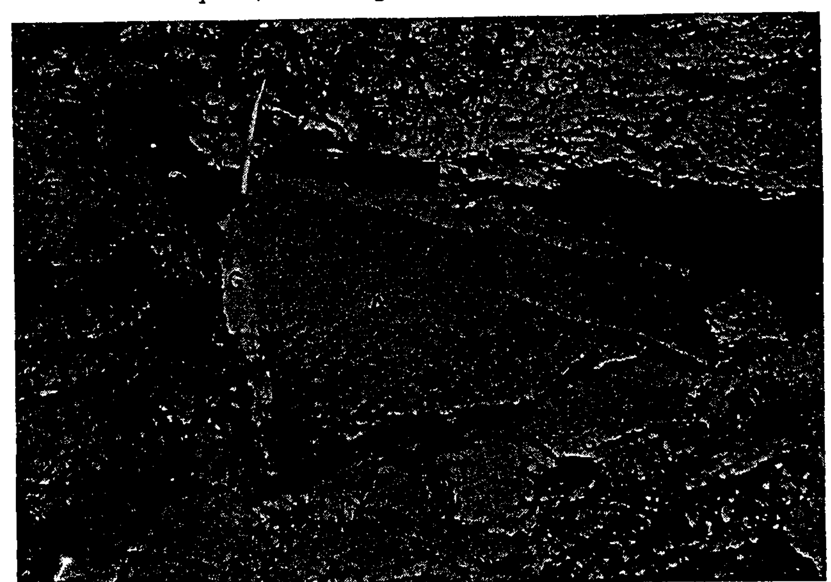


Figure 49. Residual anhydrite mass (A) in gypsum (G), Nescatunga Member, abandoned quarry in C SW¼ NE¼ sec. 26, T. 19 N., R. 12 W. Nearly vertical contact below hammer head originated by gypsification along joint surface.

transecting anhydrite, is shown in plate VII-F. Furthermore it is not uncommon to find veins of rock gypsum 1 to 2 inches wide cutting across beds of anhydrite, as is well shown in the anhydrite quarry at Prim, C SW¼ NE¼ sec. 26, T. 19 N., R. 12 W.

A further petrologic evidence indicating that anhydrite is replaced by gypsum, and therefore is older, is given by the anhydrite-containing porphyroblasts discussed above as stage G-1. The early anhydrite is replaced, commonly along grain boundaries and cleavage cracks, but the process has not gone to completion and certain optically continuous anhydrite fragments remain. Little or no evidence of a volume change during the hydration and replacement process was observed in the petrologic examination, and the author concurs with the conclusions of Muir (1934) that gypsum has replaced anhydrite generally without change of volume.

Trace minerals in the gypsum beds (detrital quartz, dolomite, residual anhydrite) either have been inherited from the anhydrite parent or have grown by epigenetic crystallization in the gypsum itself (celestite, borate minerals, thenardite), deriving the essential constituents from the earlier anhydrite.

Anhydrite, $CaSO_4$

Light-gray anhydrite, mostly of medium-crystalline texture and generally having the appearance of marble, is a common rock in the evaporite beds of the Blaine Formation. In time of origin, it precedes the formation of outcropping gypsum beds. An anhydrite bed, 1 to 7 feet thick, is present in the middle or lower part of the Nescatunga Member in outcrops through approximately the northern half of Blaine County, but anhydrite is absent from Nescatunga outcrops elsewhere and is generally absent from outcropping Shimer and Medicine Lodge Gypsums in all parts of the county. Thin beds of anhydrite appear, however, in Nescatunga and Shimer Gypsum quarries (figs. 13, 16), particularly where thick shale overburden has been removed. All the beds that crop out as gypsum are composed in subsurface of anhydrite.

A few subsurface cores of Blaine anhydrite are available from widely separated parts of western Oklahoma. They show substantially the same mineralogy, texture, and fabric as outcropping anhydrite, with the exception that halite is present in small amounts in the Nescatunga of southwestern Blaine County (pl. VI-E) and

as thick beds above the horizon of the Shimer in Beckham County, in southwestern Oklahoma (Jordan, 1959). Salt is absent from outcropping beds, the small amount originally present having been dissolved by the leaching action of ground waters. An additional difference is that gypsum, which is conspicuously present as small replacing masses and seams in outcropping anhydrite, is absent in subsurface.

It has also been observed in subsurface cores that coarsely crystallized anhydrite occurs as the cement between grains in dolomite beds underlying anhydrite, whereas on the outcrop these dolomite beds are highly porous and have lost their sulfate mineral cement by the leaching action of surface waters.

A mosaic of anhedral grains, mostly 30 to 50 microns in diameter, is the earliest stage of anhydrite formation and is designated A-1. Subsurface cores and outcrop samples alike show a particularly good development of this stage, as well as the transection of the first-formed fine-grained anhydrite by anastamosing irregular masses of the medium-crystalline anhydrite which characterizes stage A-2. Stage A-2 normally consists of blocky anhydrite grains about 0.25 to 0.5 mm in diameter, a part of the grains incorporat-

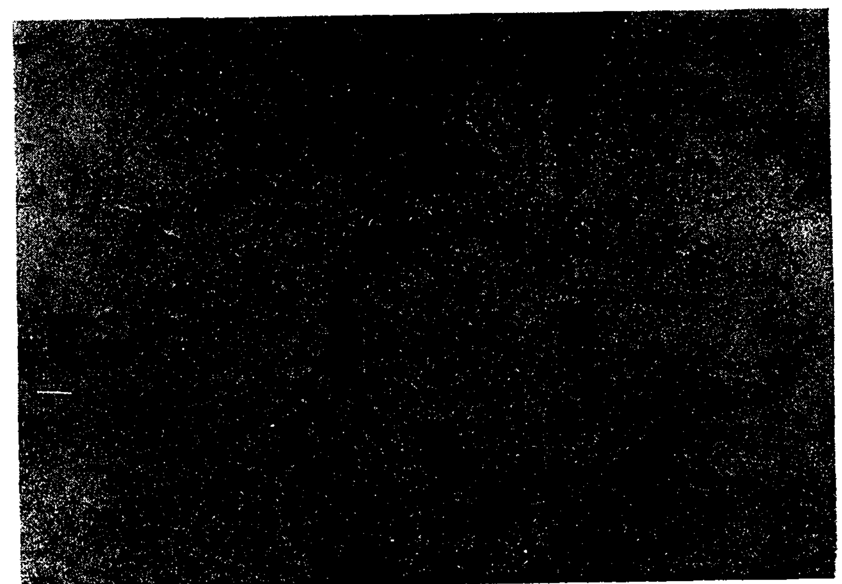


Figure 50. Massive rock anhydrite from bed 7 feet thick below Nescatunga Gypsum. Polished specimen, Walton quarry, x1.2.

ing fine-grained anhydrite of the first stage and thus showing clearly the time relations between them. The third and youngest stage, A-3, is marked by the growth of anhydrite blades, occurring as a felt of randomly oriented coarse fibers, as blades that grow perpendicularly from the walls of cavities, or in the form of radial-fibrous rosettes. Observed rosettes are as much as 2 mm in diameter, and their component blades cut cleanly across the blocky grains of the second stage. The three stages of anhydrite crystallization, the typical inequigranular texture, and the normal fabric patterns are illustrated in plate VI. Plate VI-E shows halite in anhydrite from a core taken between 464 and 468 feet in southwestern Blaine County. The coarsely recrystallized halite fills old cavities, the walls of which are lined with subhedral anhydrite blades that have grown outward from a host rock of fine-grained anhydrite.

A polished surface of characteristic Blaine anhydrite is illustrated in figure 50. The mottled appearance is typical. White to very light-gray areas are made up of 30-micron grains (A-1) and contain about 25 percent of blocky 350-micron grains (A-2). Darker cross-cutting areas are clusters of blocky grains together with radial-fibrous aggregates or rosettes (A-3). Thin-section studies indicate that about 15 percent of the rock is gypsum in the

EXPLANATION OF PLATE VI

Photomicrographs of anhydrite, anhydrite-halite, and dolomite from Blaine Formation

A. Anhydrite at base of Nescatunga Gypsum, quarry of U. S. Gypsum Co. Fine-grained early anhydrite (A-1) with later blocky crystals of anhydrite (A-2). Dolomite rhombohedron of high relief at left. Bar scale is 0.5 mm. Plain light, thin section 966.

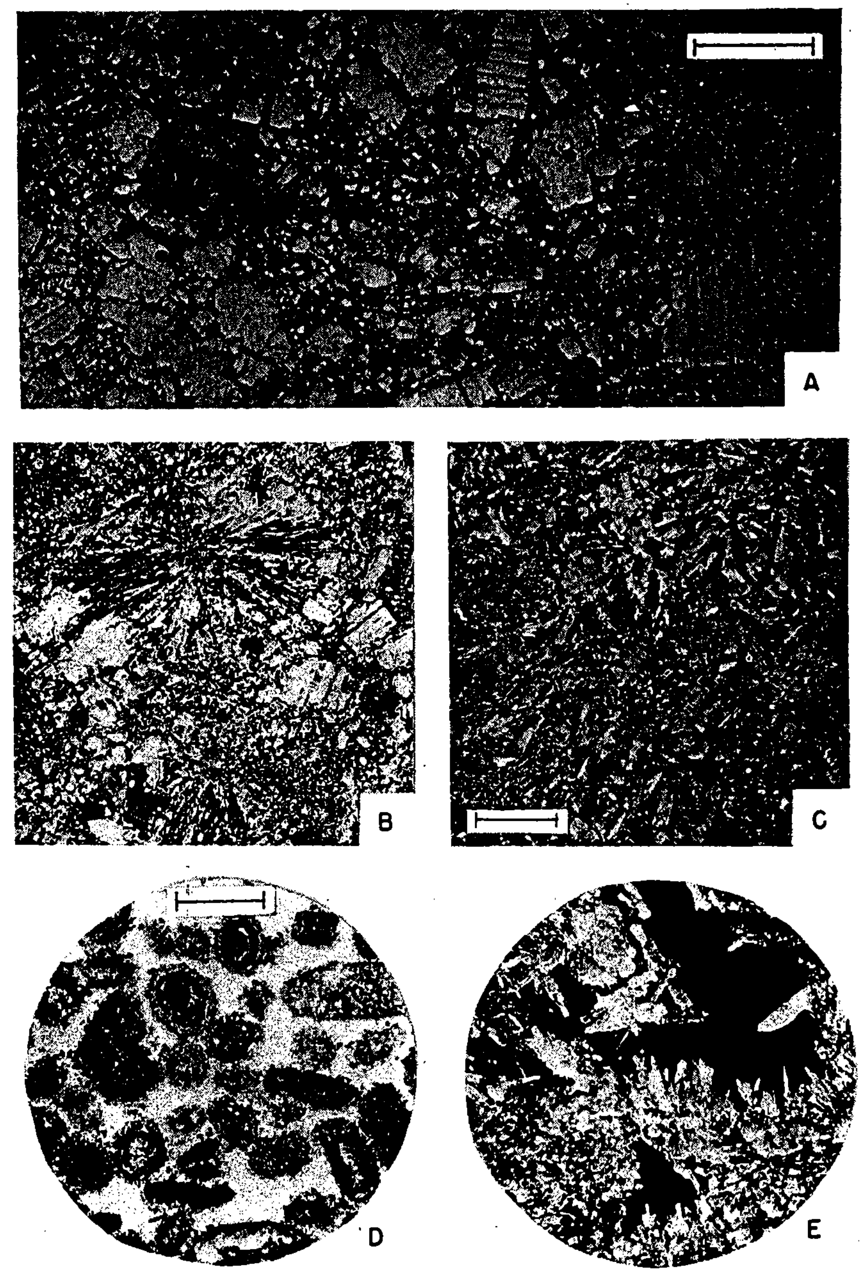
B. Fine-grained anhydrite of first stage (A-1), blocky crystals of second stage (A-2), and bladed rosettes of youngest stage (A-3). Rosette is 1.5 mm in long diameter. Crossed nicols, thin section 966.

C. Recrystallized coarse-bladed anhydrite from Nescatunga Member, abandoned quarry in C SW¼ NE¼ sec. 26, T. 19 N., R. 12 W. Bar scale is 1.0 mm. Crossed nicols, thin section 831.

D. Oölitic Magpie Dolomite at base of Nescatunga Member. Concentrically banded dolomitized oöids occur with flattened and subrounded dolomite rock fragments. Clear anhydrite fills interstitial voids. The bar scale is 0.5 mm. Sunray Mid-Continent No. 1 Baker relief well, depth 471-472 feet. Crossed nicols, thin section 984.

E. Anhydrite-halite rock, Nescatunga Member, Baker relief well, depth 464-468 feet. Recrystallized bladed anhydrite has grown from walls into cavities now filled with halite (black). The coarse blade at upper right is 0.35 mm long. Crossed nicols, thin section 982.

Plate VI



form of thin veinlets and irregular patches, not discernible in the photograph.

Dolomite is the most abundant accessory mineral in anhydrite beds of the Blaine Formation. Where gypsum has not been formed by hydration at or near the ground surface, dolomite is the only accessory constituent recognizable in the anhydrite beds. It normally makes up 1 to 2 percent of the rock. Notable amounts of boron and strontium are present in the anhydrite (table 7). They are released during the gypsification process and are concentrated as borate minerals and as celestite in the resulting gypsum.

The problem of whether the anhydrite beds were precipitated directly from the Permian sea water, or whether they passed through a primary stage of gypsum or hemihydrite, is discussed in the concluding paragraphs of this section.

Dolomite, $CaMg(CO_3)_2$

Dolomite is commonly associated with sulfate evaporites. In the Blaine Formation of western Oklahoma, beds of dolomite 1 to 8 feet thick normally underlie gypsum or anhydrite in a well-defined cyclic pattern (Ham, 1960, p. 144-149). In Blaine County these basal dolomite beds are about 1 foot thick and are best developed as the Altona Dolomite beneath the Shimer, and the Magpie

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Explanation of Plate VII

Photomicrographs of anhydrite, dolomite, and quartz in gypsum of Blaine Formation

A. Shimer Gypsum, quarry of U. S. Gypsum Co. Upper left quadrant is a single-crystal gypsum porphyroblast crowded with small grains of anhydrite, bordered by non-anhydritic younger gypsum. Bar scale is 1.0 mm. Crossed nicols, thin section 968.

B. Anhydrite inclusions in large porphyroblast of figure A, x80. Residual grains of earlier rock anhydrite stand out in relief against the gypsum background. Plain light.

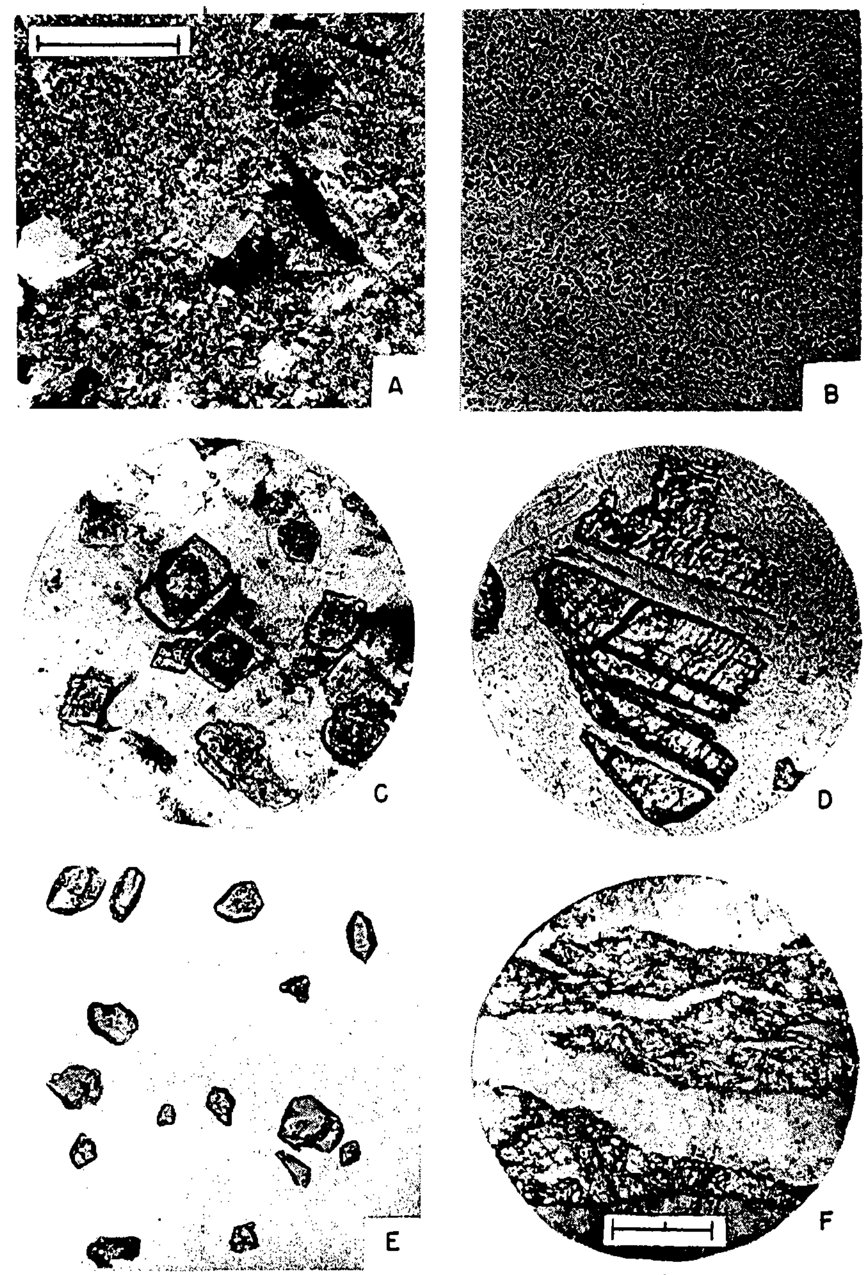
C. Dolomite rhombohedrons in Nescatunga Gypsum, quarry of Universal Atlas Cement Co. Most of the grains are 0.08 mm in diameter. Plain light, thin section 977.

D. Large grain of dolomite in same thin section as in figure C, cut through along cleavage planes by gypsum. The grain is 0.55 mm long. Plain light.

E. Acid-insoluble residue from Shimer Gypsum, consisting of subrounded and euhedral quartz grains 30 to 50 microns in diameter. Plain light.

F. Residual layers of anhydrite in Nescatunga Gypsum, from transition zone between rock gypsum and rock anhydrite, quarry of U. S. Gypsum Co. Bar scale is 2.0 mm. Gypsum replaces anhydrite in the form of seams and veinlets parallel to bedding. Plain light, thin section 965.

Plate VII



Dolomite beneath the Nescatunga. They consist mostly of dolomitized oöids and dolomite pellets (pl. VI-D), locally containing the impressions of numerous clams (fig. 12), and of microgranular laminated dolomite that contains the hopper-shaped impressions of salt crystals. The dolomite "hoppers," or "castellated dolomites," are common in the Blaine, Dog Creek, and Flowerpot Formations of western Oklahoma and have been described by Merritt (1936) and by Scott and Ham (1957). The widespread occurrence of these salt impressions in Permian dolomites indicates a general relation with evaporating sea water, and binds the dolomites closely in origin with the associated gypsum-anhydrite beds.

Normally the contact of a dolomite bed with overlying anhydrite or gypsum is sharply defined although a few dolomite oöids or pellets are generally scattered in the basal few inches of the sulfate rock. Dolomite occurring within the main body of the anhydrite-gypsum beds, however, is authigenically formed and consists of euhedral rhombohedrons (pl. VI-A, VII-C). Their omega index of refraction is 1.680, indicating a normal low-iron type of dolomite. A few of the rhombohedrons are enlargements around earlier grains, the contact between them being marked by a zone of dark inclusions. Dolomite rhombohedrons are present in anhydrite and gypsum alike. They are 0.05 to 0.5 mm in diameter and are arranged either in random distribution or in thin layers

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Explanation of Plate VIII

Photomicrographs of probertite and celestite in gypsum of the Blaine Formation

A. Nodule of probertite replacing Nescatunga Gypsum, Universal Atlas quarry. The nodule is 2.6 mm long. Plain light, thin section 974.

B. Same, crossed nicols. Probertite occurs as bundles of straight fibers.

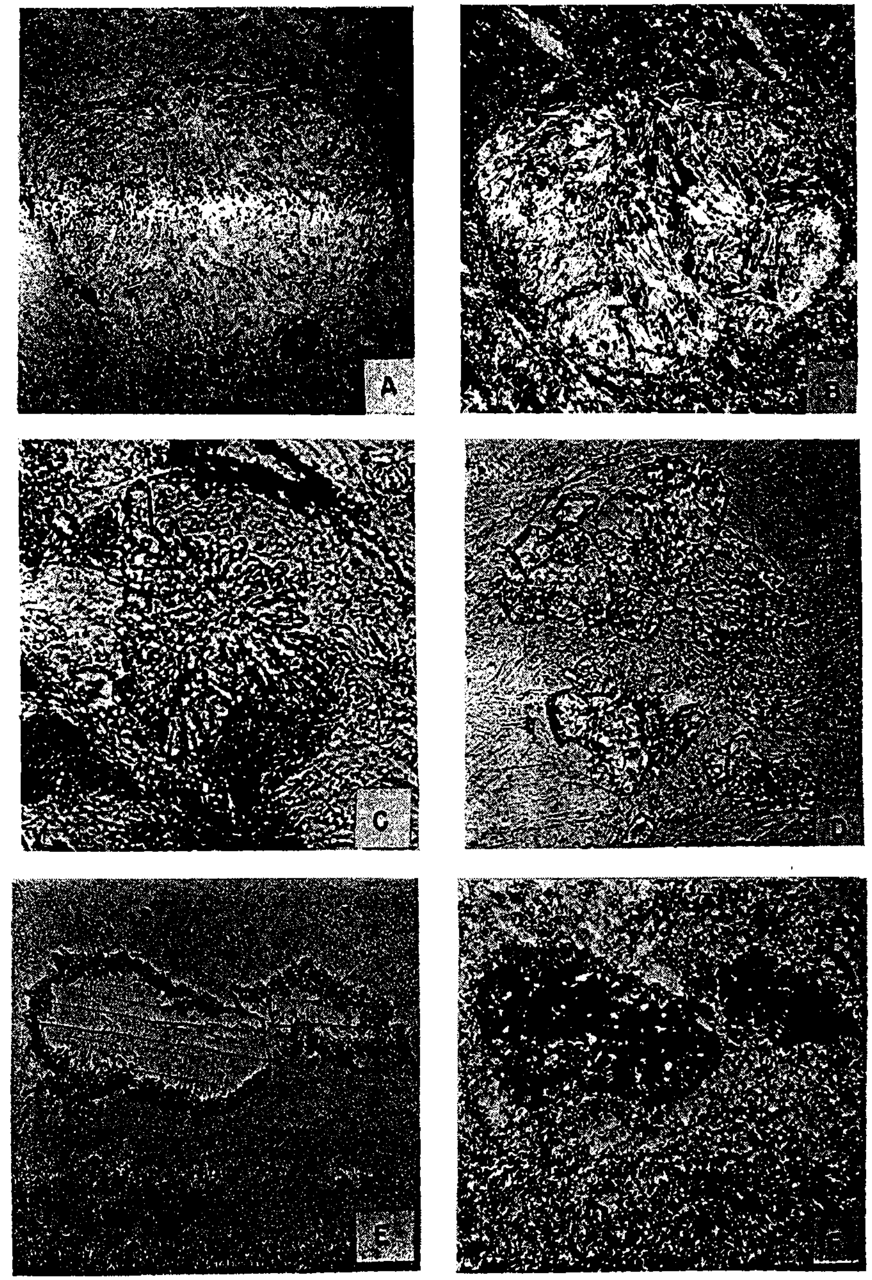
C. Celestite rosette of clustered blades, some of which are euhedral, in Nescatunga Gypsum. Maximum dimension of rosette is 0.12 mm. Photograph is an enlargement of dark grain seen just below bottom of probertite nodule in figure A. Plain light.

D. Celestite grains in recrystallized upper part of Nescatunga Gypsum, quarry of U. S. Gypsum Co. The cluster in upper part of photograph is 0.4 mm long. Plain light, thin section 964.

E. Single crystal of celestite in fine-grained Shimer alabaster, quarry of U. S. Gypsum Co. The crystal is 1.3 mm long. At right center is a veinlet of gypsum that has transected the crystal. Plain light, thin section 967.

F. Same, crossed nicols, showing optical continuity of granular border with the original crystal core. The core contains numerous inclusions of anhydrite (white irregular spots).

Plate VIII



along the plant of bedding. Where the larger grains occur in gypsum, they are irregularly replaced by gypsum or are transected and disrupted by the formation of gypsum along their cleavage traces (pl. VII-D).

In the transformation of anhydrite into gypsum, the percentage of dolomite is commonly decreased through the process of dolomite replacement by gypsum; and the percentage of calcite is increased as the result of calcite formation in the ground-water zone. Dolomite is formed only during early diagenesis and, once dissolved at shallow depth, it is not precipitated again.

Calcite, $CaCO_3$

Botryoidal encrustations, seams, and discrete grains of calcite are present in the gypsum beds of Blaine County. Calcite, identified by X-ray diffraction methods, has been found in numerous specimens collected from quarries in the Shimer Gypsum of the United States Gypsum Company and from the Nescatunga quarry of S. A. Walton and Son. The encrustations cover the walls of cavities, characteristically with pale-yellow mamillary or structureless calcite, and they are most abundant where stripped overburden is thin.

Figure 51. Probertite (white) occurring as nodular tufts of silky fibers along irregular bedding surface of Nescatunga Gypsum. U. S. Gypsum Co., x1.6.

Probertite, Ulexite, and Priceite

The occurrences of borate minerals in gypsum beds of the Blaine and Cloud Chief Formations of western Oklahoma have been described (Ham, Mankin, and Schleicher, 1961), and from the published report the following descriptions and relations are taken.

Probertite ($NaCaB_5O_9 \cdot 5H_2O$) is the dominant or exclusive borate mineral at most localities, whereas ulexite ($NaCaB_5O_9 \cdot 8H_2O$) and priceite ($Ca_4B_{10}O_{19} \cdot 7H_2O$) are of rare occurrence. Probertite and ulexite differ only in the percentage of combined water, and the percentage of B_2O_3 in probertite is almost identical to that of priceite. In B_2O_3 content the three minerals range approximately from 43 to 50 percent, and all are closely related in chemical composition and origin.

All the borate minerals occur as replacement nodules in massive

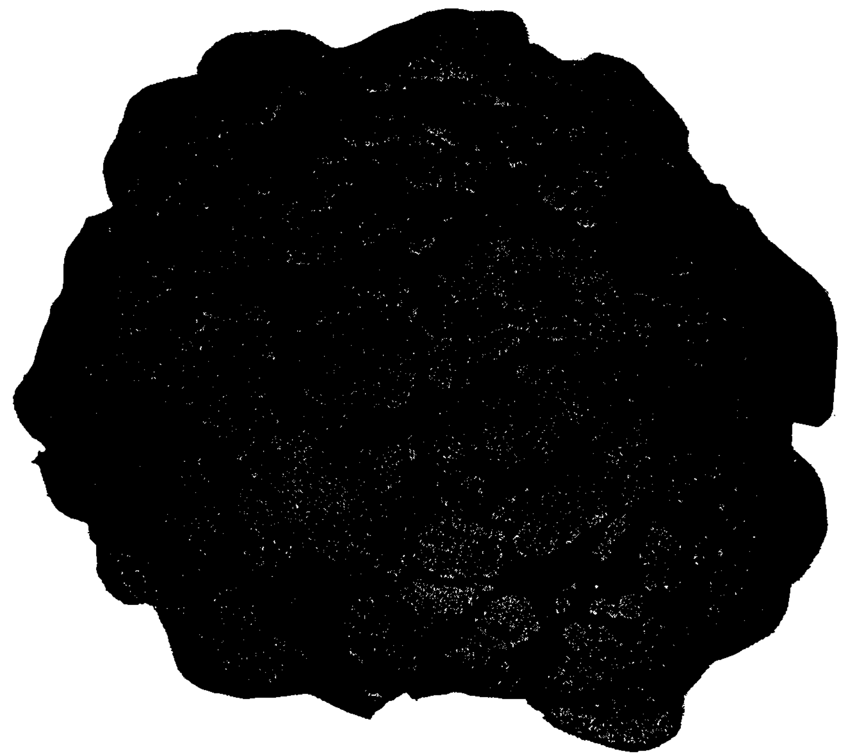


Figure 52. Discoidal nodule from the Nescatunga Gypsum. Top view showing irregular surface. Dark gray is matrix of fine-grained gypsum. U. S. Gypsum Co., x1.5.

gypsum, generally concentrated along crudely defined bedding surfaces. They are mostly white concretions about 0.25 inch in diameter, but ulexite nodules as much as 5 inches in diameter also have been found (pl. VIII-A, B; figs. 51, 52).

In Blaine County, borate minerals have thus far been found only in the Nescatunga Gypsum in the quarry of the Universal Atlas Cement Company, and in four quarries of the United States Gypsum Company. The minerals are so soluble in an environment of weathering gypsum that they are dissolved from gypsum outcrops and from quarries where less than about 7 feet of overburden has been stripped. Cavities from which probertite nodules have been dissolved are, however, abundant.

The pattern of borate mineral occurrence and distribution is everywhere the same for, although restricted in their occurrence to gypsum, the borates invariably are near beds or residual lenses of anhydrite that are now being altered to gypsum. In the quarries in the Nescatunga Gypsum of Blaine County, probertite is the dominant mineral and generally occurs in the first five feet of gypsum lying directly upon massive anhydrite. At the Universal Atlas quarry, where the anhydrite has the form of a thin bedlike lens in gypsum, probertite nodules are concentrated in the first 18 inches of gypsum below the anhydrite and in the first few inches of gypsum directly above, forming a halo of probertite nodules around the anhydrite.

Ulexite has been found in Blaine County only at one abandoned quarry, S½ SW¼ SE¼ sec. 3, T. 18 N., R. 12 W., where it occurs as cauliflower-shaped nodules 3 to 5 inches in diameter. Priceite is of the rarest occurrence, having been found in small masses at the ulexite locality and in the quarry in NW¼ SE¼ NW¼ sec. 18, T. 18 N., R. 12 W.

That part of the gypsum which is richest in probertite, about 10 percent by area along selected bedding partings, is from the Nescatunga quarry of the United States Gypsum Company in NW¼ SE¼ NW¼ sec. 18, T. 18 N., R. 12 W. Channel samples of this rock contain only 0.10 percent B_2O_3, thus indicating no probability that the deposits are a commercial source of boron compounds. The boron content of the Nescatunga Gypsum is used to advantage by the United States Gypsum Company at Southard in making special high-strength plasters, in the manufacture of which borax ordinarily would be added.

The borate minerals have been formed during the process of gypsification of boron-containing anhydrite. Blaine and Cloud Chief anhydrite in western Oklahoma contains an average of 232 ppm (0.023 percent) B_2O_3, whereas the corresponding gypsum derived from this anhydrite contains an average of 42 ppm (0.004 percent) B_2O_3 (Ham, Mankin, and Schleicher, 1961). Boron is either bound isomorphously within the anhydrite lattice or is absorbed on crystal surfaces, for the anhydrite itself contains no borate minerals. On weathering and conversion into gypsum, the boron of the anhydrite is rejected by the gypsum lattice, and this results in the concentration of approximately 200 ppm B_2O_3 in solution. The boron-rich water then reacts with gypsum and replaces it with borate minerals.

CELESTITE, $SrSO_4$

Normal anhydrite of evaporite origin contains abundant strontium as an isomorphous substitution for calcium. From a sequence of German Zechstein (Permian) anhydrites, Jung and Knitzschke (1960) obtained an average value, for 18 of their purest samples, of 1,950 ppm strontium. Kropachev (1960) reported an average value of 855 ppm Sr in 37 samples of anhydrite, and a value of 1,275 ppm Sr in 75 samples of gypsum, from Kungurian (Permian) evaporites in Russia.

In the present study it has been found that the average content of Sr in the Blaine Formation of western Oklahoma is 1,475 ppm in 22 samples of anhydrite and 970 ppm in 38 samples of gypsum (table 8). Oklahoma anhydrite thus is intermediate beween that of Germany and Russia, whereas Oklahoma gypsum is considerably lower in Sr than is that in the Kungurian of Russia. Kropachev concluded that the gypsum deposits of the fore-Urals were derived by the hydration of anhydrite and that, during the process, Sr was

TABLE 8.—STRONTIUM CONTENT OF PERMIAN ANHYDRITE AND GYPSUM FROM OKLAHOMA, GERMANY, AND RUSSIA (parts per million)

	Blaine Formation of Oklahoma	Zechstein (Werraanhydrite) of Germany	Kungurian of Russia
Gypsum	970	——	1,275
Anhydrite	1,475	1,950	855

enriched by approximately 50 percent in gypsum compared to the original content in anhydrite. Such enrichment is not typical of the Blaine Formation, in which there is instead a net strontium loss of about 30 percent.

The isomorphous substitution of strontium for calcium in Blaine anhydrite from western Oklahoma shows a range from 895 to 3,165 ppm. Yet the large clustering of control points around the average value indicates that the strontium content is surprisingly stable, in spite of the variable degree of recrystallization to which the different samples have been subjected. Furthermore, all the strontium appears to substitute within the anhydrite space lattice and does not occur in a separate phase as the mineral celestite (strontium sulfate), for no celestite has been observed in the thin sections of anhydrite thus far studied. The low birefringence of celestite is markedly different from that of anhydrite, so that it should have been noted if it were present.

On changing by hydration to gypsum, the anhydrite lattice is destroyed and a new lattice of gypsum is formed. The gypsum space lattice evidently tolerates strontium only to the extent of a few hundred parts per million; and, just as in the case of boron, the strontium becomes available to form its own mineral species in the gypsum. In the presence of abundant sulfate ions, the stable species is celestite. The process of celestite formation by this method apparently is so common as to be virtually universal in western Oklahoma, for no thin section of rock gypsum from that region has been examined which does not contain recognizable celestite.

In the 10 gypsum samples chemically analyzed in table 7, the average content of $SrSO_4$ is 0.286 percent and the range is 0.23 to 0.34 percent. The observed concentration of celestite in thin sections is estimated to range as high as 0.5 percent and to average perhaps half this maximum value, thus yielding approximately the amount required to account for most of the strontium shown by spectrographic analysis to be in the gypsum.

The original strontium apparently is precipitated in the form of celestite almost immediately after being dissolved from the anhydrite. A part of the strontium is lost and presumably is carried away in ground waters as strontium bicarbonate. That which is precipitated as celestite normally occurs as tiny bladed

crystals or as bladed rosettes (pl. VIII-C), ranging in diameter from 0.04 to 0.35 mm. In part the blades have grown along clay wisps or seams in gypsum, the clay apparently acting as a ponding device for the collection of strontium-bearing ground waters. Strangely, bladed celestite is the only epigenetically formed mineral whose precipitation is influenced by these thin seams of clay.

A second though much rarer occurrence of celestite is as non-bladed anhedral grains (pl. VIII-D) 0.1 to 0.2 mm in diameter. The third and rarest form consists of crystals more than 1 mm long, sufficiently well crystallized to show plainly the cleavage of the crystals (pl. VIII-E, F). This type occurs in alabaster and contains scattered relicts of anhydrite, and thus shows, as do the gypsum porphyroblasts of stage G-1, an early period of crystallization.

The identification of the grains, blades, and rosettes as celestite (and not barite) is based on optical properties. Residues from cold dilute hydrochloric acid solution generally yielded no sulfate minerals whatever, and the statement that celestite is virtually insoluble in acid is thus shown to be false, particularly when the mineral is fine grained and present in small quantity. Suitable concentrates were made in bromoform of specific gravity 2.60, and the mineral was found to have the following indices of refraction: alpha = 1.622 and gamma = 1.631. It is biaxial positive and has an angle for 2V approximately equal to 50°.

Thenardite, Na_2SO_4

The mineral thenardite occurs in gypsum as an alteration product of anhydrite, as do the borate minerals and celestite. The typical occurrence is as discoidal white nodules half an inch in diameter lying randomly in the plane of bedding, the nodules replacing gypsum on either side of the bedding surface along which ground waters have percolated. In a few places thenardite has the form of a bedding encrustation as much as 0.2 inch (5 mm) thick, or as nodular encrustations within vertical joints in the gypsum. The mineral has been found only in quarries, and it is concentrated mostly in gypsum beds near a contact with an anhydrite lens or bed, having derived its sodium and sulfate ions from solution of salt-bearing anhydrite.

Halite, NaCl

Traces of salt are present in outcropping gypsum and anhydrite of the Blaine Formation. Higher concentrations are found in subsurface beds, particularly as shown in cores of a well drilled near the southwestern corner of Blaine County, NW¼ SE¼ SW¼ sec. 36, T. 14 N., R. 13 W. In this well the Nescatunga Member of the Blaine Formation is 9 feet thick, it was encountered at a depth between 462 and 471 feet, and it consists of anhydrite of which the middle 4 feet contain coarsely crystallized clear halite (pl. VI-E). At shallower depths and on the outcrop most of the salt has been leached away by ground waters.

The presence of salt as a trace constituent in Blaine anhydrite is believed to have an important bearing on the origin of the associated epigenetic minerals, because the sodium ion for the building of probertite, ulexite, and thenardite probably was derived from this source.

Quartz, SiO_2

As shown in acid-insoluble and water-insoluble residues, detrital quartz is present in trace amounts in the gypsum and anhydrite beds of Blaine County. Generally of coarse silt size, they consist of authigenically enlarged and partly euhedral grains (pl. VII-E). They are associated with a few grains of feldspar, chlorite, tourmaline, zircon, and rutile.

Summary of Origin

The essential points in the genetic framework of Blaine evaporites are outlined in table 9, which traces the stages in the transformation of a primary sulfate sediment first into anhydrite and, much later, into gypsum.

The primary sediment is inferred to be gypsum or hemihydrate and not anhydrite because, despite many early investigations indicating that anhydrite can be formed from sea water at reasonable concentrations and temperatures in the laboratory, there is a probability that what the early investigators called anhydrite is actually hemihydrate. Modern experiments produce only gypsum or hemihydrate by evaporation of sea water in the laboratory; gypsum and not anhydrite is forming in present-day lagoons; and certain theoretical considerations led Conley and Bundy (1958) to

TABLE 9.--GENETIC SUMMARY OF BLAINE ANHYDRITE AND GYPSUM

Stage	Geologic Time	Major Lithology	Minor Constituents
IA Original sediment	Permian	Gypsum and/or hemihydrate	Calcite, halite
IB Diagenesis	Permian	At least partial diagenetic change on sea floor of primary sulfate minerals into anhydrite, and of calcite into dolomite.	
IIA Anhydrite	Permian and later	Anhydrite, 98-99%	Dolomite, halite B_2O_3, 230 ppm Sr, 1,475 ppm
IIIB Recrystallization	Permian-Tertiary	Burial by 1,500 feet of Permian and 1,000 (?) feet of Mesozoic sediments. Continuing formation of anhydrite from primary sulfates in presence of connate water, aided by depth of burial. First stage (A-1) fine-grained anhydrite; second stage (A-2) blocky anhydrite crystals; third stage (A-3) bladed rosettes.	
IIIA Gypsum	Late Tertiary and Pleistocene	Gypsum, 97-99%	Dolomite, *calcite, and traces of halite and of residual anhydrite. *Celestite, 0.29%. *Probertite, *ulexite, *priceite, *thenardite: <0.1%
IIB Recrystallization	Pleistocene and Recent	Uplift to within 400 feet of surface. Weathering of anhydrite to gypsum in early porphyroblastic stage (G-1); as alabaster (G-2); and as selenitic gypsum (G-3).	

*Epigenetically formed minerals.

conclude that the formation of a primary anhydrite precipitate is unlikely.

For these reasons it is here assumed that the widespread anhydrite beds of the Blaine Formation have been transformed from a now recrystallized original sediment and that the anhydrite beds represent the second episode in the history of the sedimentary rock. Presumably the first stage of anhydrite formation results from diagenesis on the sea floor, in much the same way that the great bulk of stratigraphic dolomites is thought to originate. In the case of anhydrite there is much to be said for an early diagenetic origin, for the geochemistry of the anhydrite virtually requires a sea-water source for its trace elements. In particular, the boron-rich and strontium-rich anhydrites of the Blaine Formation could not have been derived in a closed system by simple recrystallization of gypsum that is poor both in boron and strontium. On the other hand there is no problem if these ions were available from a bath of sea water, on the sea bottom or a few feet below it, when recrystallization or transformation took place. The boron content of Blaine anhydrites forces an especially strong argument in this instance. The anhydrites contain almost exactly the same amount of boron that is present in evaporated modern sea water at the stage just after the precipitation of calcium sulfate (Ham, Mankin, and Schleicher, 1961).

Perhaps the process of conversion of anhydrite is not completed on the sea floor but continues with depth of burial to environments where higher density minerals are stable, with the resulting change of any remaining hydrous sulfates into anhydrite. If so, such recrystallization likely takes place in the presence of connate fluids or brines. Here follows, in the Oklahoma examples, a long period during which anhydrite, and only anhydrite, is the stable phase. This period extends from the Late Permian through the Mesozoic and into Tertiary time. Uplift of the Rocky Mountains drove out the Cretaceous seas from western Oklahoma and initiated a steady uplift that has resulted in a present average elevation of about 3,000 feet. Most of the gypsum now seen at the surface is believed to have been formed during uplift in Late Tertiary and Pleistocene time.

Through uplift, fresh ground waters displace the connate waters in the weathering zone and so change the mineralogic

environment that gypsum becomes stable and replaces anhydrite. Anhydrite is destroyed, and its trace elements are converted into epigenetic celestite, probertite, ulexite, priceite, and thenardite. Dolomite is partly dissolved, and in the vadose zone its place is taken by calcite. The gypsification process goes to completion where the depth is shallowest and the duration of exposure to ground waters longest. These conditions are fulfilled only at and near the present ground surface, and here are found the commercially workable gypsum deposits.

Part III.—Petroleum Geology of Blaine County

John T. Bado* and Louise Jordan

INTRODUCTION

In 1956, Blaine County became the sixty-sixth county in Oklahoma known to have commercial petroleum production. Gas was discovered in the field area, now named Northwest Okeene, in the northern part of the county (fig. 53). North Cooper Field was located in 1958, Squaw Creek in 1959, South Watonga in 1960, and East Fay and Northeast Okeene in 1961.** Gas production at Northwest Okeene, Northeast Okeene, and North Cooper Fields in the northern part of the county is from Late Mississippian limestones at depths ranging from 7,500 to 7,900 feet. At Squaw Creek, in the southwestern part of the county, two levels of gas-condensate are present: the upper at approximately 10,800 feet in sandstone probably near the base of the Middle Pennsylvanian and the lower in Early Pennsylvanian or Mississippian sandstones from 11,680 to 11,860 feet. At South Watonga and at East Fay, gas production is from sandstone, Early Pennsylvanian or Late Mississippian in age, at depths from 9,750 to 9,805 and from 10,220 to 10,245 feet, respectively.

HISTORY OF EXPLORATION

Some sixteen shallow holes, ranging in depth from 1,000 to 5,550 feet and with total footage amounting to approximately 30,000 feet, were drilled in the county before 1945. Most of them did not fully penetrate the Permian section, but some were drilled into Late Pennsylvanian rocks. The earliest test was drilled at Darrow in 1906 in sec. 20, T. 19 N., R. 11 W., according to Gerald Curtin who interviewed early residents of the area (*Watonga*

*Geologist, Gulf Oil Corporation.
**Two additional fields discovered in 1961 are discussed in the section on recent development, page 180.

Table 10.—Exploratory and Development Holes Drilled in Blaine County, 1945-1961

	Exploratory				Development			
Year	Gas*	Dry	Total	Footage	Gas*	Dry	Total	Footage
1945	0	1	1	11,008				
1948	0	2	2	19,112				
1949	0	1	1	3,875				
1956	1	1	2	15,179				
1957	0	0	0	1,660**	2	0	2	15,676
1958	1	1	2	16,955	3	1	4	32,287
1959	1	1	2	19,929	2	0	2	16,072
1960	1	3	4	34,123	2	1	3	30,267
1961	7	3	10	91,683	7	4	11	94,380
Total	11	13	24	213,524	16	6	22	188,682

* Gas or gas-condensate.
** 1956 test drilled deeper.

Republican, July 10, 1958). A driller's log of the Ima Oil and Gas Company No. 1 Eberhart (sec. 7, T. 18 N., R. 10 W.) in the files of the Oklahoma Corporation Commission is the first record of a test in the county. Commenced in 1918 and completed in 1920, the hole was drilled to 2,285 feet, surprisingly with a "rotary drill." The time required to complete the test probably is summarized in the statement "twisted off 112 feet of drill stem in hole, could not lift stem from hole."

Only three significant exploratory tests, amounting to a total footage of 30,120 feet, were drilled before the 1956 discovery (table 10). These tests, drilled in the northeastern part of the county, tested rocks as old as the Arbuckle (Ordovician) and remain the deepest stratigraphic tests in the county. In 1945, the Superior Oil Company and Wilkoff No. 1 (81-17) Norris in sec. 17, T. 19 N., R. 10 W., was drilled to 11,008 feet into rocks of the Arbuckle Group (Ordovician). No shows were recorded. In 1948, Stanolind No. 1 Wildman (sec. 19, T. 19 N., R. 11 W.) was drilled into Simpson (Ordovician) rocks to 10,017 feet. Shows of gas in Chester and Meramec limestones (Mississippian) and oil staining and a show of gas in Hunton rocks were reported. The same year, Placid No. 1 Winter (sec. 18, T. 19 N., R. 11 W.) was abandoned at 9,095 feet in the Hunton (Devonian-Silurian). Oil staining and odor were observed in a core of Hunton limestone. These tests were regionally important because, having been drilled within the then practically unexplored northwestern area of the State, they yielded geologic information on stratigraphy and on thickness and dip of formations.

In the following seven-year period, 1949-1955, only one shallow hole was drilled at a location just north of Superior's deep test (T. 19 N., R. 10 W.) It was drilled to 3,875 feet, about 200 feet into rocks of Pennsylvanian age. In early 1956, W. E. Dunn made a location just east of Superior's and drilled to 6,277 feet in order to

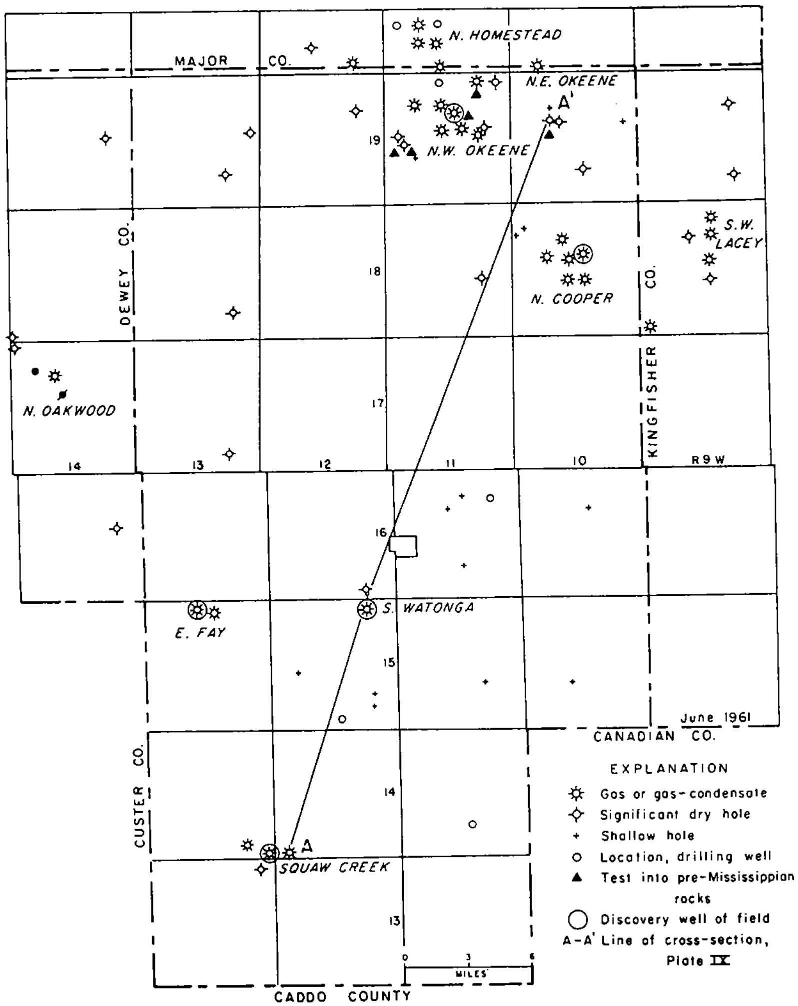


Figure 53. Map showing gas fields in Blaine County and line of cross section of plate IX.

test sandstone called "Lower Layton" (below Hogshooter Limestone). The venture proved unsuccessful. After the discovery of the Northwest Okeene Field, the hole was drilled deeper in 1957, but was abandoned after failure to find production in Mississippian rocks of Chesterian age.

Coyle and Perkins Brothers No. 1 Dougherty (SW¼ SW¼ SW¼ sec. 10, T. 19 N., R. 11 W.), discovery well for the county of commercial gas production, was completed in October 1956 in a Chester reservoir.

No exploratory tests were drilled in 1957 other than deepening of Dunn No. 1 Durham, listed above, but a test drilled in 1958, in the northern part of the county, located a new area of gas-productive Mississippian limestone at North Cooper (fig. 53). Exploration in southern Blaine County, where the thickness of the Pennsylvanian rock section increases probably more than 3,000 feet, was begun in 1959. Squaw Creek Field (fig. 53) was opened by a gas-condensate pay in rocks at 10,800 feet near the base of the Middle Pennsylvanian (Desmoinesian). Development drilling for gas, based on 640-acre spacing pattern, revealed a pay zone about 1,000 feet deeper in sandstones called Morrow by many geologists. Discoveries at South Watonga in 1960 and at East Fay in early 1961, about 12 miles northeast and northwest respectively of Squaw Creek Field, were made in similar sandstones. Gas production was located in Chester rocks at Northwest Okeene in June, 1961. Three wildcat tests in the process of drilling (locations on fig. 53) may be additional discoveries for 1961, and they will add significantly to stratigraphic knowledge of the rock section.

STRATIGRAPHY

The area of Blaine County is structurally on the north flank of the Anadarko syncline. Rocks of all systems, dipping southwestward and penetrated in wells drilled for oil and gas, range in age from Ordovician to those of the Permian exposed at the surface. Only in the northern part of the county in the vicinity of Northwest Okeene Field have rocks older than Mississippian been explored by drilling. (See Recent Development, July 1961 to February 1962.) Three wells penetrated Hunton carbonates (Devonian-Silurian); one was drilled 162 feet into the Simpson Group (Middle Ordovician); and one penetrated 1,228 feet of the Arbuckle Group (Early Ordovician). These five tests are indicated by black triangles on figure 53. Depths from the surface to the top of a unit and thickness of the unit of the two deeper stratigraphic tests are listed in table 11. Depths are to the nearer 5-foot mark.

Ordovician System

The Ordovician System is represented by rocks of the Arbuckle and Simpson Groups, Viola-"Fernvale" limestones, and Sylvan Shale (ascending order). Maximum drilled thickness of these rocks was penetrated by the Superior No. 81-17 Norris test in northern Blaine County and amounted to 2,138 feet, of which the lower 1,288 feet is in the Arbuckle Group.

ARBUCKLE GROUP

Although the Arbuckle Group contains rocks of both Late Cambrian and Early Ordovician age, it is probable that the Cambrian section was not penetrated by the Norris well. No well in northwestern Oklahoma north of the Wichita Mountain front (Northern Wichita segment of Arbenz, 1956) and west of the Oklahoma City Field and of Garber Field in Garfield County has been drilled deeply enough to reach basement, so that subdivision of pre-Simpson rocks has not been attempted. Adkison (1960) described Arbuckle rocks from 9,720 to 11,008 feet in the Norris well as follows:

> The Arbuckle group in well 8 consists of yellowish-brown, brownish-gray, and medium light-gray to medium dark-gray dolomite that is finely to coarsely crystalline in the lower 400 feet, finely crystalline to medium crystalline in the upper part. Some of the dolomite is finely sandy to medium sandy, and much of it contains light- to medium-gray chert that is oölitic in part. Some crystalline quartz is present.

The Magnolia No. 1 Miller, in sec. 22, T. 15 N., R. 16 W., (table 12) in the North Custer City Field of Custer County, 45 miles southwest of the Norris well, penetrated Arbuckle rocks. At a total depth of 17,000 feet (15,190 subsea), 928 feet of Arbuckle rocks, considered equivalent to the West Spring Creek Formation, were drilled. It is possible that, at this location, the pre-Simpson rocks above the basement are as much as 3,500 feet thick. Almost directly 60 miles south of the Norris well, Denver Producing and Refining Company's No. 1 Schoolland, drilled in 1948 (table 12), reached the top of the Arbuckle at a reported subsea depth of 15,280 feet (Dietrich, 1955). With these two wells as control points and with the realization that both wells are probably on structure, Jordan estimates the subsea depth in southern Blaine County to the top of the Arbuckle to be more than 17,000 feet, or approximately 18,600 feet below the land surface.

If the Joins, lowermost formation of the Simpson Group, is present in this area, it has been included in the Arbuckle Group.

SIMPSON GROUP

The Simpson Group is essentially a clastic rock section with dolomitic limestone predominant in the upper part. Dietrich (1955) subdivided the section into formations as illustrated in the log of Superior No. 81-17 Norris, as shown on plate IX. The lithology in the center column is taken from Adkison (1960, well 8), who placed the top of the Bromide Formation 210 feet higher than did Dietrich. Where the lower part of the Viola and the upper part of the Simpson are both dolomite, the contact between the two units is not readily distinguishable.

"FERNVALE"-VIOLA LIMESTONES AND SYLVAN SHALE

"Fernvale"-Viola overlain by Sylvan Shale is a carbonate section 225 and 275 feet thick in the wells in T. 19 N. (table 11). Adkison placed only 60 feet in the Viola (including the Fernvale) in the Superior Norris well, considering that most of the carbonate section is in the Bromide Formation. As shown on cross section of plate IX, the upper 25 feet of this 255-foot section is placed in the Sylvan, based on Adkison's determination that this interval contains "medium dark-gray to black very silty dolomite" and black shale. The normal placement by most geologists would be at the depths listed in table 11. De Jong (1958, p. 39) described the "Fernvale" in the Stanolind No. 1 Wildman as gray-buff to brown slightly mottled medium- to coarse-crystalline limestone containing beds of brown and buff granular dolomite and the underlying Viola as a light-gray to white cherty limestone.

The Sylvan Shale is 105 and 100 feet thick in the two wells listed in table 11. It is composed chiefly of medium- to dark-gray shale which is partly dolomitic or calcareous. Adkison stated that the Sylvan includes greenish-gray and black shale which may be highly silty and dolomitic.

Silurian and Devonian Systems

Unconformably overlying the Sylvan Shale, the Hunton Group is a carbonate sequence ranging from Early Silurian through Early Devonian where it crops out in the Arbuckle Mountains and Criner Hills region of south-central Oklahoma. In the subsurface, divisions similar to those of the surface are used: (a) basal dense limestone with reddish-orange crystals of calcite, a trace of glauconite, and a very light-gray to medium-gray dense chert, called Chimneyhill; (b) middle microcrystalline, partly siliceous dolomitic limestone, referred to as Henryhouse-Haragan; and (c) upper dolomite, called Bois d'Arc. The group is 455 feet thick in Stanolind No. 1 Wildman and 320 feet thick in the Superior No. 1 Norris well (table 11). The Hunton Group is regionally beveled northward by pre-Woodford erosion, but is present everywhere within the Blaine County area. Because of erosion and weathering, and even though unconformities exist within the group, it seems doubtful that the upper dolomite is everywhere equivalent to the Bois d'Arc of surface nomenclature.

Woodford Shale of Late Devonian age rests upon Hunton with angular unconformity. In secs. 18 and 19, T. 19 N., R. 11 W., the Placid and Stanolind wells penetrated approximately 30 feet of Woodford Shale, whereas in the Superior test in sec. 17, T. 19 N., R. 10 W., approximately 20 feet is present. The Woodford in the Stanolind No. 1 Wildman well is a brown pyritic shale, which

Table 11.—Deep Stratigraphic Tests in Blaine County

	Stanolind 1 Wildman 19-19N-11W Elev. 1,290		Superior 81-17 Norris 17-19N-10W Elev. 1,204	
	Depth	*Thickness*	*Depth*	*Thickness*
Permian	0	3,850	0	3,595
Pennsylvanian	3,850	3,750	3,595	3,765
Mississippian	7,600	1,395	7,360	1,175
Chester	7,600	790	7,360	565
pre-Chester	8,390	605	7,925	610
Devonian, Woodford	8,995	30	8,530	20
Devonian-Silurian, Hunton	9,025	455	8,550	320
Ordovician	9,480	537	8,870	2,138+
Sylvan	9,480	100	8,870	105
"Fernvale"-Viola	9,580	275	8,975	255
Simpson Group	9,855	162+	9,230	490
Arbuckle Group			9,720	1,288+
Total Depth	10,017		11,008	

Table 12.—Pertinent Tests of pre-Mississippian Strata in Caddo, Canadian, and Custer Counties

	Magnolia 1 Miller 22-15N-16W Elev. 1,810 TD 17,000		Cities Service 1 Porter B 5-12N-8W Elev. 1,397 TD 13,366		Denver Prod. 1 Schoolland 16-10N-9W Elev. 1,540 TD 17,094		Howell et al. Anadarko Basin 4-9N-12W Elev. 1,549 TD 21,021	
	Depth to top	*Thickness*	*Depth to top*	*Thickness*	*Depth to top*	*Thickness*	*Depth to top*	*Thickness*
Devonian, Woodford	14,258	122	11,166	156	14,305	115	19,389	131
Dev.-Sil., Hunton	14,380	443	11,320	254	14,420	795	19,520	690
Ordovician, Sylvan	14,823	97	11,574	74	15,215	165	20,210	210
"Fernvale"-Viola	14,920	500	11,648	472	15,380	505	20,420	699+
Simpson	15,420	652	12,120	844	15,885	935		
Arbuckle	16,072	928+	12,964	402+	16,820	274+		

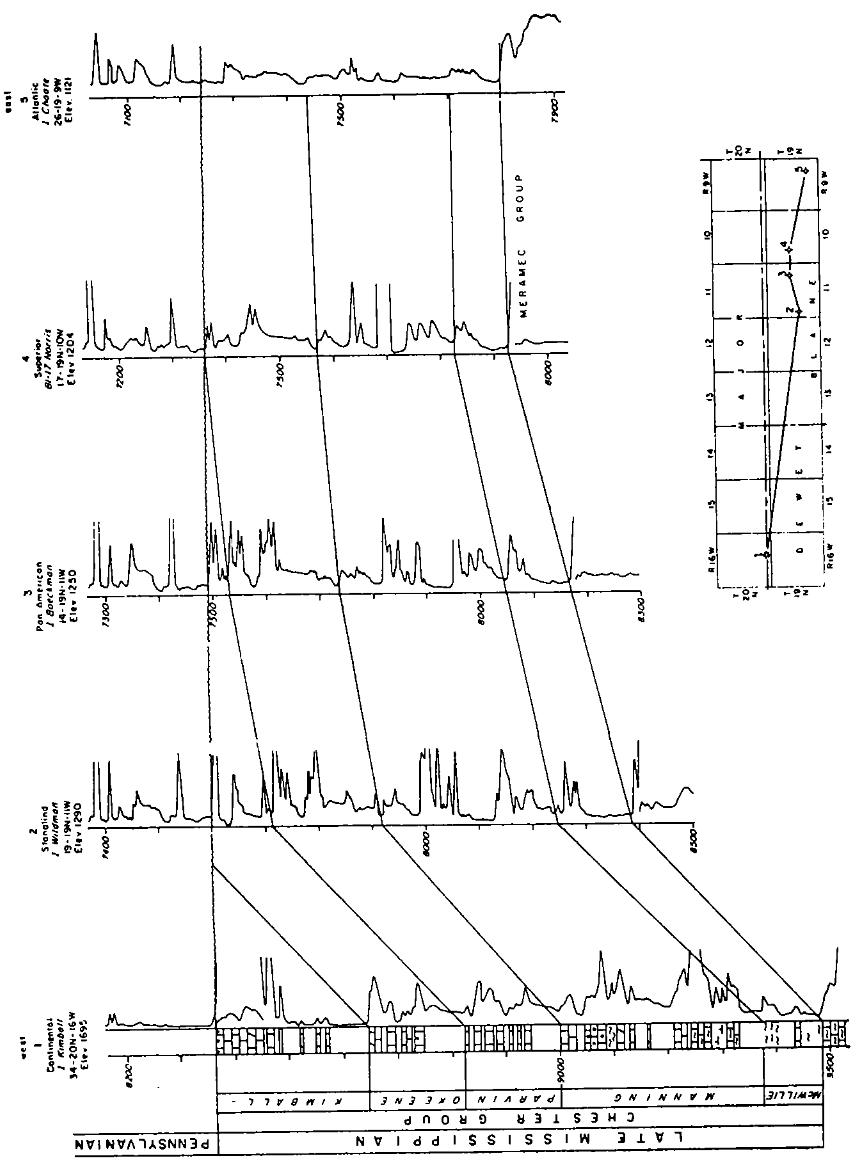


FIGURE 54. Electric-log cross section showing correlation and informal nomenclature of Chester Group, Late Mississippian in age.

probably underlies a thin layer of nodular glauconite. Glauconite, which is present in the overlying 30-foot section of gray to green silty shale and limestone (at places), appears to be concentrated near the contact of the two lithologic types in many wells in northwestern Oklahoma, where both are present. It has been observed in well-collected subsurface rock samples that, in many places in Oklahoma, glauconite (or phosphate) is commonly found immediately above the Woodford Shale as well as in the overlying basal Mississippian rocks, whether they are assigned to the Kinderhook, Osage, or Meramec Groups.

MISSISSIPPIAN SYSTEM

Mississippian rocks consisting of Kinderhook?, Osage, Meramec, and Chester Groups (ascending order) disconformably overlie Woodford Shale. Rocks in the Kinderhook-Meramec sequence are assigned to these groups on the basis of lithology, having been traced in the subsurface from southern Kansas (T. 33 S., R. 19 W., and T. 34 S., R. 16 W.) into Blaine County by Thornton (1958), McDuffie (1958), and Rowland (1958). Chester foraminifers and ostracodes were described by Harris and Jobe (1956) from the "Manning" zone of the Chester Group of the Ringwood Field of Major County. The microfaunal assemblage studied was obtained from cores between 6,801 and 6,820 feet in the lower limestone member ("Manning D" of fig. 55), which is termed "lower Manning" in the Ringwood Field area. No other faunal studies have been published concerning the Chester rock section which lies above the "Manning" and below the Pennsylvanian nonconformity (figs. 54, 55).

As of June 1961, Texaco, Inc., was drilling a hole in T. 16 N., R. 11 W., and Sunray Mid-Continent had made a location in T. 14 N., R. 12 W. (fig. 53). Information from these tests will add greatly to the knowledge of the Mississippian section in Blaine County. The five tests which penetrated the complete thickness are within eight miles of each other in the northern townships (T. 19 N., Rs. 10 and 11 W.). Thickness of the Mississippian section ranges from 1,170 feet in the easternmost well to 1,395 in the westernmost well. The increase in thickness is within the Chester Group, the thickness of individual units increasing slightly and the group being truncated less deeply westward as shown on figure 54.

KINDERHOOK ? GROUP

Rocks of the Kinderhook ? Group (not including the Woodford Shale) are less than 30 feet thick. This section is probably correlative with part of the Kinderhook Group as described by Maher and Collins (1949), and has been traced from Comanche

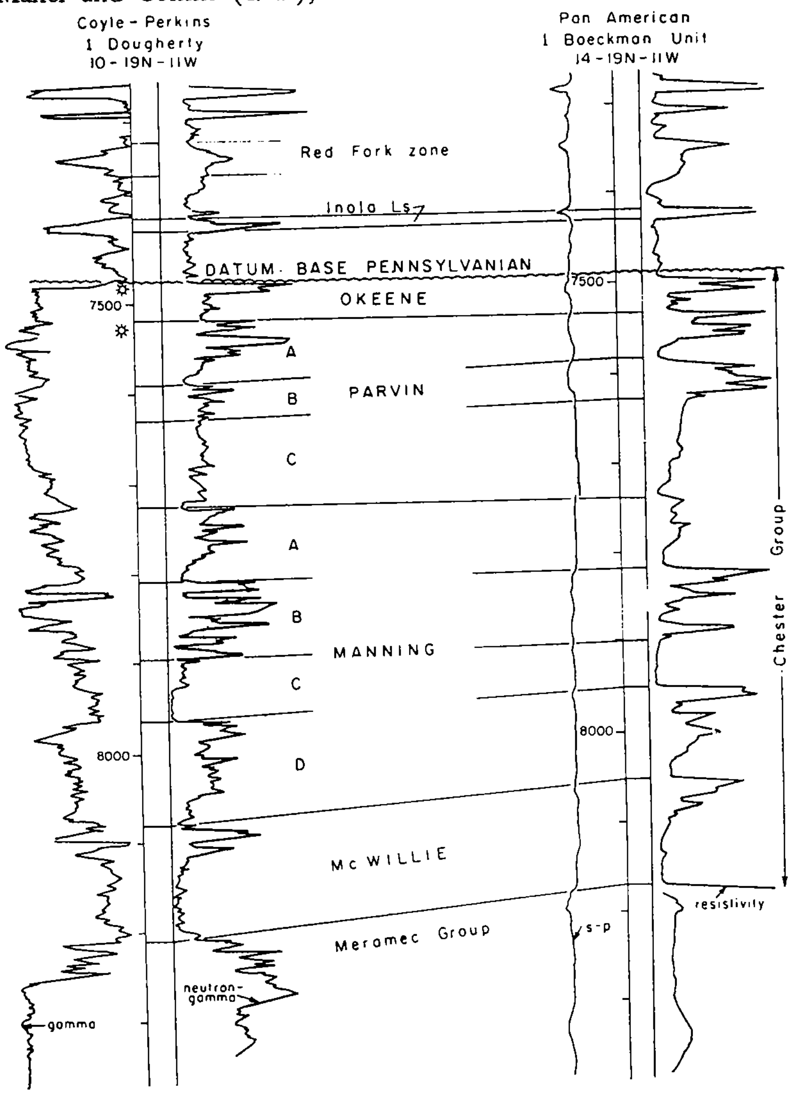


Figure 55. Electric and radiation logs showing informal divisions of Chester Group in Northwest Okeene Field and terminology used in tables 13 and 14.

County, Kansas, into Blaine County by Thornton (1958), McDuffie (1958), and Rowland (1958). Adkison (unpublished manuscript) places 23 feet of section in the Superior No. 81-17 Norris in rocks of Kinderhook ? age, which he describes as follows:

8,510-8,525 feet	Limestone, medium dark-gray, very fine- to fine-crystalline, argillaceous.
8,525-8,530	Shale, medium- to dark-gray.
8,530-8,533	Shale, light greenish-gray, soft.

This section underlies a 4-foot-thick bed of dark-gray, slightly limy siltstone containing much glauconite. At other places in northwestern Oklahoma, limestone is present at the base of the unit. Thornton (1958, p. 49) placed a 50-foot bed of siltstone underlain by 10 feet of limestone in the Kinderhook ? in a well in sec. 19, T. 29 N., R. 5 W. He described the rock above the siltstone as a dark-brown argillaceous, cherty limestone with glauconite in the basal portion.

OSAGE-MERAMEC GROUPS

The exact boundary between the Osage and Meramec Groups is problematical, but in this area and to the east, carbonate rocks assigned to the Meramec are highly silty, at places grade to calcareous siltstone or very fine sandstone, and normally do not contain chert. The Meramec section lithologically resembles that of the subsurface "Mayes" east of the Central Oklahoma arch, which is equivalent to Meramecian Moorefield Formation of surface nomenclature which crops out in the Ozark Mountain region of eastern Oklahoma (Jordan and Rowland, 1959, p. 131). The Osage limestones, on the other hand, are generally darker in color, silty and argillaceous at places, and contain varying amounts of gray or dark-gray chert.

Both oil and gas are being discovered and are produced from Meramec rocks, particularly eastward in Kingfisher and Garfield Counties. To the west in sec. 14, T. 15 N., R. 15 W., Custer County, Mobil Oil Company, in April 1961, dually completed a new discovery with gas from the Meramec and Oswego (Marmaton Group, Des Moines, Middle Pennsylvanian). No production has been established in Blaine County. More holes are now being drilled through the Chester Group to test the Meramec section.

CHESTER GROUP

The Chester Group includes alternating strata of limestone and shale, and at places sandstone and siltstone. In northern Blaine County, the group is divided into four productive zones (ascending order): McWillie, Manning, Parvin, and Okeene, as shown on figures 54 and 55. The Manning production was discovered in the Ringwood Field of Major County (Kornfeld, 1951, p. 6), and the Parvin in the Southwest Lacey Field, Kingfisher County (Jordan, 1960, p. 304). It is proposed informally that the limestone and shale section which underlies the Manning be termed McWillie after the North McWillie Field (sec. 14, T. 24 N., R. 11 W., Alfalfa County) where the limestone member of the Chester Group underlying the Pennsylvanian unconformity is oil-productive (Bado, 1959, p. 209). The term Okeene is proposed for the interbedded limestone and shale section which lies above the Parvin (as illustrated in figs. 54 and 55) and below the low-resistivity shale section (termed Springer by some geologists), the base of which is at 9,745 feet in the Texaco No. 1 Devereaux well (sec. 9, T. 17 N., R. 14 W., Dewey County) and at 8,648 feet in the Continental No. 1 Kimball well (sec. 34, T. 20 N., R. 16 W., Major County).

In southern Blaine County, the base of the low-resistivity shale is thought to be at 12,215 feet in the Sunray Mid-Continent No. 1 Baker "A" well and at 10,025 feet in the Texaco No. 1 Sallstrom well (pl. IX) although these two tests did not drill into the Meramec Group and, therefore, correlation of the Chester Group is uncertain.

As shown on the cross sections (fig. 54, pl. IX) a section of low-resistivity shale with thin interbeds essentially of limestone rests upon the Okeene? or upon the section which is referred to by local geologists as "correlatable Chester." The shale is termed Springer by some geologists because it exhibits low electrical resistivity and it lithologically resembles the Springer Shale in the southern part of the State. The limestone interbeds are normally dark gray or brown, fine crystalline and argillaceous, at places silty and finely oölitic. In the Northeast Seiling Field (T. 20 N., R. 16 W., Major County), a 125-foot section of light-colored limestone in the Continental No. 1 Kimball, 8,365-8,490 feet is oölitic at the top and is described as being fine- to very coarse-

crystalline, porous and dense, containing crinoids and brachiopods. A few 1- to 3-foot-thick beds of calcareous shale (Riley Reproduction log no. OC-25269) rest upon low-resistivity shale, which contains thin interbeds of limestone. The limestone is gas-productive and has been known as the Kimball zone, named after the lease on which Continental made the discovery in 1952. The limestone is referred to the Chester Group although it is not known that the age of fossils has been determined. *Archimedes* was noted at 8,500 feet. It is suggested, again informally, that the rock section from the base of the low-resistivity shale to the top of the productive limestone be called the Kimball zone (fig. 54). Some geologists believe that the sandstones contained within the section of low-resistivity shale are Mississippian rather than Morrowan in age. They would therefore place the system unconformity at the higher position shown in the two southern wells on plate IX and refer the entire sequence below the unconformity to the top of the Okeene? to the Kimball zone.

The productive reservoirs in Northwest and Northeast Okeene and North Cooper Fields are at several levels in the Chester Group and will be discussed later under their respective fields.

PENNSYLVANIAN SYSTEM

The Pennsylvanian System in Blaine County is essentially a sequence of alternating interbedded limestone, sandstone, siltstone, and shale with a few beds of coal. The characteristics of the Pennsylvanian rocks of northern Blaine County are illustrated in figure 56 by lithologic and electric logs in a columnar section of the Superior No. 81-17 Norris well in T. 19 N., R. 10 W. Rocks of Desmoinesian age, 550 feet thick, rest unconformably upon the Chester Group of Late Mississippian age, and are overlain successively by those of Missourian and Virgilian age, comprising a total thickness of approximately 3,700 feet of Pennsylvanian section.

In southern Blaine County, rocks, termed Atoka and Morrow by many geologists, onlap the Mississippian erosion surface and wedge out below those of Desmoinesian age. The wedging is the result of truncation by pre-Atokan and pre-Desmoinesian erosion and of depositional thinning during transgression. Placements of the base of the Des Moines unit and of the tops of Atoka, Morrow, and Mississippian units are all uncertain and subjects of controversy among geologists. The Texaco No. 1 Sallstrom well (fig. 53, pl. IX) in the South Watonga Field is approximately 12 miles northeast of the Sunray Mid-Continent No. 1 Baker "A" well at Squaw Creek. These wells have Pennsylvanian rock sections which are older than those in the Superior No. 81-17 Norris well in the northeast township of the county. The additional section in the Sallstrom well amounts to about 400 feet, and the Baker "A" well to 1,200 feet.

Because of the sparsity of well control between the northern and southern wells, there is little agreement among geologists on how to correlate the section below the Red Fork sand zone (pl. IX). The sandstone below 9,750 feet in the Sallstrom well is termed variously as Morrow, Springer, or Mississippian. Many geologists place the top of the Chester where the top of the Okeene? is placed on the cross section of plate IX. Others would place the top of the Mississippian at the base of the sandstone section and some would place it as high as 9,720 feet in the Sallstrom well and 11,615 feet in the Baker "A" well. Although neither the top nor the bottom of the sequence can be placed with certainty at this time, thickness of Pennsylvanian rocks increases from 3,700 feet in northern Blaine County to probably more than 6,500 feet in the southern part of the county. The total rock section increases both because of thickening of individual groups of formations and because of addition of older formations at the base. The older formations probably include those of the Des Moines, Atoka, and Morrow, some of which wedge out in a northeasterly direction approximately along a line trending south-southeast through, or near, Watonga (fig. 53).

ROCKS OF MORROWAN AGE

In northwestern Oklahoma, the shale and sandstone section below the base of the Thirteen-finger lime to the top of Mississippian rocks is called the Morrow formation by most Oklahoma geologists. In southwestern Kansas, the name Kearny Formation was proposed formally for the subsurface rock section by Thompson (1944, p. 414) when he described a 127-foot section of cores and rock cuttings from 4,752 to 4,879 feet in the Stanolind Oil and

Gas No. 1 Patterson well, SE cor. sec. 23, T. 22 S., R. 38 W., Kearny County, Kansas. Thompson found fusulinids which are present in the Brentwood Limestone Member of the Bloyd Shale at the type locality of the Morrow in Arkansas. If, in the Sunray

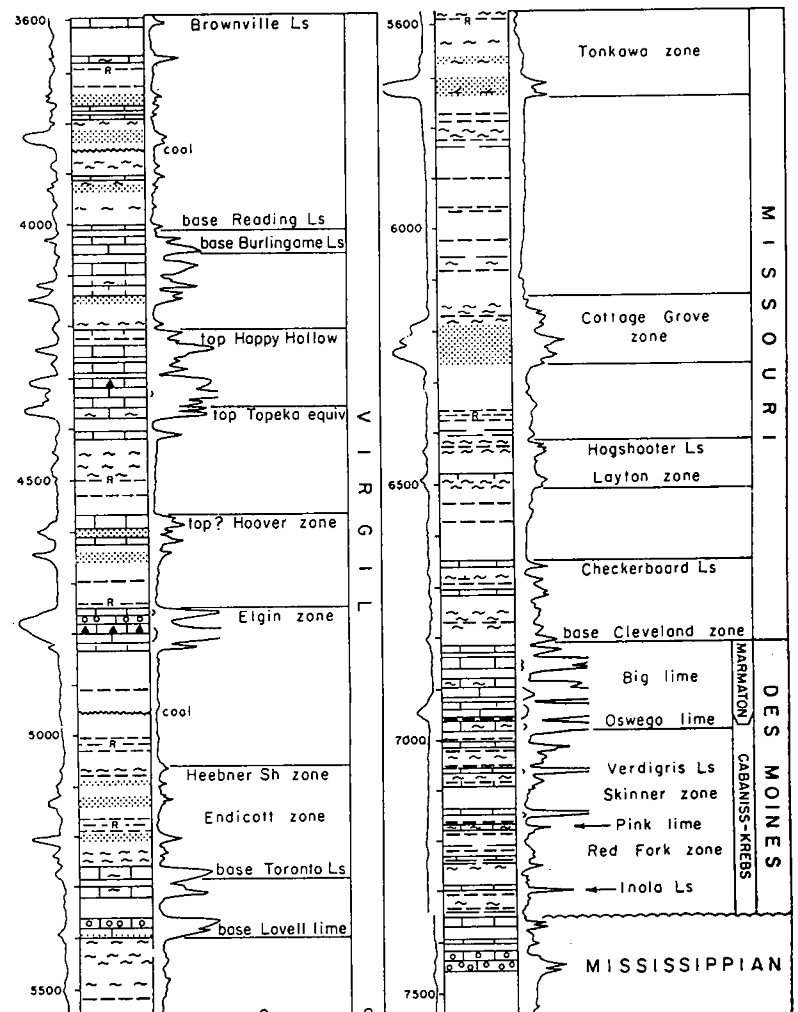


Figure 56. Columnnar section of Pennsylvanian rocks in the Superior No. 81-17 Norris (NE¼ NE¼ NE¼ sec. 17, T. 19 N., R. 10 W., northern Blaine County showing selected nomenclature of rock units. Lithologic description modified after Adkison (1960). Nomenclature by Gerald C. Maddox includes both formal and informal terms.

Mid-Continent No. 1 Baker "A" well (pl. IX), the unit from 11,355 to 11,435 feet is correlative to the Thirteen-finger lime, then the underlying section is probably Morrowan in age and could be called Kearny Formation.

As shown on plate IX, neither the top nor the base of the Kearny (Morrow) Formation is placed with any certainty. Two sandstone zones, "A" and "B", each of which was perforated for production, are present in the No. 1 Baker "A" well. Sandstones "A" are described as slightly glauconitic, and sandstones "B" are white and slightly calcareous. Zone "A" is apparently absent in the Texaco No. 1 Sallstrom well of the South Watonga Field. Some geologists place sandstone zones "A" and "B" in the Morrow, or call it Springer, whereas others place them in the Kimball? zone (as defined) of Mississippian age.

ROCKS OF DESMOINESIAN AND ATOKAN AGE

The base of the Des Moines unit, as indicated in the Baker "A" well (pl. IX), is questioned because geologists working in the area place the contact at the base of the Squaw Creek sand or at the base of the second limestone below the Squaw Creek sand at depths from 11,130 to 11,160 feet. Lower Desmoinesian fusulinids were found in this limestone. Jordan believes that some of the section below is in the Krebs Group and that the limestones correlate generally with the limestone section from 12,080 to 12,200 feet in the Denver Producing and Refining Company No. 1 Schoolland in sec. 16, T. 10 N., R. 9 W., which contains Cherokee fossils. The 200-foot section below 11,300 feet in the Baker "A" well may be all of Atokan age. Atokan fusulinids were found at 11,355 feet. In eastern Oklahoma the Boggy, Savanna, McAlester, and Hartshorne Formations underlie the Red Fork sand zone. It seems reasonable to expect that additional formations of the Krebs Group should be present in the thicker sedimentary section in the Anadarko basin. The problem will not be solved without fossil evidence.

The Des Moines unit, as defined, increases in thickness from 550 feet in the Norris well (sec. 19, T. 19 N., R. 10 W.) to approximately 2,000 feet in the Baker "A" well. Rate of regional dip at the top of the unit is 54 feet per mile and at the base is nearly 100 feet per mile. Average depth to the top of the unit ranges from

6,500 feet in the northeastern part of the county to more than 9,500 feet in the southwestern part. Gas production from the Des Moines unit includes that from Red Fork zone at Northwest Okeene Field and from the Squaw Creek pay at Squaw Creek Field.

ROCKS OF MISSOURIAN AND VIRGILIAN AGE

The rock section of Missourian and Virgilian age in northern Blaine County is illustrated in figure 56. It consists of alternating sequences of limestone, sandstone, and shale. Two coal beds were noted in the Virgil unit (fig. 56) by Adkison (1960). For the most part the shales are gray, but some beds of red-brown, olive-green, gray-green, grayish-black, and black shales are present. The Missouri-Virgil contact is uncertain and placement depends on whether or not the sandstone, called Tonkawa in this area, is equivalent to the Tonganoxie Sandstone of the surface. Adkison (1960) placed the top of the Missouri at 5,620 feet, a point above the sandstone termed Tonkawa; other geologists place the contact higher or lower than did Adkison.

The Missouri section increases in thickness at a rate of 8 feet per mile from approximately 1,200 feet in the northeast to 1,500 feet in the southwest part of the county, whereas the Virgil increases at a rate of about 11 feet per mile from 2,000 to about 2,400 feet.

Without more information, it seems unwise to present nomenclature for the stratigraphic section in the southern wells. Different terms are applied to the same unit by various operators. Correlation of formations and members in the Virgil unit from north to south is uncretain, but the radioactive Heebner Shale is a good marker bed. In the Missouri, the radioactive shale beds at and near the top of the Cottage Grove zone (the datum used in pl. IX) are reliable time markers.

A structure map (fig. 57) contoured at the top of the Hogshooter Limestone shows a regional southwesterly dip of 40 to 60 feet per mile. Small noses on the regional monocline are present at Northwest Okeene, North Cooper, and Southwest Lacey Fields, where control is more dense than in other areas. Gradual increase in dip is shown from northeast to southwest.

No hydrocarbon production has been found in the Virgil-Missouri section. A show of gas was obtained in a drill-stem test between 7,022 and 7,080 feet in the Sunray Mid-Continent No. 1 Baker "A" at Squaw Creek Field in sandstone about 200 feet above the Heebner Shale.

Permian System

Rocks of Wolfcampian, Leonardian, and Guadalupean age represent the Permian System in the subsurface of Blaine County.

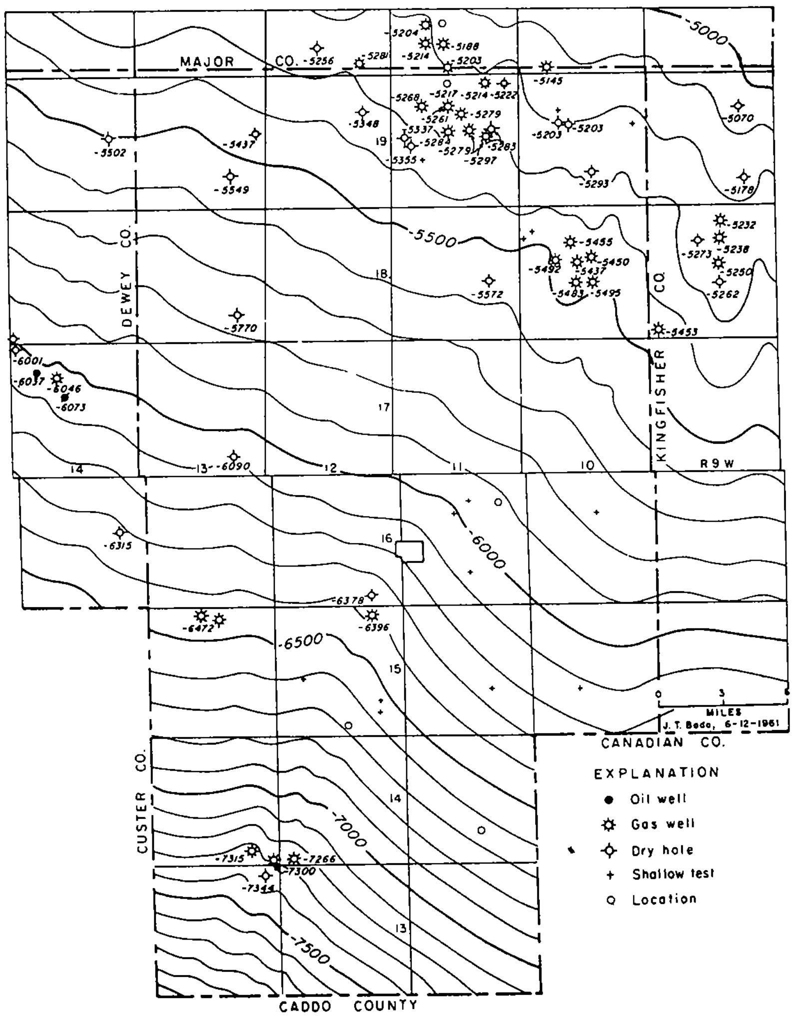


Figure 57. Structure map contoured at top of Hogshooter Limestone (Missourian in age). Contour interval is 100 feet.

Rock units in ascending order are: Admire, Council Grove, and Chase Groups, Wellington Formation, Garber-Hennessey-Flowerpot equivalent, Blaine Formation, Dog Creek Shale, and Marlow Formation. The rocks dip southwestward and except for the units below the Cedar Hills Member of the Hennessey, are exposed at the surface in Blaine County. The stratigraphic section in northern Blaine County where the Blaine Formation has been removed is illustrated by an electric log of the Pan American No. 1 Boeckman well to a depth of 2,735 feet (fig. 58). The lithologic log and the remainder of this section are from the Superior No. 81-17 Norris well. Flowerpot, Blaine, Dog Creek, and Marlow Formations in southwestern Blaine County are shown in the Texaco No. 1 Woodruff well (fig. 58).

Rocks of Wolfcampian age include the Admire, Council Grove, and Chase Groups (ascending order), which contain alternating sequences of limestone and shale with some sandstone, siltstone, and coal. Useful datum beds, which are surface-named formations or members, are indicated on figure 58. The thickness of the Wolfcampian rocks ranges from 1,100 feet in the northeast to 1,200 feet in the northwest, and to 1,600 feet in the southwest part of the county. No shows of oil or gas have been reported from this section.

The overlying Permian rock section of Guadalupean-Leonardian age includes evaporites (anhydrite and salt) in the Wellington Formation at the base and in the Blaine Formation near the top. These two formations are separated by a section of variegated red and red-brown shales containing minor amounts of sandstone and siltstone; this section is equivalent to the Garber, Hennessey, and Flowerpot Formations of the surface. Adkison (1960) logged beds of dolomite, limestone, anhydrite, and grayish-black shale, but none of these beds is sufficiently thick to be recorded by the gamma-ray and 16-inch normal laterolog curves of the Pan American No. 1 Boeckman well. Thus no bed exists within the section which can be used as a datum level. The thickness of the section from the base of the Wellington Formation to the base of the Blaine ranges from 2,950 feet (sec. 26, T. 19 N., R. 13 W.) to 3,300 feet (sec. 36, T. 14 N., R. 13 W.), 31 miles to the south. The thickness of the Wellington Formation, which is 1,180 feet at the north, increases less than 20 feet in this distance.

The base of the Permian is encountered at an average depth of 3,500 feet in the northeast, at 4,400 feet in the northwest, and at 5,600 feet in the southeast part of the county. Although hydrocarbons might be found in rocks of Wolfcampian age, it is doubtful that oil or gas will be discovered in younger rocks.

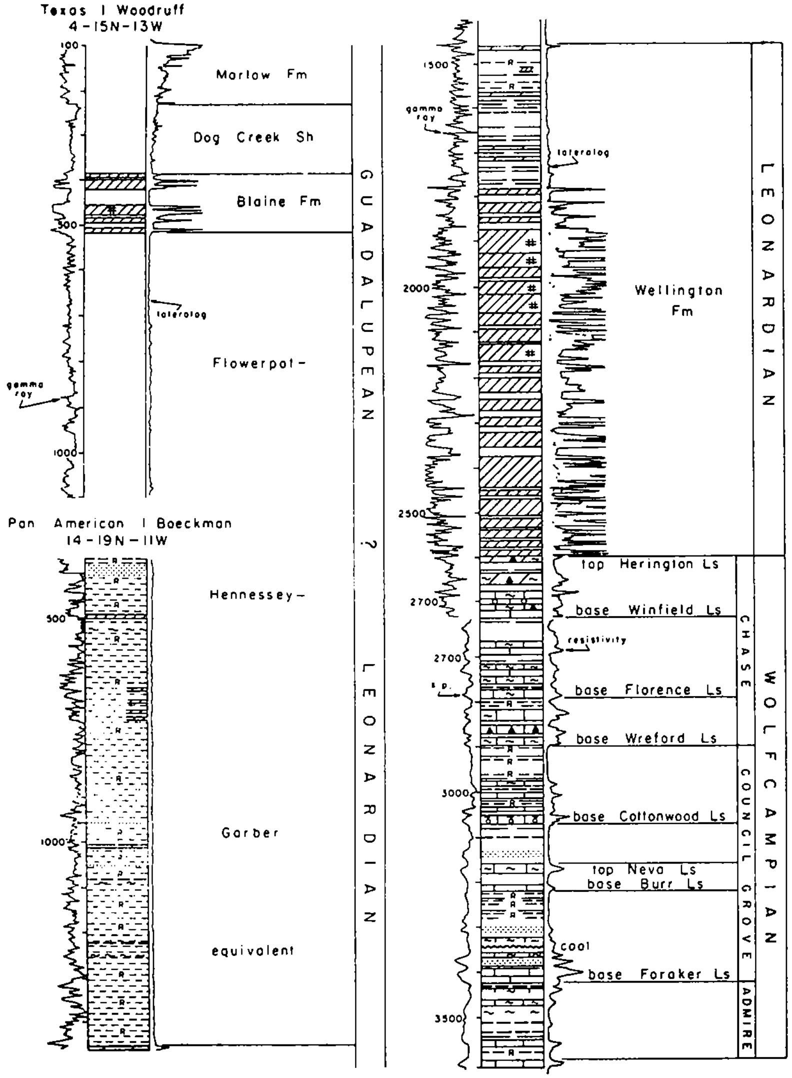


Figure 58. Columnar section of Permian rocks in Blaine County from the Texaco No. 1 Woodruff, of the East Fay Field, for the section including the Blaine formation; from the Pan American No. 1 Boechman to 2,730 feet, and Superior No. 81-17 Norris (sec. 17, T. 19 N., R. 10 W) from 2,620 to 3,600 feet. Lithologic description modified after Adkison (1960).

DEVELOPMENT AND PRODUCTION

Six fields, Northwest Okeene, Northeast Okeene, North Cooper, South Watonga, Squaw Creek, and East Fay, have been discovered in Blaine County since 1956 (fig. 53). None of the field areas has been defined entirely by dry holes in all directions. Gas wells are located on a 640-acre spacing pattern. Production has been established in the Red Fork sand (Des Moines), in sandstones called Morrow, and at several levels in the Chester limestone of Mississippian age.

No pipeline purchases of gas have been made in Blaine County. As of June 1961, the county had only one major pipeline, that of the Arkansas Louisiana Gas Company. It is laid from the west center of the county to the northeast corner. Pan American Petroleum Corporation had not committed any of its gas but was negotiating with Arkansas Louisiana Gas Company and with Oklahoma Natural Gas Company. Texaco, Inc., and Sunray Mid-Continent Oil Company, discoverers of the three fields in the southern part of the county, had committed some gas to Mustang Fuel Corporation, with the possibility of purchasing beginning within the next month (B. G. Barby, personal communication).

NORTHWEST OKEENE (NORTH HOMESTEAD) FIELD

Northwest Okeene Field in northern Blaine County and North Homestead Field in southern Major County (fig. 59) were discovered in 1956 and 1960, respectively. Development drilling on a 640-acre spacing pattern joined the areas of production. North Homestead was discontinued as a field name on June 22, 1961, and the combined producing area was designated Northwest Okeene Field. Gas production is from several porous limestones in the Chester Group of Late Mississippian age in all wells except two (secs. 2 and 14, T. 19 N., R. 11 W.) where gas was found in the Red Fork sand zone of early Middle Pennsylvanian age (table 13). A few wells produce dually from Red Fork and Chester.

John Coyle and Perkins Bros. No. 1 Dougherty well (sec. 10, T. 19 N., R. 11 W.) established the first commercial production for the county in the discovery of Northwest Okeene Field. The well was drilled to a total depth of 8,895 feet into Hunton limestone. A drill-stem test from 8,833 to 8,842 feet recovered 8,100 feet of gas-cut salt water, and the well was abandoned in August 1956. One month later the hole was re-entered by the same operators, and, after repeated drill-stem tests of sections in the Inola and Chester limestones, possible gas production was indicated. The well was completed on October 10, 1956, wih 5.5-inch casing set at 7,795 feet and perforated in four intervals in the Okeene and Parvin zones (Chester Group) (table 13).

In March 1961, a new productive zone was discovered when Pan American No. 1 Worley Unit (sec. 2, T. 19 N., R. 11 W.) was completed, flowing 15.8 million cubic feet of gas per day from Red Fork pay, a sandstone of Middle Pennsylvanian age (Krebs Group, Des Moines) between 7,212 and 7,216 feet. The position of the sandstone in the Pennsylvanian section is shown on figure 55, where

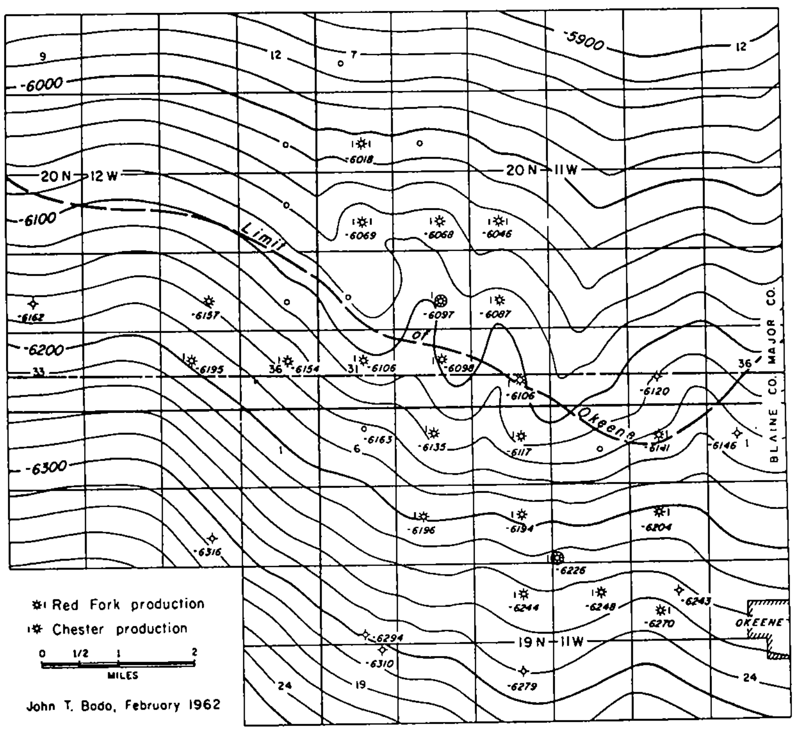


Figure 59. Map of Northwest Okeene Field area contoured at Mississippian-Pennsylvanian angular unconformity. Contour interval is 20 feet. Discovery well of Northwest Okeene in sec. 10, T. 19 N. R. 11 W., and that of the former North Homestead Field in sec. 29, T. 20 N., R. 11 W., are shown by circles. Dashed line is northern extent of Okeene zone limestone (division of Chester Group).

a type section of Mississippian productive zones is illustrated by gamma-neutron, gamma, and self-potential-resistivity logs from the Northwest Okeene Field. Most of the production, except for that from the Red Fork, is from Okeene, Parvin A and B zones, but two wells are perforated in the Parvin C and Manning A zones (fig. 55).

North Homestead was discovered by the Pan American No. 1 Reames Unit (sec. 29, T. 20 N., R. 11 W.), which was drilled to evaluate the prospects of Hunton production north of Northwest Okeene Field. The Hunton dolomite was found non-productive and the well was plugged back to establish gas production in the Parvin A zone (Okeene zone being absent) of the Chester Group. The well, completed in August 1960, had an open-flow potential of 7.2 million cubic feet per day.

Figure 59 is a map of the Northwest Okeene (North Home-

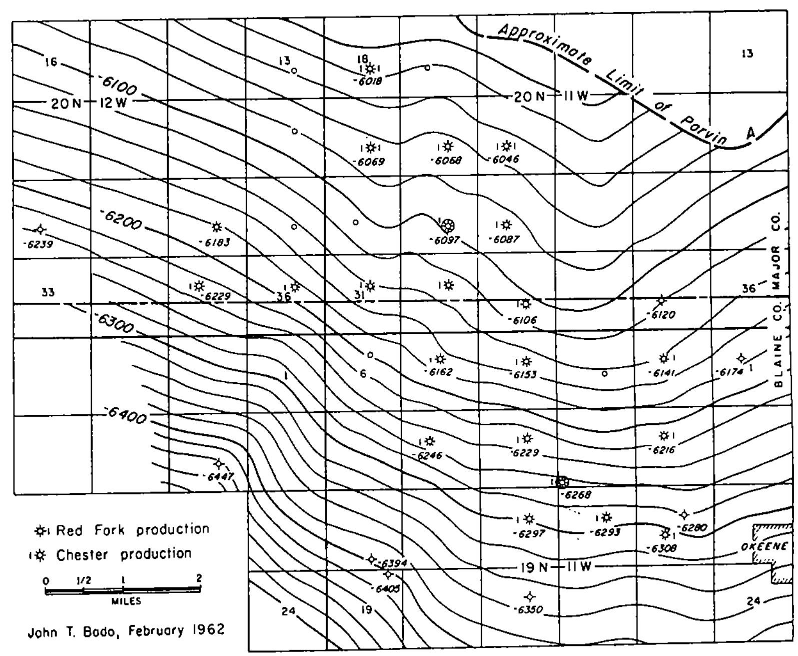


Figure 60. Structure map of Northwest Okeene Field area contoured at the top of the Parvin A zone (see fig. 55 for definition of Parvin A zone). Contour interval is 20 feet.

stead) area contoured at the Mississippian-Pennsylvanian unconformity. Figure 60 is a structure map of the area contoured at the top of the Parvin A zone. Because none of the wells has been connected to pipelines, it is not possible to judge true capacity, but Mississippian production does not seem to be related to the structural position of the unconformity, the configuration of which is based on control points one mile apart. Pan American No. 1 Blankenship unit (sec. 4, T. 19 N., R. 11 W.), with a calculated open-flow of 43 million cubic feet per day, is the best well as indicated by data on potentials. Porosity and permeability of the limestone are probably the controlling factors which determine the extent of the reservoir.

Table 13 (pages 182-187) is a summary of the development history of the two fields.

North Cooper Field

Gulf Oil Corporation-John Coyle No. 1 Clester well (sec. 15, T. 18 N., R. 10 W.), discovery well of North Cooper Field, was

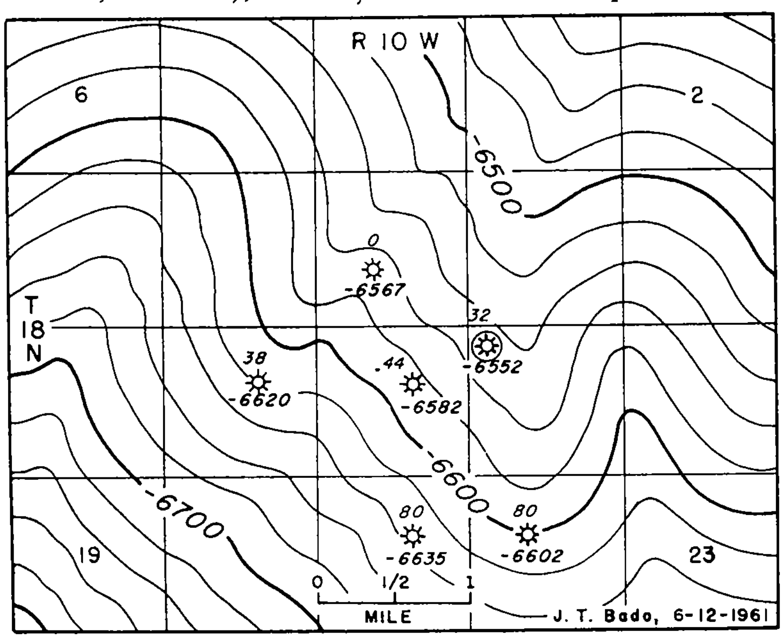


Figure 61. Map of North Cooper Field area contoured at Mississippian-Pennsylvanian unconformity. Contour interval is 20 feet. Discovery well is circled. Number above well location is thickness of Chester rocks (Mississippian) above top of Parvin A zone.

completed in December 1957, with perforations in the Parvin A zone. Initially it flowed 2,150 MCF of gas per day plus 16.8 barrels of 62.4°-gravity condensate per million. The No. 1 Clester, drilled to a total depth of 7,940 feet in the Parvin C zone, was perforated in Parvin B and C limestones, which failed to produce but gave slight shows of gas. The well was plugged back to 7,800 feet and perforated in the Parvin A zone, resulting in the discovery.

The Okeene zone is present in all wells except the Humble No. 1 Haworth (sec. 9). This zone has been perforated and tested only in the Eason Oil No. A-1 Clester well.

Figure 61 is a map contoured at the Mississippian-Pennsylvanian unconformity. The discovery well in sec. 15 is at the highest known elevation of the unconformity, but the initial potential of the Gulf No. 1 Pavlu well, sec. 16 to the southwest, far exceeded that of any other well. Table 14 (page 188) is a summary of development data for the field.

Squaw Creek Field

Squaw Creek Field is approximately 11 miles northeast of Weatherford and 17 miles southwest of Watonga (fig. 53). In October 1959, Sunray Mid-Continent Oil Company completed the No. 1 Baker (C SE¼ SE¼ sec. 36, T. 14 N., R. 13 W.) as the discovery well with an initial potential of 3.1 million cubic feet of gas daily on 11/64-inch choke with 177 barrels of 53.2°-gravity condensate per million. A calculated open flow of 41 million cubic feet per day was also reported on a 10/64-inch choke.

At a depth of 10,806 feet, a blowout of gas occurred, which was gauged at 4 million cubic feet per day. After experiencing continued gas-pressure problems, the drill pipe was cemented in the hole and cut off, and 1.5-inch tubing was set at 10,330 feet. The well was completed from 10,776 to 10,806 feet in sandstone, now termed Squaw Creek, which is considered to be in the Krebs Group of Desmoinesian age (or Cherokee, as it is called in most of northern and western Oklahoma).

Upon completion of the discovery, the Sunray Mid-Continent No. 1 Baker "A" well was drilled in C SW¼ SE¼, sec. 31, T. 14 N., R. 12 W. (pl. IX), to a total depth of 12,485 feet into rocks of the Chester Group. Drill-stem tests of the Squaw Creek pay recovered slightly gas-cut mud. Drill-stem tests of sandstones between 11,607 and 11,690 feet and between 11,834 and 12,051 feet gave good indication of gas. After reaching the total depth, 7⅝-inch casing was set at 10,644 feet and a 5-inch liner was run from 10,032 to 12,040 feet. The sandstones, termed Morrow, were perforated between 11,665 and 11,680 feet, 11,754 and 11,761 feet, and 11,847 and 11,856 feet. After clean-up with mud acid, the No. 1 Baker "A" well was completed on March 23, 1960, as a new-zone discovery with an initial potential flow of 603,000 cubic feet of gas per day through 16/64-inch choke.

On the electric and lithologic logs of this well (pl. IX), the sandstones are placed tentatively in the Morrow with both the top and base of the unit in question. Some geologists believe that the sandstone zones A and B or B only are of Mississippian age. On plate IX, two possible locations of the Mississippian-Pennsylvanian unconformity are shown. Other geologists place the unconformity even lower in the section.

Sunray Mid-Continent No. 1 Baker "B" (C SE¼ NW¼, sec. 1, T. 13 N., R. 13 W.) was drilled to a total depth of 12,350 feet into Chester rocks. Perforations in the Squaw Creek pay from 10,717 to 10,740 feet indicated a capability of flowing 325,000 cubic feet of gas per day with 8 barrels of condensate and 120 barrels of salt water per day through 20/64-inch choke. Testing through perforations of the sandstones termed Morrow from 11,496 to 11,504 feet and 11,720 to 11,730 feet gave only slight indications of gas, The No. 1 Baker "B" was considered noncommercial and was plugged on November 28, 1960.

On February 15, 1961, Sunray Mid-Continent No. 1 Baker "C" (C SE¼ NE¼, sec. 35, T. 14 N., R. 13 W.), fourth well in the field, was completed as a Squaw Creek gas well, flowing 270,000 cubic feet of gas per day plus 18 barrels of condensate per day from perforations between 10,612 and 10,648 feet. No further development has been indicated in the field area.

South Watonga Field

South Watonga Field, approximately three miles southwest of Watonga, contains one gas producer and is offset one mile to the north by a dry hole (fig. 53).

Texaco No. 1 Sallstrom well (C SW¼ NE¼ sec. 2, T. 15 N., R. 12 W.), drilled to a total depth of 10,253 feet into rocks of Mississippian age, was completed in July 1960. During drilling and coring between 9,610 and 9,690 feet, the well nearly blew out. Cores taken from 9,615 to 9,655 feet were essentially a light-gray to white, slightly glauconitic and slightly calcareous sandstone, which contained asphaltic stain. Near the base of the sandstone section, at 9,720 feet, coarse-grained sandstone or very fine-grained gravel is reported to be present. The stratigraphic position of the sandstone is uncertain.

Sandstone interbedded with gray shale between 9,750 and 9,807 is described as being medium grained to fine grained, well cemented and slightly oil stained. Various indications of gas were present between 9,783 and 9,878 feet and in Chester limestone from 10,110 to 10,136 feet during drilling.

Production was established on March 23, 1960, in the lower sandstone, called Morrow by many geologists, with perforations from 9,784 to 9,764 feet, 9,766 to 9,788 feet, and 9,798 to 9,807 feet. The calculated open-flow potential was reported as 5,500,000 cubic feet of gas per day with 41 barrels of 55°-gravity condensate per million cubic feet of gas.

A second test, Texaco No. 1 Balenti Unit, drilled one mile north in center of NW¼ SE¼, sec. 35, T. 16 N., R. 12 W., was abandoned as a dry hole in November 1960. The total sandstone section of 197 feet in the No. 1 Sallstrom, which contained gas at two levels, amounted to 136 feet in the No. 1 Balenti.

East Fay Field

Texaco, Inc., discovered the East Fay Field in January 1961 with the completion of its No. 1 Woodruff well (C SW¼ NE¼ sec. 4, T. 15 N., R. 13 W.), which was drilled to a total depth of 10,428 feet into rocks of the Chester Group. The productive sandstone, termed Morrow, is 23 feet thick and at a depth of 10,220 feet. Perforations from 10,220 to 10,240 feet produced a flowing potential of 7,021,000 cubic feet of gas plus 336 barrels of 55°-gravity condensate in 24 hours. The well has a shut-in pressure of 5,970 pounds and flowing tubing pressure of 3,300 pounds.

A southeast offset, the No. 1 Winter well (NE¼ SW¼ sec. 3, T. 15 N., R. 13 W.), was being completed in sandstone at 10,340 to 10,348 and 10,356 to 10,362 feet. As of June 1961 a reported flowing test indicated 5,100,000 cubic feet of gas plus 48 barrels of condensate per day through a 11/64-inch choke. The reservoir is stratigraphically lower than that of the discovery well.

Northeast Okeene Field

A discovery of gas production from Chester rocks was established in late June 1961 by the Pan American No. 1 Fleshman Unit (SE¼ NE¼ SW¼ sec. 32, T. 20 N., R. 10 W.), about 5 miles northeast of the nearest Chester production.

Open-hole completion with 4.5-inch casing set at 7,303 feet and with total depth of 7,339 feet gave an open-flow potential of 1.98 million cubic feet of gas per day from the Parvin B zone. The top of the Parvin B zone (top of Mississippian section in the well) is at 7,300 feet and that of the Parvin C is at 7,330 feet.

RECENT DEVELOPMENT, JULY 1961 TO FEBRUARY 1962

Since completion of the report in July 1961, three significant tests have been drilled and completed in Blaine County. Texaco, Inc., discovered the Northeast Watonga Field at the location in T. 16 N., R. 11 W. (fig. 57). The No. 1 Swanegan (C SE¼ NE¼ sec. 11), was bottomed at 9,400 feet, penetrating the top of the Mississippian at 9,185 feet, according to the operators. The Chester limestone, Okeene? zone, was recahed at 9,242 feet, but the top of the Mississippian may be as high as 9,090 feet.

During drilling of the hole, a drill-stem test of the Oswego lime recovered only mud. The Red Fork zone between 8,780 and 8,790 feet was tested through perforations with a reported recovery of 6 barrels of condensate with 810,000 cubic feet of gas in 18 hours through a ¼-inch choke. This zone was squeezed off. The producing zone, a sandstone called Cherokee by the operators, was encountered between 9,020 and 9,090 feet. This sandstone may be equivalent in part to that between 9,608 and 9,722 feet in the Texaco No. 1 Sallstrom (pl. IX). A 7-inch liner was hung between 8,275 and 9,123 feet and perforations were made in the intervals between 9,033 and 9,044, 9,052 and 9,064, and 9,071 and 9,077 feet. The potential test is reported as gas flowing at a rate of 5.4 million

cubic feet per day with 62 barrels of 56°-gravity condensate. Shut-in tubing pressure was 6,200 psi.

The location shown on figure 57 in the southern part of T. 15 N., R. 12 W., is that of Texaco, Inc., No. 1 Ruth (C NE¼ SW¼ sec. 34), discovery well of West Greenfield Field. After drill-stem testing of the section called Verdigris between 9,535 and 9,623 feet without success, perforations were made in sandstones termed Morrow at depths between 10,484 and 10,490, 10,513 and 10,522, and 10,528 and 10,535 feet. The production gauged 691,000 cubic feet of gas with 1 barrel of 58°-gravity condensate and 37 barrels of water in 24 hours through a 16/64-inch choke with flowing tubing pressure of 1,200 psi. The total depth at 11,011 feet was in Chester limestone and shale, with the top of the Okeene? zone at 10,945 feet. Atokan fusulinids were found in the limestone between 10,310 and 10,330 feet.

The third test, Sunray Mid-Continent Oil Company No. 1 McNeely-Fahl (NE¼ NE¼ SW¼ sec. 27, T. 14 N., R. 11 W.), was drilled into the Hunton Group of Devonian-Silurian age to a total depth of 13,340 feet. Gas-cut mud was obtained in a drill-stem test of the Oswego section between 9,750 and 9,900 feet. Tests through perforations in sandstones, called Morrow by the operator, at depths between 10,812 and 11,028 feet revealed gas shows mostly less than 200,000 cubic feet per day. The well was plugged as non-commercial. This test (elevation: 1,550 feet) gives the only information on depths to and thickness of pre-Pennsylvanian units in southern Blaine County. Depths to the tops of these units are as follows: Kimball? zone, 10,950? feet; Okeene? zone, 11,335 feet; Meramec, 12,345 feet; Woodford, 13,100 feet, and Hunton, 13,265 feet.

In the East Fay area, a test drilled in sec. 10, T. 15 N., R. 13 W., resulted in a dry hole. A wildcat drilled in sec. 30, T. 19 N., R. 12 W., was unsuccessful. Two wildcats, drilling in February 1962, several miles from production, were the Texaco test in sec. 8, T. 14 N., R. 12 W., and the Pan American test in sec. 5, T. 17 N., R. 12 W.

Development drilling in Northwest Okeene since June 1961, caused Bado to revise figures 59 and 60 and table 13. Figures 53 and 57 were not changed and therefore more wells are shown on figures 59 and 60. Data for 1961 were added to table 10.

TABLE 13.—DEVELOPMENT HISTORY, NORTHWEST OKEENE FIELD

Operator- Well name- Completion date-	Location- Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth- Deepest formation penetrated- Remarks-
John W. Coyle & Perkins Bros. No. 1 Dougherty October 10, 1956	SW SW SW 10-19N-11W 1,252 KB	Okeene 7,478 Parvin A 7,520 Parvin B 7,590 Meramec 8,210 Hunton 8,820	7,486-7,494 7,526-7,536 7,544-7,554 7,556-7,562	6 10 10 6	F 2,800 MCFG in 4 hrs thru 54/64" Zones commingled	8,895 Hunton Discovery well NW Okeene Field
Perkins Bros. No. 1 Robinson February 19, 1957	NE SW NE 9-19N-11W 1,241 KB	Okeene 7,435 Parvin A 7,470 Parvin B 7,540 Parvin C 7,580 Manning A 7,673	7,444-7,446 7,450-7,458 7,471-7,475 7,478-7,482 7,487-7,497 7,542-7,572 7,583-7,593 7,679-7,689	2 8 4 4 10 30 10 10	F 7,224 MCFGPD thru 20/64" choke Zones commingled	7,795 Chester
Perkins Bros. No. 1 Brickman April 23, 1957	SW NE 15-19N-11W 1,252 KB	Okeene 7,500 Parvin A 7,545 Parvin B 7,613 Parvin C 7,655 Manning A 7,759	7,512-7,518 7,534-7,544 7,550-7,556 7,560-7,570 7,576-7,582 7,588-7,598 7,618-7,628 7,630-7,640 7,646-7,652 7,674-7,684 7,764-7,770	6 10 6 10 6 10 10 10 6 10 6	F 5,300 MCFGPD thru 3/4" choke Zones commingled	7,878 Chester
Pan American No. 1 Outhier unit December 23, 1957	SE NW 8-19N-11W 1,274 KB	Okeene 7,470 Parvin A 7,520 Parvin B 7,590	7,522-7,526 7,542-7,546	4 4	F 2,740 MCFGPD thru 1/8" choke	7,804 Chester

Operator- Well name- Completion date-	Location- Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth- Deepest formation penetrated- Remarks-
Pan American No. 1 Kramer unit January 7, 1958	SW NE 16-19N-11W 1,256 DF	Okeene 7,500 Parvin A 7,553 Parvin B 7,630	7,503-7,509 (?) 7,559-7,563 7,586-7,592	6 4 6	F 680 MCFGPD Zones commingled	7,797 Chester
Pan American No. 1 Boeckman January 7, 1958	SW NE 14-19N-11W 1,250 DF	Okeene 7,495 Parvin A 7,530 Parvin B 7,590 Manning A 7,738 Meramec 8,170	7,504-7,509 7,532-7,537		Dry and abandoned	8,500 Meramec Swab water
Pan American No. 1 Worley unit March 10, 1961	SE NW 2-19N-11W 1,219 DF	Red Fork 7,207 Parvin A 7,360 Parvin B 7,400 Parvin C 7,443 Manning A 7,542 Manning B 7,610 Manning C 7,695 Manning D 7,760 McWillie 7,857 Meramec 7,980 Hunton 8,583	7,212-7,216	4	COF 15,800 MCFGPD	8,740 Hunton New zone (Red Fork) discovery
Perkins Production No. 1 Weber March 10, 1961	SW NE SW 14-19N-11W 1,250 KB	Red Fork 7,358 Okeene 7,520 Parvin A 7,558 Parvin B 7,623	7,360-7,378	18	COF 3,900 MCFGPD 24/64" choke	7,797 Chester
Pan American No. 1 Strickler unit May 12, 1961	SE NW 1-19N-11W 1,276 KB	Red Fork 7,249 Okeene 7,422 Parvin A 7,450			Dry and abandoned	7,501 Chester
Pan American No. 1 Blankenship unit June 29, 1961	SW NE 4-19N-11W 1,244 KB	Okeene 7,361 Parvin A 7,397	7,390-7,394 7,418-7,422	4 4	COF 43,000 MCFGPD	7,500 Chester
Sun Oil No. 1 Kratz August 4, 1961	SE NW 11-19N-11W 1,250 KB	Red Fork 7,303 Okeene 7,454 Parvin A 7,466 Parvin B 7,524 Parvin C 7,560	7,306-7,328	22	COF 3,400 MCFGPD	7,650 Chester

TABLE 13 (cont.)

Operator- Well name- Completion date-	Location- Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth- Deepest formation penetrated- Remarks-
Perkins Bros. No. 1 Laubach July 14, 1961	SW NE 21-19N-11W 1,266 KB	Okeene 7,545 Parvin A 7,616 Parvin B 7,696 Parvin C 7,739			Dry and abandoned	7,800 Chester
Pan American No. 1 Straeder unit October 18, 1961	NW SW NE 5-19N-11W 1,262 KB	Okeene 7,397 Parvin A 7,424 Parvin B 7,482	7,470-7,473	3	COF 12,800 MCFGPD	7,530 Chester
Pan American No. 1 Outhier unit February 15, 1962	C W/2 NE 6-19N-11W 1,288 KB	Okeene 7,451				In process of completion
Sun Oil No. 1 Bedwell February 14, 1962	NW SE 3-19N-11W 1,223 KB					7,520 Running electrical surveys
Pan American No. 1 Reames unit August 10, 1960	NW SE 29-20N-11W 1,259 KB	Parvin A 7,356 Parvin B 7,398 Parvin C 7,440 Manning A 7,527 Manning B 7,596 Manning C 7,658 Manning D 7,724 McWillie 7,822 Meramec 7,944 Hunton 8,597	7,378-7,390	12	COF 7,200 MCFGPD	9,046 Hunton Discovery well N Homestead Field
Pan American No. 1 Freed unit November 30, 1960	NE SW 28-20N-11W 1,248 KB	Parvin A 7,335	7,335-7,474		COF 4,700 MCFGPD	7,474 Chester Open hole
Pan American No. 1 Hendricks unit April 19, 1961	NW SE 20-20N-11W 1,251 DF	Parvin A 7,319	7,322-7,402		COF 2,850 MCFGPD	7,402 Chester Open hole

Operator- Well name- Completion date-	Location- Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth- Deepest formation penetrated- Remarks-
Pan American No. 1 Reames unit "B" February 22, 1961	NW SE 33-20N-11W 1,251 DF	Parvin A 7,357	7,359-7,411		COF 15,900 MCFGPD	7,411 Chester Open hole
Pan American No. 1 Bergmann unit August 2, 1961	NE SW 21-20N-11W 1,246 KB	Red Fork 7,158 Parvin A 7,292 Parvin B 7,306	7,178-7,181 }7,293-7,320	3 }27	Red Fork COF 1,070 MCFGPD Chester COF 1,970 MCFGPD	7,420 Chester
Pan American No. 1 Brown unit "H" August 23, 1961	NW SE 19-20N-11W 1,273 KB	Red Fork 7,206 Parvin A 7,342 Parvin B 7,366 Parvin C 7,411	7,215-7,219 7,344-7,348 7,352-7,354 7,368-7,371 7,380-7,383 7,390-7,394 7,410-7,414	4 }20	Red Fork COF 1,800 MCFGPD Chester COF 12,000 MCFGPD	7,477 Chester
Pan American No. 1 Reames unit "D" August 16, 1961	NE SW 35-20N-11W 1,210 KB	Red Fork Parvin A 7,330 Parvin B 7,370 Parvin C 7,420	7,194-7,198 7,330-7,333 7,343-7,346 7,354-7,357 7,372-7,375		Dry and Abandoned	7,460 Chester
Pan American No. 1 Reames unit "C" September 6, 1961	SW NE 32-20N-11W 1,261 KB	Okeene? 7,359	7,360-7,363 7,372-7,375 7,402-7,406	3 3 4	COF 11,200 MCFGPD	7,495 Chester
Kingwood Oil No. 1 Krause November 17, 1961	NW SE 18-20N-11W 1,264 KB	Red Fork 7,143 Parvin A 7,282 Parvin B 7,300 Parvin C 7,340 Manning A 7,420 Manning B 7,486	7,147-7,172 7,283-7,293 7,304-7,319 7,334-7,340	25 10 15 6	Red Fork COF 2,465 MCFGPD Chester COF 4,830 MCFGPD + 2.25 bbls condensate per hr	7,549 Chester
Livingston Oil No. 1 Smith "A"	NE NE SW 30-20N-11W					"Tight" hole, reported as a completed well

TABLE 13 (cont.)

Operator- Well name- Completion date-	Location- Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth- Deepest formation penetrated- Remarks-
Kingwood Oil No. 1 Thomas January 11, 1962	SW NE 31-20N-11W 1,292 KB	Okeene? 7,398	7,406-7,410 7,422-7,433 7,440-7,446 7,450-7,472	4 11 6 22	COF 27,000 MCFGPD	7,553 Chester No electric log available
Pan American No. 1 Foote unit	NE SW 7-20N-11W					Location January 19, 1962
Pan American No. 1 Wiens unit "A"	NE SW 17-20N-11W					Drilling below 757 feet, January 28, 1962
Pan American No. 1 Brewer unit February 26, 1958	NE SW 28-20N-12W 1,461 KB	Okeene 7,623 Parvin A 7,700 Parvin B 7,770 Parvin C 7,820	7,705-7,708 7,712-7,717		Failed to produce	7,902 Chester
Pan American No. 1 Nichols unit April 26, 1961	NE SE NW 35-20N-12W 1,334 KB	Okeene 7,529 Parvin A 7,563 Parvin B 7,627 Parvin C 7,678 Manning A 7,757 Manning B 7,820 Manning C 7,854 Manning D 7,938 McWillie 8,032 Meramec 8,177 Hunton 8,860	7,530-7,544 7,564-7,582	14 18	COF 735 MCFGPD	9,410 Sylvan

Pan American No. 1 Weaver unit August 16, 1961	SW NE 36-20N-12W 1,306 KB	Okeene ? 7,460	7,463-7,466 7,490-7,493 7,528-7,531 7,483-7,486 7,506-7,509	3 3 3 3 3	COF 11,000 MCFGPD	7,635 Chester No electrical survey available
Pan American No. 1 Nightingale unit October 25, 1961	NW SE 26-20N-12W 1,317 KB	Okeene 7,474 Parvin A 7,500 Parvin B 7,562	7,477-7,480 7,508-7,511 7,564-7,567	3 3 3	COF 2,400 MCFGPD	7,604 Chester
Eason Oil No. 1 Ewing unit	SW NE 24-20N-12W					7,487 Chester In process of completion
Oklahoma Natural No. 1 Houk	NW SE 13-20N-12W					Location January 22, 1962
Pan American No. 1 Weaver unit "B"	NW SE 25-20N-12W					Drilling below 3,000 feet February 14, 1962

TABLE 14.—DEVELOPMENT HISTORY, NORTH COOPER FIELD

Operator-Well name-Completion date-	Location-Elevation (feet)-	Depth to top of unit (feet)	Perforations	Amount of Pay (feet)	Initial potential	Total depth-Deepest formation penetrated-Remarks-
John Coyle-Gulf Oil No. 1 Clester December 10, 1957	NW NW NW 15-18N-10W 1,148 DF	Okeene 7,700 Parvin A 7,732 Parvin B 7,819 Parvin C 7,850	7,732-7,761 7,761-7,790 7,820-7,840 7,850-7,862 7,876-7,885	29 29 0* 0** 0**	F 2,150 MCFGPD + 16.8 bbls condensate (62.4°) per MM	7,940 Chester Discovery well North Cooper Field
Gulf Oil No. 1 Pavlu May 21, 1958	SW NE 16-18N-10W 1,149 DF	Okeene 7,731 Parvin A 7,775 Parvin B 7,868 Parvin C 7,900 Manning A 8,045 Manning B 8,100	7,776-7,828 8,102-8,116	52 0*	F 9,576 MCFGPD + 5 bbls condensate per MM	8,170 Chester
Eason Oil No. 1 Clester Unit February 11, 1959	SE NW 22-18N-10W 1,178 KB	Okeene 7,780 Parvin A 7,860	7,882-7,922	40	F 3,400 MCFGPD + 11 bbls condensate per MM	8,000 Chester Log to 7,870
Eason Oil No. A-1 Clester May 6, 1959	SW NE 21-18N-10W 1,169 KB	Okeene 7,804 Parvin A 7,884 Parvin B 7,965 Parvin C 8,030	7,804-7,810 7,820-7,828 7,840-7,864 7,884-7,916	6 8 24 32	F 1,000 MCFGPD	8,051 Chester
Humble Oil No. 1 Haworth July 27, 1960	NE SW 9-18N-10W 1,151 KB	Parvin A 7,718 Parvin B 7,811 Parvin C 7,860	7,720-7,760	40	F 1,400 MCFGPD	7,900 Chester
Kingwood Oil No. 1 Julius May 8, 1961	SW NE 17-18N-10W 1,163 KB	Okeene 7,783 Parvin A 7,820 Parvin B 7,923 Parvin C 7,982	open hole 7,790-8,012		F 1,200 MCFGPD	8,012 Chester
Pan American No. 1 Debo Unit	NE SW 14-18N-10W					Drilling
Humble Oil No. 1 Capps Unit	NE SW 27-18N-10W					Drilling

* Gas show
**No show

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APPENDIX TO PART I

Stratigraphic Sections

Measured by Robert O. Fay

In the following sections, the term red shale means reddish-brown blocky clay shale, the color ranges from moderate to dark reddish brown. The term green shale means light greenish-gray to greenish-gray blocky clay shale. The sandstone of the Marlow, Rush Springs, and Cloud Chief Formations is fine-grained, quartzose, with subrounded to subangular grains unless otherwise noted.

I. Section measured just east of road on south bank of stream in C W½ SW¼ sec. 9, T. 18 N., R. 10 W., and NW¼ SE¼ sec. 9 at mouth of creek.

	Feet
Flowerpot Shale	
Shale, red; with some 1- to 2-inch-thick orange-brown platy siltstone layers	5.0
Shale, red, well-indurated; forming inconspicuous ledge	2.0
Cedar Hills Member of Hennessey Shale (exposed thickness, 21.6 feet)	
Bed 5: (type section for Bed 5)	
Siltstone, light greenish-gray, quartzose, argillaceous, calcareous, gypsiferous; well indurated and thin bedded at top; moderate reddish orange to reddish brown and more massive at base; forms ledge	2.25
Unnumbered beds:	
Shale, red, silty; with local ¼- to ½-inch greenish-gray spots	2.5
Siltstone, moderate reddish-brown, argillaceous, thin-bedded, well-indurated; with some ¼- to ¾-inch greenish-gray spots	2.75
Siltstone, moderate reddish-orange, poorly indurated; as above	0.5
Siltstone, moderate reddish-brown and mottled greenish-gray, argillaceous, wavy bedded; with some moderate reddish-orange siltstone lenses; exposed	3.6
Covered	5.0
Shale, red, silty	1.0
Bed 4:	
Siltstone, mottled, moderate reddish-brown and greenish-gray, vuggy; with many 1/16- to ¼-inch-wide holes; deeply weathered near base of Salt Creek	1.0
Unnumbered bed:	
Shale, red, silty; with black stains; at water level; exposed	3.0

II. Section measured on road, in gully just north of road, and in creek under bridge in SE¼ SW¼ sec. 10, T. 18 N., R. 10 W.

	Feet
Cedar Hills Member of Hennessey Shale (exposed thickness, 28.5 feet)	
Bed 5:	
Siltstone, greenish-gray, argillaceous, weakly indurated	2.0+
Siltstone, moderate reddish-brown well-indurated; speckled with many small greenish-gray spots	0.25
Unnumbered beds:	
Siltstone, reddish-brown, argillaceous, blocky, well-indurated; speckled with some ¼- to ½-inch greenish-gray spots	2.8
Siltstone, moderate reddish-brown; as above; with asymmetrical ripple marks that strike N 80° E with steep side toward the north	0.1

	Feet
Siltstone, moderate reddish-orange, well-indurated	4.0
Siltstone, greenish-gray mottled moderate reddish-brown, medium-bedded; with undulatory lower surface with one-foot relief	1.5
Siltstone, moderate reddish-brown, mottled with many layers and 1- to 2-inch spots of greenish-gray siltstone, with 2-inch greenish-gray seam at base	2.5
Siltstone, moderate reddish-brown, massive; as above; weakly indurated, porous, and greenish-gray in basal portion	2.75
Bed 4: (type section for Bed 4)	
Siltstone, moderate reddish-brown, argillaceous, blocky, well-indurated; mottled light greenish-gray; with many clusters of ¼-inch or smaller vugs; forms ledge	1.0
Unnumbered beds:	
Shale, red; with some ¼- to ½-inch greenish-gray spots	3.0
Siltstone, moderate reddish-brown, argillaceous, slightly dolomitic, massive, well-indurated; forms small ledge	0.8
Shale, red, weakly indurated; with some moderate reddish-brown siltstone lenses	0.8
Siltstone, moderate reddish-brown, massive, well-indurated; mottled with some greenish-gray layers; thin bedded toward base	5.0
Shale, red, well-indurated; exposed	2.0+

III. Section measured in south bank of Salt Creek, beginning in the shale at the base of section II and continuing down section, in SE¼ NE¼ sec. 10, T. 18 N., R. 10 W. Bed 4 and underlying beds down to the 5-foot siltstone, as described above, occur in the hill just south of the creek.

	Feet
Cedar Hills Member of Hennessey Shale (exposed thickness, 14 feet)	
Unnumbered beds: (between Beds 3 and 4)	
Shale, red, silty, well-indurated; mottled with some 1/16-inch greenish-gray spots; same as exposed shale at base of section II above	2.6
Siltstone, moderate reddish-brown, blocky, massive, well-indurated; speckled greenish-gray	0.55
Shale, red, silty	1.25
Siltstone, moderate reddish-brown; as above; with a thin discontinuous greenish-gray layer at base	0.9
Shale, red, silty; with 4-inch indurated bed in middle	2.4
Siltstone, mottled greenish-gray and moderate reddish-brown, blocky, massive, well-indurated; with a thin green band at base and top; upper contact slightly undulatory	1.2
Shale, red, silty	2.5
Sandstone, moderate reddish-brown, fine-grained, well-indurated, undulatory	0.1
Shale, red, silty; with sporadic ½-inch greenish-gray spots; exposed	2.5+

IV. Section measured along Salt Creek in SE¼ SW¼ sec. 2, T. 18 N., R. 10 W., beginning approximately 15 feet below the base of the above section III.

	Feet
Cedar Hills Member of Hennessey Shale (exposed thickness, 29.7 feet)	
Unnumbered beds: (between Beds 3 and 4)	
Covered section, the top of which would come at the base of the 2.5 foot shale at base of measured section III	15.0
Shale, red, silty; with some ¼- to 1-inch greenish-gray spots	4.0
Sandstone, mottled moderate reddish-brown and greenish-gray, fine-grained, crinkly bedded,w ell-indurated	0.1
Shale, red, silty; with some moderate reddish-brown platy siltstone lenses	5.0

	Feet
Siltstone, moderate reddish-brown, well-indurated; mottled with small greenish-gray spots; some thin fine-grained sandstone near middle	0.3
Shale, red, silty; with vertical joints that strike N 80° W	4.75
Siltstone, dark reddish-brown, argillaceous, massive, blocky, well-indurated; speckled sparsely with 1/16-inch greenish-gray spots; exposed to water level	0.55

V. Section measured along creek bank southeast of Salt Creek in NW¼ SE¼ sec. 11, T. 18 N., R. 10 W., and thence northwest into SE¼ NW¼ sec. 11, beginning in Bed 4.

CEDAR HILLS MEMBER OF HENNESSEY SHALE (exposed thickness, 25.75 feet)

	Feet
Bed 4:	
Siltstone, moderate reddish-brown to light greenish-gray, vuggy	1.0
Unnumbered beds:	
Shale, red, silty, weakly indurated	3.0
Siltstone, speckled moderate reddish-brown and greenish-gray, massive, weakly indurated	0.75
Siltstone, greenish-gray, massive, weakly indurated; with even lower contact	2.2
Siltstone, moderate reddish-brown, argillaceous, massive, weakly indurated; speckled greenish-gray near top	1.75
Siltstone, greenish-gray, weakly indurated; speckled moderate reddish-brown in middle	0.8
Siltstone, moderate reddish-brown, massive, well-indurated; speckled greenish-gray near top; with some large vugs	0.8
Shale, red, silty; with some siltstone lenses	2.25
Siltstone, moderate reddish-brown, blocky, massive, well-indurated; with some ¼- to ½-inch greenish-gray spots	0.6
Shale, red, silty	0.8
Siltstone, moderate reddish-brown; as above; with two sets of ripple marks. The upper set is asymmetrical and strikes N 20° W with steep side to east, and the lower set is symmetrical and strikes N 35° W	1.0
Shale, red; with a massive siltstone near middle	2.5
Siltstone, moderate reddish-brown, mottled greenish-gray, massive, indurated; less indurated in middle portion	1.25
Shale, red, silty	2.5
Sandstone, moderate reddish-brown, fine-grained, undulatory; in thin beds	0.2
Shale, red, silty	2.3
Sandstone; as above	0.05
Shale, red, silty; exposed to base of bank	2.0+

VI. Section measured along creek bank east of Salt Creek near C NE¼ sec. 1, T. 18 N., R. 10 W., with the top of the first unit being about 22 feet below the base of Bed 4.

CEDAR HILLS MEMBER OF HENNESSEY SHALE (exposed thickness, 21.65 feet)

	Feet
Unnumbered beds: (starting 22 feet below base of Bed 4)	
Shale, red; with many paper-thin calcite veins in upper two feet	5.0
Sandstone, greenish-gray, crinkly, well-indurated	0.05
Shale, red, silty	5.0
Bed 3: (type section for Bed 3)	
Siltstone, moderate reddish-brown; well-indurated, massive; with many 1/16- to 1-inch greenish-gray spots; forms resistant ledge	0.2
Unnumbered beds:	
Shale, red, weakly indurated	2.0

	Feet
Shale, red, well-indurated; with many greenish-gray shale spots	0.5
Sandstone, greenish-gray, crinkly, well-indurated	0.05
Shale, red, silty; grading into argillaceous siltstone	6.0
Shale, mottled greenish-gray and reddish-brown, crinkly	0.2
Shale, red, silty	0.3
Siltstone, moderate reddish-brown, platy, weakly indurated	0.3
Sandstone, greenish-gray, crinkly, indurated	0.05
Shale, red, silty; speckled with 1/16- to ¼-inch greenish-gray spots; exposed	2.0+

VII. Section measured along creek south of Salt Creek, beginning at top in section line road near C SW¼ sec. 31, T. 19 N., R. 9 W., and ending near C NW¼ sec. 31, just east of Blaine County, in Kingfisher County, Oklahoma. Beginning in Bed 4 at top. Named Parvin section.

CEDAR HILLS MEMBER OF HENNESSEY SHALE (exposed thickness, 73.5 feet)

	Feet
Bed 4:	
Siltstone, mottled moderate reddish-brown and greenish-gray, vuggy	1.0
Unnumbered beds:	
Covered. Probably reddish-brown shale and siltstone	12.0
Shale, red, silty, well-indurated; with siltstone near top	5.0
Siltstone, moderate reddish-brown; with greenish-gray spots	0.5
Siltstone, moderate reddish-brown to dark reddish-brown, argillaceous, blocky, well-indurated	2.5
Siltstone, greenish-gray and moderate reddish-brown, well-indurated; with 1- to 2-inch flat sandstone nodules near top	0.8
Shale, red, silty, well-indurated	8.0
Sandstone, greenish-gray, crinkly, well-indurated	0.1
Shale, red, silty, well-indurated	5.0
Bed 3:	
Siltstone, moderate reddish-brown, well-indurated; mottled with many 1/16-inch greenish-gray spots; ¼- to 1-inch beds; forms a ledge with some light greenish-gray stains	0.25
Unnumbered beds:	
Shale, red, silty; grading into argillaceous siltstone; with some thin crinkly greenish-gray sandstone seams	15.0
Bed 2: (type section for Bed 2)	
Siltstone, light greenish-gray, calcareous, well-indurated; mottled moderate reddish-brown; ½- to 2-inch beds; brecciated with 1/16- to ½-inch greenish-gray pebbles; with symmetrical ripple marks that strike N 30° W; forms ledge	0.25
Shale, dark reddish-brown, silty, well-indurated; greenish-gray at top; with uneven surface at base	0.6
Siltstone, greenish-gray, mottled moderate reddish-brown, weakly indurated	0.8
Siltstone, greenish-gray, mottled reddish-brown, well-indurated, dense; dolomitic appearance; forms ledge	0.65
Unnumbered beds:	
Shale, red, silty; with two siltstone bands, each 6 to 9 inches thick, about 2½ and 5½ feet above base	7.5
Bed 1: (type section for this composite bed, the base of which is Pch, on the map)	
Siltstone, moderate to dark reddish-brown, argillaceous, well-indurated; mottled with greenish-gray patches; forms ledge	0.25
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, weakly indurated; forms greenish-gray band	1.25
Siltstone, greenish-gray, mottled moderate reddish-brown, dolomitic, argillaceous, well-indurated; forms prominent thick ledge	1.25

	Feet
Siltstone, moderate reddish-brown, argillaceous, weakly indurated	2.75
Siltstone, greenish-gray, mottled moderate reddish-brown, massive, well-indurated; undulatory at base; forms ledge	0.75
Siltstone, greenish-gray, mottled moderate reddish-brown, weakly indurated	1.2
Siltstone, dark reddish-brown, mottled greenish-gray, well-indurated; forms massive ledge	0.75
Siltstone, moderate to dark reddish-brown, argillaceous; with ½-inch beds at top; grading into silty shale at base	0.6
Siltstone, light greenish-gray, argillaceous, calcareous, quartzose, massive, well-indurated; mottled with moderate to dark reddish-brown patches; forms prominent light greenish-gray ledge	3.75
Unnumbered beds:	
Shale, red; exposed to bottom of bulldozed pond	1.0 +

VIII. Section measured along northeastward flowing creek, starting in SE¼ SE¼ sec. 2, T. 19 N., R. 10 W., and ending in NW¼ SW¼ sec. 1, with all parts of Beds 1 and 2 present; the same as section VII. Upper beds not described again.

CEDAR HILLS MEMBER OF HENNESSEY SHALE (measured thickness, 20.85 feet)

Bed 2: Top has asymmetrical ripple marks that strike northwest, with the steep side toward the southwest.

Bed 1: The basal 3.75-foot bed has asymmetrical ripple marks that strike N. 25° W., with steep side toward the west (3.75)

	Feet
Unnumbered beds:	
Shale, red, silty; speckled with many 1/16- to ½-inch greenish-gray spots	1.0
Siltstone, moderate reddish-brown, argillaceous, blocky; speckled with many 1/16- to ½-inch greenish-gray spots; with prominent ¼-inch greenish-gray undulating band at base	0.75
Shale, red; as above	4.0
Siltstone, moderate reddish-brown; as above	0.5
Shale, red; as above	1.0
Siltstone, moderate reddish-brown, undulatory; as above	0.2
Shale, red; as above	1.0
Siltstone, moderate reddish-brown, undulatory, well-indurated; as above; forms prominent resistant ledge	0.5
Siltstone, moderate reddish-brown, argillaceous, weakly indurated; as above	1.75
Siltstone, moderate reddish-brown; as above; grading into shale; with ¼- to 1-inch crinkly bedded white to greenish-gray gypsum band at top	0.9
Siltstone; as above; with same type of gypsum band at top as bed above	0.9
Siltstone; as above; with crinkly gypsum band at top forming resistant band that forms a ledge	0.6
Shale, red, silty; as above; with discontinuous stringers of white selenite and some 1- to 6-inch gypsum nodules	2.5
Siltstone, moderate reddish-brown, massive, well-indurated; as above; with 1-2 inches of crinkly greenish-gray and white gypsum at top; forms prominent ledge	0.75
Siltstone, moderate reddish-brown, argillaceous, weakly indurated; as above; with ¼- to ½-inch greenish-gray to greenish-white platy crinkly discontinuous laminae of gypsum	2.5
Siltstone, moderate reddish-brown; as above; forms ledge	0.25
Siltstone, moderate reddish-brown, weakly indurated; as above; greenish-gray at base; exposed	1.75

IX. Section measured in NE¼ sec. 22, T. 15 N., R. 10 W., along creek, and along road between secs. 14 and 15, continuing into NE¼ sec. 14, and ending in SE¼ sec. 11, T. 15 N., R. 10 W., southeastern Blaine County.

DOG CREEK SHALE (top not exposed; exposed thickness, 75.95 feet)	Feet
Shale, red, silty; with some 1- to 2-inch greenish-gray spots	2.0
Shale, red, platy; as above; with some thin calcite layers	0.2
Shale, red, silty	3.0
Shale, red; as above; with thin calcite layers	0.8
Shale, red, silty	0.8
Shale, green, silty; with 3-inch reddish-brown band in middle	0.8
Shale, red, silty	1.2
Shale, red, silty, platy, well-indurated	1.7
Shale, red, silty	1.5
Shale, green, silty	0.2
Shale, red, silty; speckled with ⅛- to 2-inch greenish-gray spots	7.0
Dolomite, light gray, fine-grained, well-indurated, massive	0.3
Shale, red, silty, dolomitic, well-indurated, blocky	0.8
Shale, red; as above; more indurated	0.25
Shale, red, silty	0.2
Shale, green, silty	0.1
Shale, red, silty, dolomitic; mottled tan to greenish-gray in middle	1.0
Shale, green, dolomitic; mottled with moderate reddish-brown spots	0.2
Shale, dark reddish-brown, mottled purplish-brown, dolomitic, blocky	0.2
Shale, red, silty	1.5
Shale, red, silty; with 1- to 2-inch greenish-gray spots	0.5
Shale, red, silty	0.5
Shale, greenish-gray and reddish-brown, silty	0.5
Shale, red, silty	3.25
Shale, mottled greenish-gray and purplish-brown, blocky	1.0
Shale, purplish-brown; blocky; with three 1-inch layers of greenish-gray shale at top, in middle, and at base	1.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, well-indurated, vuggy, wavy bedded; with dendrites and some shale streaks; with ½- to 1-inch beds; forms resistant ledge	0.3
Dolomite, argillaceous, nodular; as above	0.2
Shale, purplish-brown, weakly indurated	0.2
Dolomite, argillaceous, nodular; as above	0.2
Shale, purplish-brown; as above	0.1
Dolomite, light bluish-gray; mottled purplish-brown; ½- to 1-inch beds	0.25
Shale, light bluish-gray, dolomitic, silty	0.5
Shale, purplish-brown, dolomitic, well-indurated	0.5
Shale, moderate reddish-brown, silty, dolomitic, well-indurated	1.7
Siltstone, moderate reddish-brown, argillaceous, vuggy, massive; with some ½-inch greenish-gray spots	1.5
Shale, light bluish-gray, dolomitic, thin-bedded, platy	0.3
Dolomite, light bluish-gray, argillaceous, fine-grained; in two beds	0.25
Siltstone, light bluish-gray, dolomitic, thin-bedded, well-indurated	0.2
Dolomite, light bluish-gray, silty, wavy-bedded; with interbedded shale; ⅛- to ¼-inch beds	0.2
Haskew Bed:	
Siltstone, light brown; mottled with ¼-inch greenish-gray shale streaks; massive at top; thin-bedded at base; forms resistant ledge	2.5

	Feet
Unnamed beds:	
Shale, red; with occasional ½-inch satin spar layers	4.5
Siltstone, greenish-gray, argillaceous, dolomitic, blocky, well-indurated; grading into gypsiferous shale at base	0.25
Shale, red, silty, with ⅛- to 1-inch greenish-gray spots	0.6
Shale, greenish-gray and reddish-brown, silty, blocky	0.3
Shale, red, silty; with ¼- to ½-inch greenish-gray spots and many ½- to 1-inch satin spar veins and layers	4.6
Shale, green, gypsiferous, silty, well-indurated; with much satin spar	0.3
Shale, red, silty; mottled with many 1 mm greenish-gray spots; with many 1- to 2-inch satin spar layers; partly covered	2.5
Gypsum, mottled pinkish-white and greenish-gray; with some interbedded shale; forms resistant ledge	0.6
Shale, red, silty; with some ¼-inch satin spar seams	0.9
Shale, purplish-brown; with greenish-gray gypsiferous shale streaks	1.0
Shale, red, silty; with many thin satin spar layers	3.0
Shale, greenish-gray and reddish-brown, gypsiferous, nodular	0.2
Shale, red, silty; with ¼- to 1-inch satin spar layers	1.5
Shale, greenish-gray, gypsiferous, well-indurated	0.25
Shale, red, silty	0.6
Shale, greenish-gray; as above	0.1
Shale, red, silty; with much satin spar	0.5
Shale, greenish-gray and reddish-brown, gypsiferous, wavy bedded; with many ¼- to 1-inch satin spar layers	1.2
Shale, red, silty, wavy bedded; with much satin spar	3.0
Shale, greenish-gray, gypsiferous, well-indurated, wavy bedded; with much satin spar	2.0
Shale, red, silty; with much satin spar	5.25
Shale, greenish-gray, gypsiferous, well-indurated	0.6
Shale, red; as above	1.8
Shale, moderate reddish-brown, mottled greenish-gray, weakly indurated, gypsiferous, silty	0.5
Siltstone, moderate reddish-brown, mottled greenish-gray, argillaceous	0.5
BLAINE FORMATION (total thickness, 90.9 feet)	
Shimer Gypsum Member:	Feet
Gypsum, white, coarsely crystalline, wavy bedded; interbedded at top with reddish-brown shale	2.0
Gypsum, white, mottled pinkish-white and greenish-white, coarsely crystalline, laminated, wavy bedded; forms ledge	4.5
Siltstone, gray, mottled reddish-brown, argillaceous, wavy bedded, well-indurated; grading upward into gypsum	0.25
Altona Dolomite Bed:	
Shale, greenish-gray, dolomitic, finely laminated, even-bedded, platy, well-indurated; with some gypsum	1.0
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic; with many *Permophorus* resembling a coquina; ⅛- to 1-inch beds; forms massive ledge. Symmetrical ripple marks strike west	0.75
Unnamed beds:	
Shale, green, silty	0.75
Shale, red, silty	1.2
Shale, green, siltly	0.2
Shale, green, dolomitic, lenticular, well-indurated	0.2
Shale, red, silty; with some 1- to 2-inch greenish-gray streaks and spots	11.3
Shale, green, silty	0.5
Shale, red, silty	5.5
Shale, green, silty; with some lenticular reddish-brown shale	0.5

	Feet
Shale, red, silty	15.75
Nescatunga Gypsum Member:	
Gypsum, white, mottled reddish-brown, coarsely crystalline	1.0
Gypsum, white, mottled greenish-gray, finely granular, wavy bedded; weathering white like weathered anhydrite	2.0
Gypsum, white, mottled reddish-brown and greenish-gray, coarse-crystalline, wavy bedded	4.25
Magpie Dolomite Bed:	
Shale, greenish-gray, dolomitic, platy, well-indurated; ⅛- to ¼-inch beds	0.2
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic; ⅛- to ¼-inch beds at top; 2- to 3-inch beds at base, with some *Permophorus* and green streaks resembling malachite in lower portion; forms massive ledge	1.75
Unnamed beds:	
Shale, green, silty	0.75
Shale, red, silty	4.0
Shale, green, gypsiferous; with some ¼- to 2-inch satin spar layers	0.6
Shale, red, silty	0.25
Shale, green; as above	0.1
Shale, red, silty	0.2
Shale, green; as above; with many ¼- to 1-inch reddish-brown spots	0.4
Shale, red, silty; with some 1- to 2-inch greenish-gray spots	5.25
Shale, green, gypsiferous, silty; with some satin spar	0.2
Shale, red, silty; partly covered	4.0
Kingfisher Creek Gypsum Bed:	
Gypsum, white, mottled greenish-gray, finely granular, well-indurated; forms ledge	0.75
Gypsum, greenish-white, finely granular, well-indurated, crinkly bedded, mottled with moderate reddish-brown streaks; forms ledge	0.8
Gypsum, greenish-gray, argillaceous, dolomitic, finely crystalline, wavy bedded; with 1- to 2-inch bands; forms ledge	0.4
Unnamed beds:	
Shale, green, silty	0.1
Shale, moderate reddish-brown, silty; with some ¼-inch satin spar layers and many ¼- to 1-inch greenish-gray spots	2.5
Shale, mottled greenish-gray and reddish-brown, silty, blocky	3.75
Shale, green, gypsiferous, well-indurated; forms ledge	0.2
Shale, red, silty	0.2
Shale, green; as above; with much white nodular gypsum	0.25
Shale, red, silty	2.8
Gypsum, white, nodular	0.2
Shale, red, silty; becoming greenish-gray; with gypsum nodules at base	5.0
Medicine Lodge Gypsum Member:	
Gypsum, pinkish-white, mottled greenish-white, coarsely crystalline, selenitic; forms ledge	4.5
Cedar Springs Dolomite Bed:	
Dolomite, pinkish-gray, fine-grained, wavy bedded, dense, nodular; grading upward into gypsum; with green stains of a mineral resembling malachite	0.1
FLOWERPOT SHALE (exposed thickness, 71.2 feet)	
Shale, dark reddish-brown to purplish-brown, argillaceous, blocky; with greenish-gray shale at top	3.0
Gypsum, white, mottled greenish-gray, argillaceous, wavy bedded, well-indurated; forms ledge	0.25
Shale, red, silty; with some greenish-gray spots and streaks	1.5

	Feet
Shale, green, silty, gypsiferous, with some reddish-brown shale	0.25
Shale, green, gypsiferous, silty, wavy bedded, well-indurated; ½- to 1-inch beds; forms ledge	0.3
Shale, greenish-gray, mottled reddish-brown, gypsiferous; forms ledge	0.2
Shale, red, silty; with many thin satin spar layers and veins	1.75
Shale, green, gypsiferous; with some reddish-brown shale	0.5
Shale, red, silty; with much satin spar in middle	4.75
Shale, green, gypsiferous, well-indurated	0.3
Shale, red, silty; with some ½-inch greenish-gray spots and white nodular gypsum, and with much paper-thin satin spar	10.0
Shale, green, gypsiferous, silty; well-indurated near base	1.0
Shale, red, silty; dolomitic near top	4.5
Gypsum, white, nodular, wavy bedded; forms small ledge	0.25
Shale, red, silty	1.5
Shale, green, gypsiferous; well-indurated in upper part	0.4
Shale, red, silty	4.0
Gypsum, pinkish-white, nodular	0.25
Shale, red, silty	2.0
Gypsum, white to pinkish-white, nodular; with matrix of selenitic shale	0.5
Shale, red, silty	1.25
Gypsum; as above	0.1
Shale, red, silty	0.75
Siltstone, greenish-gray, argillaceous, weakly indurated	0.2
Shale, red, silty	0.25
Gypsum, white to orange-white, nodular	0.2
Shale, red, silty, dolomitic, blocky, well-indurated; with some ½-inch greenish-gray spots	3.0
Shale, mottled reddish-brown and greenish-gray, silty	0.75
Shale, red, silty	2.75
Gypsum, white, nodular, mottled pink	0.1
Shale, red, silty	0.75
Gypsum; as above	0.2
Shale, red, silty; with thin gypsiferous band in middle	2.0
Gypsum, white; mottled greenish-gray and moderate reddish-brown	0.2
Shale, red, silty	3.25
Gypsum, white, mottled reddish-brown, nodular	0.3
Shale, red, silty	2.0
Shale, greenish-gray, silty; with ½- to 2-inch gypsum nodules	0.25
Shale, red, silty	4.25
Gypsum, pinkish-white, nodular	0.1
(This place marks the base of the upper portion of the Flowerpot Shale, below which there is little to no gypsum)	
Shale, red, silty	0.75
Siltstone, greenish-gray, argillaceous, platy; with a few ½- to 1-inch white gypsum nodules and selenite	0.6
Shale, red, silty, well-indurated	3.0
Siltstone, mottled greenish-gray and reddish-brown, argillaceous, cross-bedded	4.0
Shale, red, silty; exposed	3.0 +

X. Section measured along State Highway 33 beginning at top in SW¼ sec. 24, T. 16 N., R. 11 W., continuing east into SW¼ sec. 19, T. 16 N., R. 10 W., NE¼ sec. 30, SW¼ sec. 20, ending in NE¼ SE¼ sec. 20, T. 16 N., R. 10 W.

Dog Creek Shale (top not exposed; exposed thickness, 71.5 feet)	Feet
Shale, red, silty; with ⅛- to ½-inch greenish-gray spots	4.0
Shale, red, silty, platy	0.5

	Feet
Shale, red, silty; with many ⅛- to ½-inch greenish-gray spots and veins	5.5
Shale, green, well-indurated; silty near top	0.6
Shale, red; as above	5.25
Shale, green, silty	0.25
Shale, red; as above	3.25
Shale, green, dolomitic, well-indurated	0.3
Shale, red; as above	8.0
Shale, green, dolomitic, well-indurated	0.75
Shale, red, dolomitic, well-indurated	2.0
Dolomite, light-gray, argillaceous, dense, well-indurated, fine-grained, massive, blocky; forms blocks	0.2
Shale, red, silty	1.0
Dolomite, moderate reddish-brown, mottled greenish-gray, argillaceous, fine-grained, dense, well-indurated; ½- to 2-inch beds; forms ledge	0.6
Shale, green and red, silty	0.6
Shale, green, dolomitic	0.25
Shale, dark reddish-brown, platy	0.3
Shale, greenish-gray, dolomitic	0.25
Shale, dark reddish-brown, mottled greenish-gray, silty	1.0
Shale, greenish-gray; with a few ¼-inch layers of dolomite	1.0
Watonga Dolomite Bed: (type section)	
Dolomite, light bluish-gray, fine-grained, dense, compact, argillaceous, well-indurated, platy; ¼- to 1-inch beds; forms prominent ledge	0.3
Shale, light bluish-gray, dolomitic, blocky	1.0
Shale; as above; with many ¼- to ½-inch dolomite beds; orange band at top	1.25
Siltstone, light bluish-gray to greenish-gray, dolomitic, argillaceous	0.6
Shale, light bluish-gray, argillaceous, platy	0.25
Dolomite, light bluish-gray; as above; with ¼- to ½-inch vugs	0.2
Shale, light bluish-gray, mottled dark reddish-brown, platy	0.75
Dolomite, light bluish-gray; as above	0.25
Shale, greenish-gray, mottled reddish-brown, dolomitic, silty, platy	0.6
Shale, greenish-gray, gypsiferous, and interbedded thin dolomite; with some satin spar in middle	0.9
Unnamed beds:	
Shale, greenish-gray, mottled reddish-brown, gypsiferous; with many ¼-inch reddish-brown gypsum nodules and some satin spar; silty near base	1.2
Haskew Bed:	
Siltstone, light brown, gypsiferous, massive, well-indurated; with many ¼-inch reddish-brown gypsum nodules and satin spar layers; forms prominent ledge	3.0
Unnamed beds:	
Shale, red, silty, well-indurated; with many ¼- to ½-inch satin spar seams	1.5
Siltstone, greenish-gray, gypsiferous, argillaceous, well-indurated	0.2
Siltstone, reddish-brown, gypsiferous, argillaceous, well-indurated	0.25
Siltstone, greenish-gray; as above	0.25
Shale, red, silty, with some 1-inch satin spar layers	2.25
Shale, alternating greenish-gray and reddish-brown; with many ¼- to ½-inch satin spar layers	3.0
Shale, red, silty; with ¼- to 1-inch greenish-gray spots	1.5
Shale, green, platy	0.5
Satin spar, pinkish-white, crinkly bedded	0.5
Shale, green, silty	0.2

	Feet
Shale, red, silty	0.7
Shale, greenish-gray, gypsiferous, well-indurated, crinkly bedded; with 1/16- to ½-inch beds and many ¼- to 1-inch satin spar beds	1.6
Shale, red, silty; with ¼- to ½-inch greenish-gray shale spots	1.5
Shale, greenish-gray, gypsiferous; as above	0.25
Satin spar; as above	0.2
Shale, red; as above	0.75
Shale, greenish-gray, silty, blocky	0.2
Shale, red; as above	0.6
Shale, greenish-gray; as above	0.2
Shale, red; as above	0.75
Shale, greenish-gray, gypsiferous; with many thin satin spar layers	0.6
Shale, moderate reddish-brown, argillaceous, silty, blocky	0.9
Satin spar; as above	0.4
Shale, moderate reddish-brown, silty, gypsiferous	0.8
Shale, greenish-gray, mottled reddish-brown, gypsiferous, crinkly bedded, weakly to well-indurated; with many ¼- to 1-inch satin spar layers	6.0
BLAINE FORMATION (type section) (total thickness, 93.75 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, massive, porous; with a 1-foot bed of dense white weathered alabaster-like portion in middle; forms a prominent white ledge, covered with coarse selenite	12.0
Altona Dolomite Bed: (type section)	
Dolomite, light-gray to yellowish-gray, dense, porous, fossiliferous, well-indurated, oölitic; with ¼-mm oölites; ¼- to 1-inch beds; with the dense portions more to the top and bottom and oölitic portion in middle; grading upward into gypsum	1.0
Unnamed beds:	
Shale, green, silty	1.1
Shale, red, silty; with some greenish-gray shale streaks and some ¼- to 2-inch satin spar veins and layers	13.0
Shale, green, silty, well-indurated	1.75
Shale, red, well-indurated; with some ½-inch satin spar layers	4.0
Shale, greenish-gray, gypsiferous, well-indurated, silty	0.6
Shale, red, silty; with some 2- to 3-inch greenish-gray spots and many ½-inch satin spar veins	8.0
Shale, green, mottled reddish-brown, silty	0.3
Shale, red, silty	2.25
Shale, green, silty, gypsiferous; with much satin spar	0.7
Shale, red, silty	0.4
Shale, greenish-gray, gypsiferous; with interbedded reddish-brown shale beds	1.7
Shale, greenish-gray, silty; with ½-inch satin spar layers	0.8
Shale, red, silty	0.25
Shale, greenish-gray, gypsiferous, wavy bedded; well-indurated in places; with some satin spar	1.0
Shale, reddish-brown, gypsiferous; with some greenish-gray layers; with basal 1 inch well-indurated in places	0.3
Nescatunga Gypsum Member:	
Gypsum, white, finely crystalline, laminated to banded, dense; mottled greenish-gray at top; forms ledge	2.0
Alabaster, light-gray, fibrous, compact, finely crystalline; forms bright-white resistant ledge	1.25
Gypsum, mottled gray; as above	3.0
Gypsum, mottled pinkish-white; as above	1.0
Gypsum, mottled gray; as above	2.5

	Feet
Magpie Dolomite Bed: (type section)	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, fossiliferous, oölitic; with ¼ mm oölites; with dense portion more toward basal 3 inches, which also contains greenish-colored stains of a mineral-like malachite; upper portions more oölitic; grading into gypsum; upper surface with ripple marks that strike N 55° W; forms prominent ledge	1.5
Unnamed beds:	
Shale, greenish-gray, silty, platy	0.2
Shale, red, silty; with many 1/16- to ¼-inch greenish-gray spots	6.0
Shale, alternating greenish-gray and reddish-brown, silty	0.75
Shale, red; as above; with some 1-inch gypsum nodules and many ¼- to 1-inch satin spar veins and layers	3.5
Shale, alternating green and red, silty	0.5
Shale, red, silty	1.0
Shale, alternating green and red, silty	0.25
Shale, red, silty	2.0
Shale, green, silty; with much gypsum	0.3
Kingfisher Creek Gypsum Bed: (type section)	
Gypsum, white to greenish-gray, argillaceous, well-indurated; becoming more argillaceous near base; forms prominent ledge	2.0
Unnamed beds:	
Shale, greenish-gray, gypsiferous, well-indurated, silty	0.3
Shale, red, silty; with some selenite veins	6.0
Shale, green, silty	0.3
Shale, red, silty	0.25
Shale, green, silty	0.25
Shale, red, silty	0.25
Shale, green and mottled reddish-brown, silty	0.2
Shale, red, silty	3.0
Shale, green, silty; with some ½-inch yellowish-green gypsum nodules	0.1
Shale, red, silty	1.5
Shale, alternating reddish-brown and greenish-gray; with 1-inch yellowish-green gypsum nodules and ¼-inch layers of satin spar	0.5
Shale, red, silty	2.0
Medicine Lodge Gypsum Member:	
Gypsum, white, mottled pale-pink, fine- to coarse-crystalline, porous; forms resistant ledge covered with selenite crystals	4.0
Cedar Springs Dolomite Bed:	
Dolomite, olive to reddish-brown, porous, finely crystalline, well-indurated; weathering reddish-brown; grading upward into gypsum	0.2
FLOWERPOT SHALE (exposed thickness, 107 feet)	
Shale, red, silty; with upper several inches greenish-gray; and with many ½- to 2-inch veins and spots of greenish-gray shale	4.25
Shale, dark reddish-brown, argillaceous, flaky; with several 1-inch greenish-gray gypsiferous shale bands	1.5
Dolomite, greenish-gray, gypsiferous, crinkly bedded; forms resistant ledge	0.7
Shale, red; with much ¼- to ½-inch satin spar	2.0
Gypsum and shale, greenish-gray, thin-bedded, crinkly bedded, well-indurated; forms resistant ledge	0.25
Shale, red; as above	5.0
Gypsum and shale, greenish-gray; as above; forms ledge	0.9
Shale, red, silty; with much nodular gypsum	7.0

	Feet
Shale, greenish-gray, gypsiferous, silty	0.6
Shale, red, silty	4.0
Shale, mottled greenish-gray and reddish-brown, dolomitic, silty	0.3
Shale, red, silty; with satin spar	2.0
Shale, green, gypsiferous; with white gypsum concretions; forms ledge	0.7
Shale, red; as above	3.5
Shale, green; as above	0.2
Shale, red, dolomitic; as above	1.0
Shale, green; as above; with gray-blue concretionary gypsum	0.2
Shale, red; as above	5.0
Shale, green; as above; with 3-inch reddish-brown dolomitic shale, with mud cracks in upper part and concretionary gypsum in lower part	1.0
Shale, moderate reddish-brown, silty; with satin spar	4.5
Shale, red, dolomitic, dense, well-indurated, blocky	0.2
Shale, moderate reddish-brown; as above	4.5
Gypsum, white, nodular, well-indurated; forms ledge	0.4
Shale, green, dolomitic, dense, well-indurated; forms ledge	0.2
Shale, red, dolomitic, well-indurated; forms resistant ledge	3.5
Gypsum, greenish-gray, well-indurated; concretionary in gypsiferous green shale; forms ledge	1.0
(Gypsum is primarily absent from the sequence below, this place marking the base of the upper portion of the Flowerpot Shale.)	
Shale, red, silty	6.5
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, flaky	0.6
Shale, moderate reddish-brown, silty	3.5
Siltstone, moderate reddish-brown, mottled greenish-gray, cross-bedded; ⅛-inch beds; with dip of 23° in N 30° E direction on cross-beds	1.0
Siltstone, greenish-gray, mottled moderate reddish-brown, cross-bedded; same as bed above	0.5
Shale, red, silty	2.5
Shale, mottled greenish-gray and reddish-brown, silty, thin-bedded; with some nodular gypsum	0.7
Shale, red, silty, partly covered	9.0
(section extrapolated to SE¼ sec. 20, T. 16 N., R. 10 W.)	
Shale, mottled greenish-gray and reddish-brown, silty	2.0
Shale, mottled greenish-gray and reddish-brown, dolomitic, well-indurated, blocky; lenticular beds ¼- to 3-inches thick; forms resistant ledge	1.0
Shale, red, silty	3.0
Shale, green, silty; mottled with some moderate reddish-brown spots	0.5
Shale, red, silty; with some ¼-inch greenish-gray spots and a 2-inch well-indurated dolomitic layer 2 feet above base	7.0
Shale, green, dolomitic, thin-bedded, well-indurated	0.25
Shale, red, silty; with 2-inch greenish-gray streak in middle	3.75
Shale, mottled greenish-gray and reddish-brown, silty, blocky	1.0
Shale, red, silty	1.0
Siltstone, greenish-gray, mottled moderate reddish-brown, cross-bedded; with 14° dip in N 75° W direction; same as 2nd light band of section XIV	1.5
Shale, red, silty	0.8
Gypsum, white, mottled pinkish-white, nodular, flattened	0.2
Shale, red, silty; mottled with some ½-inch greenish-gray spots	5.0
Siltstone, greenish-gray, argillaceous, weakly indurated	0.3
Shale, red, silty, covered; base not exposed	1.0

XI. Section measured along State Highway 8, near Bucher Siding, beginning at top in NW¼ sec. 33, T. 17 N., R. 11 W., continuing into NE¼ sec. 33, NW¼ sec. 34, NE¼ sec. 34, and ending in NE¼ sec. 27, for measurements of the Dog Creek, Blaine, and upper part of Flowerpot Formations. For Chickasha and lower parts of the Flowerpot, the section is continued in NW¼ sec. 26, NE¼ sec. 24, and NE¼ sec. 13, T. 17 N., R. 10 W., with the portion below the Chickasha Tongue not measured, but thickness computed from differences in elevation.

	Feet
DOG CREEK SHALE (top not exposed; exposed thickness, 73 feet)	
Shale, dark reddish-brown, silty	6.25
Shale, moderate reddish-brown, silty; with some greenish-gray layers	2.0
Shale, greenish-gray, blocky	0.25
Shale, dark reddish-brown, silty, well-indurated; with 6-inch greenish-gray layer 2 feet above base	7.0
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, blocky, weakly indurated	1.75
Shale, dark reddish-brown, silty	3.0
Dolomite, mottled gray and reddish-brown, argillaceous, blocky, well-indurated; weathering light gray	0.1
Shale, dark reddish-brown, silty	5.5
Siltstone, greenish-gray, argillaceous, blocky; with a thin reddish-brown shale streak near middle and several thin dolomite beds near base	2.0
Shale, dark reddish-brown, silty	3.5
Shale, greenish-gray, flaky	0.25
Shale, dark reddish-brown, silty	0.2
Shale, greenish-gray, argillaceous, blocky	0.25
Shale, red, silty	5.25
Shale, green, dolomitic, well-indurated	0.5
Shale, red, silty; with 1-inch greenish-gray dolomitic layer 1 foot up from base	4.0
Shale, mottled greenish-gray and reddish-brown, dolomitic, blocky, well-indurated	1.25
Shale, red, silty	2.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, argillaceous, fine-grained, dense, compact, blocky, well-indurated; with ¼- to 2-inch beds; weathering into light bluish-gray massive blocks forming a prominent ledge	0.75
Shale, light bluish-gray, dolomitic, argillaceous, blocky, well-indurated	0.25
Shale, moderate reddish-brown, dolomitic, argillaceous, blocky	0.5
Shale, light bluish-gray; as above	0.25
Dolomite, light bluish-gray; as above; with ½- to 3-inch beds	0.6
Shale, light bluish-gray, mottled moderate reddish-brown, dolomitic	3.5
Dolomite, light bluish-gray, argillaceous, dense, well-indurated; three layers alternating with two shale layers; ¼- to 1-inch beds	1.1
Haskew Bed:	
Siltstone, light-brown, mottled greenish-gray, gypsiferous, argillaceous; with crinkly bedded upper contact	4.5
Unnamed beds:	
Shale, red, silty, platy	1.5
Shale, red, silty, crinkly bedded; with some greenish-gray layers and much satin spar	15.0
BLAINE FORMATION (total thickness, 99.25 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, porous, massive, leached; forms massive ledge covered with coarse selenite crystals	14.0

	Feet
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained; with ¼ mm oölites, ½-1 inch beds; with *Permophorus*, denser portion near base; oölitic portion above; forms massive ledge	1.25
Unnamed beds:	
Shale, green, weakly indurated	0.25
Shale, red, silty	2.0
Shale, green, silty	0.25
Shale, red	3.5
Shale, green	0.6
Shale, red; with occasional greenish-gray shale streaks and 1-inch satin spar layers	5.75
Shale, green	0.5
Shale, red, silty	6.0
Shale, green	1.0
Shale, red; with a 1-foot greenish-gray and reddish-brown light band 2 feet above base, and with many ¼- to 1-inch satin spar veins and layers	11.0
Shale, greenish-gray, gypsiferous, weakly indurated	0.5
Shale, red	0.5
Shale, greenish-gray, gypsiferous; with some well-indurated satin spar	0.3
Shale, red, well-indurated	0.75
Shale, greenish-gray, gypsiferous	0.3
Shale, red, mottled greenish-gray, blocky	0.2
Satin spar, pinkish-white, crinkly bedded	0.2
Shale, red; with some satin spar	1.5
Shale, greenish-gray, gypsiferous; with ¼- to ½-inch satin spar layers	0.3
Shale, reddish-brown and greenish-gray; with gypsum nodules	0.75
Nescatunga Gypsum Member:	
Gypsum, white, medium- to finely granular, laminated to coarsely banded, compact; forms ledge	4.0
Anhydrite, light-gray, compact, fibrous; interbedded with well-indurated gypsum; weathers white; forms a resistant ledge	6.0
Gypsum, white; as above	5.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic; with denser portion near base; ¼- to 6-inch beds; with *Permophorus*, grading upward into gypsum; forms a massive resistant ledge	2.0
Unnamed beds:	
Shale, green; with red shale seam near top	0.3
Shale, red; with some 1- to 6-inch greenish-gray shale layers in basal 4 feet	11.5
Shale, green, flaky	1.2
Shale, red, silty	0.25
Shale, green, silty	0.5
Kingfisher Creek Gypsum Bed:	
Gypsum, white to greenish-gray, finely granular, laminated, wavy bedded, well-indurated	1.2
Unnamed beds:	
Shale, greenish-gray, gypsiferous, wavy bedded, well-indurated	0.2
Shale, red, silty; with many ¼- to ½-inch greenish-gray spots	5.0
Shale, green, silty	1.0
Dolomite, greenish-gray, gypsiferous, crinkly bedded, well-indurated; ⅛- to ¼-inch beds	0.25
Shale, red; with 3- to 4-inch layers and spots of greenish-gray shale and many ½- to 1-inch gypsum nodules and paper-thin selenite layers	6.75

	Feet
Medicine Lodge Gypsum Member:	
Gypsum, white, mottled moderate reddish-brown to pale-pink, fine- to coarse-granular, porous, well-indurated; forms ledge	2.0 +
Cedar Springs Dolomite Bed:	
Dolomite, reddish-brown, ferruginous, well-indurated; with greenish-colored stains of a mineral resembling malachite	0.2
FLOWERPOT SHALE (total thickness, 465 feet)	
Shale, red, silty, with thin greenish-gray seam at top; and with ½- to 1-inch veins of greenish-gray gypsiferous shale	6.5
Shale, green, silty, mottled moderate reddish-brown	0.25
Shale, purplish-brown, argillaceous, flaky	1.0
Shale, greenish-gray, gypsiferous, crinkly bedded, well-indurated; with ¼- to ½-inch satin spar layers; forms ledge	0.9
Shale, moderate reddish-brown, silty; with many ¼- to ½-inch satin spar layers	2.0
Dolomite, greenish-gray, gypsiferous; with malachite? stains	0.25
Shale, moderate reddish-brown, gypsiferous; as above	5.0
Shale, green; with some ½-inch satin spar seams	1.0
Shale, red, silty; with some ¼-inch satin spar layers	0.5
Shale, green, silty, gypsiferous	0.2
Shale, red; as above; with some greenish-gray spots	0.3
Shale, red, silty; with some ½- to 1-inch tan silty veins	4.0
Shale, green; as above	0.2
Shale, moderate reddish-brown, silty	1.5
Shale, green; as above	0.2
Shale, moderate reddish-brown, silty	9.0
Gypsum, yellowish-green, nodular	0.25
Shale, moderate reddish-bdown, silty	5.0
Shale, tan, dolomitic, argillaceous, dense, blocky, well-indurated	0.3
Shale, red, silty	1.0
Siltstone, light greenish-gray, argillaceous, quartzose, moderately to weakly indurated; mottled with small moderate reddish-brown spots; forms a prominent light-colored band	1.0
Shale, red, silty	5.0
Shale, red, greenish-gray and reddish-brown; with 1- to 2-inch beds of siltstone alternating with the shale	1.0
Shale, red, silty	4.2
Gypsum, greenish-gray; ½- to 1-inch nodules	0.2
Shale, red, silty; with some dolomitic streaks	5.0
Shale, green, gypsiferous; with some pink nodular and layered satin spar	0.5
Shale, red, silty	0.5
Shale, green, gypsiferous; as above	0.5
Shale, red, silty; markedly without gypsum, whereas the red shales above have secondary selenite. The top marks base of gypsiferous upper portion of the Flowerpot Shale; exposed	5.0
(section extrapolated to NW¼ sec. 26, T. 17 N., R. 10 W.)	
Covered in part. Shale, red, silty with many thin light greenish-gray siltstone layers, and portions of the Chickasha conglomerate in the lower 30 feet	97.0
Chickasha Tongue, marked Pfc, on map, at base of this unit:	
Siltstone-mudstone conglomerate, moderate reddish-brown, well-indurated; with some light greenish-gray layers; with interbedded shale, siltstone, and fine-grained sandstone; upper portion cross-bedded; forms ledge	15.0
Unnumbered Chickasha beds:	
(section extrapolated to NE¼ sec. 24, T. 17 N., R. 10 W.)	
Covered in part. Siltstone, shale, reddish-brown, argillaceous	14.0
Siltstone-mudstone conglomerate, moderate reddish-brown, mottled greenish-gray, well-indurated; grading into sand-	

	Feet
sized particles or smaller, in a siltstone matrix; cross-bedded, lenticular-bedded; with interbedded cross-bedded siltstone and fine-grained quartzose sandstone that is argillaceous and micaceous and weakly indurated	10.0
Siltstone, moderate reddish-brown, cross-bedded, lenticular; with occasional greenish-gray streaks, grading into fine-grained quartzose sandstone with subrounded to subangular grains	7.5
Chickasha bed, Pfc₃ on map:	
Siltstone, light greenish-gray, quartzose, argillaceous, micaceous, weakly indurated, cross-bedded; forming light-colored streak in region	1.25
Unnumbered Chickasha beds:	
Shale, red, silty	6.25
Siltstone, greenish-gray and reddish-brown, argillaceous; forms light-colored band; same as 8th band below top of section XIV	3.0
Siltstone, greenish-gray, argillaceous, platy	0.5
Shale, red, silty	3.0
Siltstone, greenish-gray and reddish-brown, argillaceous, platy	1.0
Shale, red, silty; partly covered	5.25
Siltstone, greenish-gray, argillaceous, platy, weakly indurated	0.25
Siltstone, moderate to dark reddish-brown, argillaceous, cross-bedded, well-indurated; with an occasional greenish-gray band	4.75
Siltstone, greenish-gray, conglomeratic, platy, well-indurated	0.2
Shale, red, well-indurated; with occasional greenish-gray layers	3.0
Siltstone-mudstone conglomerate, mottled reddish-brown and greenish-gray; grading into sandstone composed of siltstone-mudstone particles; interbedded with siltstone, sandstone, and some shale as above; contains fossil bones of a reptile, with ribs approximately 1 foot long and backbone 1-inch in diameter; approximately the same as the 9th light-colored band down from the top of section XIV	1.0
Shale, green, silty	0.3
Shale, red, silty	1.0
Siltstone-mudstone conglomerate; as above; forms ledge	0.8
Siltstone, light greenish-gray, platy, cross-bedded, lenticular	0.6
Shale, red, silty, cross-bedded	5.25
Siltstone, greenish-gray, argillaceous, platy	0.75
Siltstone, moderate to dark reddish-brown, platy; with occasional greenish-gray streaks	13.5
Chickasha bed Pfc₂ on map:	
Siltstone-mudstone conglomerate, reddish-brown and greenish-gray, cross-bedded, well-indurated; as above; with interbedded siltstone	1.0
Unnumbered Chickasha beds:	
Siltstone and shale, red, platy to blocky, argillaceous	10.0
(section along road NE¼ sec. 13, T. 17 N., R. 10 W.)	
Siltstone, mottled moderate reddish-brown and greenish-gray, cross-bedded, well-indurated	3.0
Siltstone, greenish-gray, cross-bedded, well-indurated	0.25
Shale, red, silty	2.0
Siltstone, greenish-gray, cross-bedded, well-indurated	1.0
Shale, red, silty, well-indurated	3.0
Chickasha bed Pfc₁ on map, marking base of Chickasha:	
Siltstone-mudstone conglomerate, greenish-gray, well-indurated, cross-bedded, lenticular; as above; mottled reddish-brown in places; forms light-colored bench	4.5

	Feet
Unnumbered Flowerpot beds:	
Shale, red, silty	5.25
Siltstone, greenish-gray, platy, weakly indurated	0.25
Shale, red, silty	4.0
Siltstone, greenish-gray, cross-bedded	0.25
Shale, red, silty	3.5
Siltstone, greenish-gray, mottled moderate reddish-brown, cross-bedded	0.6
Shale, red, silty; with 6-inch greenish-gray siltstone in middle	2.75
Siltstone, greenish-gray, cross-bedded; forming prominent light-colored band in region	4.0
Shale, red, silty	5.0
Siltstone, greenish-gray, cross-bedded, lenticular	2.0
Shale, red, silty; partly covered	32.0
Siltstone, greenish-gray, platy, weakly indurated	0.25
Shale, red, silty	2.0 +
(section not measured below this point, elevation 1,180 feet; base exposed about 5 miles to the northeast at elevation 1,150 feet)	
Shale, red, silty; with a few light greenish-gray siltstone beds	120.0
CEDAR HILLS MEMBER OF HENNESSEY SHALE	
Siltstone, light greenish-gray, argillaceous; mapped as Pch₅ on map	1.0 +

XII. Section measured along Cat Creek Canyon in north-central part of sec. 30, T. 17 N., R. 11 W., extending into SW¼ sec. 19, T. 17 N., R. 11 W., then Roman Nose Park in NE¼ sec. 24, T. 17 N., R. 12 W., extending into NW¼ sec. 19, T. 17 N., R. 11 W., for Dog Creek-Blaine portions, ending in NW¼ sec. 16 and SW¼ sec 9, T. 17 N., R. 11 W., for Flowerpot portion.

DOG CREEK SHALE (top not exposed; exposed thickness, 96.3 feet)	Feet
Shale, red, silty, mottled greenish-gray	1.0
Shale, dark reddish-brown, silty; with greenish-gray streaks at top and bottom	0.5
Shale, red, silty	1.0
Dolomite, light-gray, fine-grained, dense, well-indurated; ⅛- to 1-inch beds; forms ledge	0.25
Shale, green, silty	1.0
Shale, moderate reddish-brown, blocky, silty	1.5
Shale, green, silty	0.7
Shale, red, silty	0.6
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-crystalline, compact, silty; with small black specks; forms massive ledge	0.25
Unnamed beds:	
Shale, green, silty	0.25
Shale, red, silty; with greenish-gray spots	4.0
Shale, green, silty	0.5
Shale, moderate reddish-brown, silty, blocky; with some greenish-gray shale spots	1.75
Shale, green, silty	1.0
Shale, moderate reddish-brown, silty; becoming dark reddish-brown at base	1.0
Shale, green, silty	0.5
Shale, red, silty; with 3-inch to 1-foot greenish-gray spots	10.5
Shale, green, silty; with many ¼- to 1-inch satin spar layers and with white gypsum nodules	2.0
Shale, red, silty	7.25
Shale, green, silty, platy; with some ¼- to ½-inch satin spar at top; becoming more indurated and dolomitic toward base	2.25

	Feet
Shale, red, silty; with many ¼- to 1-inch satin spar layers and with selenite veins	3.5
Shale, green, silty; with much satin spar and yellowish-white nodular gypsum	0.75
Shale, moderate reddish-brown, silty; with satin spar and nodular gypsum in middle and selenite toward base	5.5
Shale, green, silty	0.75
Shale, red, silty; mottled with some greenish-gray spots; with yellowish-white gypsum nodules in middle	3.5
Shale, green, silty	0.2
Shale, red, silty	0.2
Gypsum, yellowish-white and greenish-gray, nodular	0.2
Shale, moderate reddish-brown, mottled greenish-gray, silty; with many gypsum nodules as above	2.0
Shale, green, silty	0.25
Shale, red, silty; with some 2- to 6-inch greenish-gray spots	3.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, well-indurated, blocky; with some shale; forms ledge	0.2
Shale, purplish-brown, argillaceous, blocky	0.7
Dolomite, light bluish-gray, platy; as above; ¼-1 inch beds	0.5
Shale, red, silty	0.5
Shale, green, silty	0.5
Shale, purplish-brown, blocky	1.0
Dolomite, light bluish-gray, thin-bedded; as above; with interbedded shale; forms ledge	1.5
Dolomite, light bluish-gray, massive; as above	0.25
Haskew Bed:	
Siltstone, light-brown, mottled greenish-gray, argillaceous	0.3
Siltstone, light-brown, gypsiferous, argillaceous, with some thin greenish-black gypsum layers	1.25
Shale, green, gypsiferous, well-indurated; forms ledge	0.75
Siltstone, green, argillaceous	0.2
Satin spar, greenish-gray	0.2
Shale, red, silty	0.2
Siltstone, tan, gypsiferous, well-indurated, argillaceous	0.25
Siltstone, light-brown, gypsiferous, argillaceous, well-indurated; with much satin spar and nodular gypsum; forms ledge	3.6
Unnamed beds:	
Shale, red, silty; with much satin spar	1.0
Siltstone, light-brown; as above	0.5
Shale, green, silty, platy; with 1-inch satin spar seam near base	0.5
Shale, red, silty; with ¼- to 1-inch greenish-gray shale spots and layers; with much satin spar	2.6
Shale, green, silty, highly gypsiferous, crinkly bedded	0.5
Satin spar, pinkish-white	5.0
Shale, green, gypsiferous; as above	0.3
Shale, red, silty; with much selenite and many satin spar veins	1.25
Shale, green; as above; with 2-inch satin spar at top	0.5
Shale, red, silty; with 3-inch satin spar seam at base	2.0
Shale, green, silty; with some nodular gypsum	0.25
Shale, red, silty; with some satin spar	1.0
Shale, green, silty, thin-bedded, highly gypsiferous	0.2
Shale, red, silty, mottled greenish-gray	1.7
Shale, green, silty, gypsiferous, crinkly bedded	0.5
Shale, red, silty; with 1-inch greenish-gray band in middle	1.2
Shale, greenish-black, gypsiferous, well-indurated, crinkly bedded	0.5
Shale, red, silty; with much 2- to 3-inch satin spar	1.5
Shale, red, silty, highly gypsiferous, crinkly bedded; with much satin spar; lower 6 inches greenish-black; with 6 inches of relief	2.75

	Feet
Shale, red, silty, with much satin spar	2.0
Shale, green, gypsiferous, silty, crinkly bedded; with about 1 foot of relief; with much nodular gypsum and satin spar	1.0
Blaine Formation (total thickness, 92.35 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, porous, massive; with about 3-9 inches of gray anhydrite, 6 to 7 feet below top; forms prominent ledge	12.0
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic; with *Permophorus* molds; with symmetrical ripple marks that strike N 75° W; forms massive ledge	1.0
Unnamed Beds:	
Shale, green, silty	0.5
Shale, red, silty	2.0
Shale, green, silty	0.5
Shale, red, silty	10.5
Shale, green, silty	0.3
Shale, red; with greenish-gray streaks and spots	4.5
Shale, green, silty; with some selenite veins and layers	3.0
Shale, red, silty	5.0
Shale, green, silty	1.5
Shale, red, silty; with much selenite and yellowish-white concretionary gypsum in middle	2.25
Shale, green, gypsiferous, platy, well-indurated	0.3
Shale, green, mottled with small brown spots, silty	0.8
Shale, red, silty	0.75
Shale, green, gypsiferous, well-indurated	0.25
Shale, green, silty	0.2
Shale, red, selenitic; becoming greenish-gray at base, with even-bedded lower contact	1.5
Nescatunga Gypsum Member:	
Gypsum, white, fine-crystalline, dense, compact, finely laminated; mottled greenish-gray and moderate reddish-brown at top, forms ledge	6.0
Anhydrite, light-gray, fibrous, compact, fine-crystalline; forms massive resistant bright-white pitted ledge	4.0
Gypsum, white, coarse-crystalline, selenitic, compact, massive	3.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, well-indurated, porous, fossiliferous; forms massive ledge	1.2
Unnamed beds:	
Shale, green, silty	0.2
Shale, red, silty; with some greenish-gray spots and vertical selenite veins	5.75
Shale, green, mottled moderate reddish-brown, silty; selenitic at base	0.75
Shale, green, silty; mottled with brown shale spots	0.5
Shale, red, silty	2.0
Kingfisher Creek Gypsum Bed:	
Gypsum, greenish-white, argillaceous, laminated, well-indurated, finely crystalline; forms ledge	0.4
Gypsum, pinkish-white, argillaceous, banded; forms ledge	0.2
Shale, greenish-gray, silty	0.5
Gypsum, maroon, hematitic, platy, well-indurated, argillaceous	0.025
Shale, red, silty	0.25
Gypsum, maroon; as above	0.025
Gypsum, greenish-white, mottled reddish-brown, well-indurated, fine-crystalline, selenitic; forms ledge	1.25

	Feet
Unnamed beds:	
Shale, green, silty	0.2
Shale, red, silty; with some ¼-inch seams of satin spar and selenite	2.0
Shale, green, silty; with some satin spar and reddish-brown shale	0.7
Shale, red, silty; with some ½-inch layers of satin spar	2.0
Shale, green, silty	0.3
Shale, red, silty	4.0
Shale, green, silty; with dolomitic tan shale at base	0.5
Shale, red, silty	1.5
Shale, green, silty	0.2
Shale, red, silty	1.5
Gypsum, reddish-brown, nodular; in red shale	0.1
Shale, red, silty; mottled with ⅛-inch greenish-gray spots	0.25
Medicine Lodge Gypsum Member:	
Gypsum, white to pinkish-white, fine- to coarse-crystalline, selenitic, massive; mottled greenish-white in lower 2 feet; forms pinkish ledge	6.0
Cedar Springs Dolomite Bed:	
Dolomite, mottled reddish-brown and greenish-gray, fine-crystalline, porous, well-indurated; ¼- to ½-inch beds; grading upward into gypsum	0.2
FLOWERPOT SHALE (exposed thickness, 138.2 feet)	
Shale, red, silty; with upper part greenish-gray	3.5
Shale, purplish-brown, flaky	0.5
Shale, green, gypsiferous, well-indurated, crinkly bedded; with much satin spar; forms ledge	0.75
Shale, red, silty, well-indurated; with many ⅛- to 1-inch satin spar veins and layers	2.5
Shale, green, gypsiferous; with 1-inch satin spar layers	0.5
Shale, red, silty	4.0
Shale, green, highly gypsiferous; forms ledge	0.1
Dolomite, greenish-gray, finely crystalline, dense, compact, vuggy; with greenish-colored mineral resembling malachite; forms ledge	0.5
Shale, red, silty; with many ¼- to 1-inch greenish-gray spots	4.0
Shale, green, gypsiferous; well-indurated	0.25
Shale, red, silty	1.25
Shale, green, gypsiferous	0.25
Shale, red, silty; with some 1-inch greenish-gray spots and many selenite layers and veins	11.75
Shale, green, dolomitic, mottled reddish-brown	0.2
Shale, red, silty	0.75
Gypsum, yellowish-green, nodular; with selenite in red shale	1.0
Shale, red, silty	3.5
Shale, green, silty, gypsiferous; with nodular gypsum	0.5
Shale, red, silty	0.8
Siltstone, greenish-gray, argillaceous, weakly indurated	0.25
Shale, red, silty	1.5
Gypsum, nodular; as above	0.5
Shale, red, silty	6.25
Gypsum, pinkish-white, nodular, argillaceous	1.0
Shale, red, silty; marking top of non-gypsiferous part of the Flowerpot Shale; the section above being designated as the upper part of the Flowerpot Shale	17.0
Shale, reddish-brown, dolomitic, well-indurated, blocky	0.25
Shale, moderate reddish-brown, silty	3.0
Shale, greenish-gray, mottled moderate reddish-brown, silty	0.8
Shale, moderate reddish-brown, silty	9.0
Shale, greenish-gray and reddish-brown, silty	1.0

	Feet
Shale, moderate reddish-brown, silty	1.5
Shale, greenish-gray, dolomitic, crinkly bedded, well-indurated	0.025
Shale, moderate reddish-brown; with some mud cracks 1 foot above base	5.25
Siltstone, greenish-gray, argillaceous, dolomitic, cross-bedded; with 18° dip in N 40° W direction on cross-bedding; same as 1st light band below top of Flowerpot Shale of measured section XIV	0.7
Shale, red, silty	10.75
Siltstone, greenish-gray, argillaceous, dolomitic, thin-bedded, cross-bedded; mottled with ¼- to 1-inch moderate reddish-brown spots; with 20° dip in N 85° W direction on cross-bedding; same as 2nd light band below top of Flowerpot Shale of measured section XIV	2.0
Shale, red, silty	3.0
Siltstone, greenish-gray, mottled moderate reddish-brown, dolomitic, flaky, thin-bedded, wavy bedded	0.5
Shale, red, silty; mottled with many ½-inch greenish-gray spots	2.0
Siltstone, greenish-gray, flaky; as above	0.25
Shale, red, silty	15.0
Siltstone, greenish-gray, weakly indurated; with a vertical vein of cross-bedded dolomitic siltstone in it; striking N 85° W, with a dip of 22° on the cross-bedding in the same direction as the strike of the vein	1.5
Shale, red, silty	5.25
Siltstone, mottled greenish-gray and reddish-brown, argillaceous, weakly indurated; forms a light band; same as 3rd light band below top of Flowerpot Shale of section XIV	2.0
Shale, moderate reddish-brown, silty, blocky; with greenish-gray shale streaks and spots; with dark reddish-brown shale in middle	3 0
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, blocky, well-indurated	0.75
Shale, moderate reddish-brown, silty	4.0
Numbered Pf_4 on map:	
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, blocky, well-indurated; same as 4th light band below top of Flowerpot Shale of section XIV	0.6
Unnumbered beds:	
Shale, red, silty; exposed	3.0 +
(Below this point, eastward, there are many cross-bedded, well-indurated siltstones, siltstone-mudstone conglomerates, and fine-grained sandstones of the Chickasha Tongue, not measured.)	

XIII. Section measured west of Hitchcock in SE¼ sec. 11, T. 17 N., R. 12 W., south of road along creek, in Dog Creek and Blaine Formations, ending in SE¼ sec. 6, T. 17 N., R. 11 W., in bluff north of road for Flowerpot Shale portion.

DOG CREEK SHALE (top not exposed; exposed thickness, 91.85 feet)	Feet
Dolomite, light greenish-gray, fine-grained, silty, thin-bedded, weakly indurated	1.0
Shale, red, silty	2.0
Shale, green, dolomitic, silty	1.5
Shale, red, silty	0.25
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, well-indurated, thin-bedded; weathering tan; forming massive ledge	0.3

	Feet
Unnamed beds:	
Shale, green, silty, flaky	0.2
Shale, red, silty, thin-bedded to blocky; mottled with greenish-gray shale spots and streaks; with some satin spar	7.5
Shale, red, silty; with some reddish-brown streaks	1.75
Shale, brown, argillaceous, blocky; with some greenish-gray streaks; and with many ⅛- to 1-inch satin spar layers	9.5
Siltstone, greenish-gray; with some dolomitic nodules; and many reddish-brown and greenish-gray satin spar layers	1.75
Shale, red, silty, mottled greenish-gray, flaky	1.75
Shale, greenish-gray, silty, dolomitic, blocky, mottled tan	1.0
Shale, red, silty; with some greenish-gray spots and ¼-inch satin spar layers at top and bottom	4.25
Siltstone, greenish-gray, dolomitic, argillaceous; with some wavy bedded ½-inch seams of satin spar and reddish-brown shale	1.0
Shale, red, silty; with some ½-inch satin spar layers	4.25
Siltstone, greenish-gray, argillaceous, dolomitic; with some satin spar and gypsum nodules	1.0
Shale, red, silty; with some greenish-gray shale and with gypsum nodules	12.0
Shale, greenish-gray, dolomitic, blocky, well-indurated; with some satin spar	1.0
Shale, red, silty; with some greenish-gray streaks	0.75
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, argillaceous, well-indurated; forms resistant ledge	0.25
Shale, red, silty	0.25
Siltstone, greenish-gray; with some ½- to 1-inch satin spar layers	0.75
Shale, purplish-brown, mottled reddish-brown, silty, argillaceous; flaky at top; blocky at base	0.75
Dolomite, light bluish-gray, argillaceous, silty, fine-grained, dense, vuggy; ⅛- to 1½-inch beds; interbedded with light bluish-gray shale; forming resistant escarpment	1.5
Unnamed beds:	
Shale, light-brown, silty; with some light bluish-gray shale streaks	1.5
Siltstone, greenish-gray, gypsiferous, argillaceous, well-indurated; with ½- to 1-inch satin spar seams	1.0
Shale, red, silty	1.0
Haskew Bed:	
Siltstone, light brown, gypsiferous, argillaceous, well-indurated; with many ¼- to 2-inch satin spar layers; forming resistant ledge	3.0
Unnamed beds:	
Siltstone, greenish-gray, gypsiferous, argillaceous	0.5
Siltstone, reddish-brown, dolomitic; with some greenish-gray shale seams and spots; and with much satin spar	5.0
Siltstone, greenish-gray; as above	0.5
Shale, red, silty, gypsiferous	2.0
Gypsum, pinkish-white, crinkly bedded; with satin spar	0.6
Shale, red, silty; with many greenish-gray shale layers and much satin spar	2.25
Shale, green, gypsiferous, silty, well-indurated; forming ledge	0.75
Shale, red, silty, crinkly bedded; with some green shale layers and satin spar; with much satin spar in basal part	17.5
BLAINE FORMATION (total thickness, 97.8 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, banded; mottled greenish-gray at top; with a more indurated 6-inch anhydrite-like layers near middle; forming resistant ledge	14.5

	Feet
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, silty, fossiliferous, vuggy; forms massive ledge; grading upward into gypsum	1.0
Unnamed beds:	
Shale, green, silty	0.5
Shale, red, silty, gypsiferous	2.0
Shale, green, mottled reddish-brown, silty	0.25
Shale, red, silty; with some greenish-gray shale streaks; with selenite, and with gypsum nodules; many ¼-inch satin spar layers	11.0
Shale, green, silty; with some selenite	1.5
Shale, red, silty; with some greenish-gray shale spots	2.5
Shale, green, silty	0.25
Shale, red, silty; with some greenish-gray shale in middle	2.0
Shale, green, silty	2.0
Shale, red, silty	2.0
Shale, green, silty	5.0
Shale, red, silty; with many greenish-gray shale layers; with much selenite and satin spar	4.0
Shale, green, gypsiferous, silty, well-indurated, selenitic; with less-indurated middle portion; forming even-bedded contact at base	2.0
Nescatunga Gypsum Member:	
Gypsum, white, fine-crystalline, thinly laminated, dense, compact; forms white ledge covered with coarse-crystalline selenite	5.0
Anhydrite, light-gray, fine-crystalline, fibrous, compact, well-indurated; interbedded with gypsum; forms bright-white ledge	3.0
Gypsum, white, fine- to coarse-crystalline, porous, selenitic	4.5
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, vuggy, fossiliferous; grading upward into gypsum; forms resistant ledge	1.0
Unnamed beds:	
Shale, green, silty	0.5
Shale, red, silty; with some greenish-gray shale streaks	6.0
Shale, green, silty, gypsiferous	0.25
Shale, red, silty	1.5
Shale, green, gypsiferous	1.0
Shale, red, silty	4.0
Kingfisher Creek Gypsum Bed:	
Gypsum, greenish-white, mottled pinkish-white, argillaceous, thin-bedded, crinkly bedded; forms small ledge	0.5
Shale, greenish-gray, gypsiferous, mottled reddish-brown	0.75
Gypsum, greenish-white; as above	0.75
Unnamed beds:	
Shale, green, silty	0.75
Shale, red, silty	2.0
Shale, green, silty	0.5
Shale, green, gypsiferous, crinkly bedded, well-indurated	0.25
Shale, red, silty	5.0
Shale, green, silty, gypsiferous	0.25
Shale, red, silty	4.0
Shale, green, silty, weakly indurated	0.25
Medicine Lodge Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, crinkly bedded, well-indurated, thin-bedded; mottled moderate reddish-	

brown to pale-pink; with middle part greenish-gray; forms massive ledge 5.5

Cedar Springs Dolomite Bed:

Dolomite, tan to greenish-gray, fine-crystalline; grading upward into gypsum; occurring sporadically 0.05

FLOWERPOT SHALE (exposed thickness, 54.25 feet)

Shale, dark reddish-brown, silty, blocky, selenitic; with some gypsum nodules; with greenish-gray shale at top and ¼-inch hematite band near base 5.25
Shale, greenish-gray, gypsiferous, well-indurated; with much satin spar; ¼- to ½-inch beds; forming resistant ledge 1.0
Shale, red, silty, gypsiferous; with many satin spar layers and with some resistant ledge-forming greenish-gray shale layers 5.5
Dolomite, light-gray to tan, fine-grained, vuggy, well-indurated; forming ledge 0.5
Shale, red, silty; with much satin spar 5.5
Shale, green, silty, gypsiferous, well-indurated 0.5
Shale, red, silty 8.0
Shale, green, silty 0.5
Shale, red, silty; with some satin spar 5.0
Shale, red, silty; with two greenish-gray nodular bands of gypsum at top and bottom 0.75
Shale, red, silty 5.0
Gypsum, greenish-gray, nodular 0.5
Shale, moderate reddish-brown, silty; mottled with some 1- to 3-inch greenish-gray spots and veins of shale; the top of this unit marking the base of the upper part of the Flowerpot Shale 6.5
Shale, green, silty, selenitic; with some white gypsum nodules.. 0.5
Shale, red, silty 4.0
Shale, greenish-gray, mottled reddish-brown, dolomitic; well-indurated at top; forms light band 2.25
Shale, red, silty; exposed ..... 3.0 +

XIV. The following composite section along Salt Creek Canyon and tributaries to Salt Creek represents many detailed measured sections beginning in the upper part of the Dog Creek Shale at the top and ending in the Cedar Hills Member as described in section I. Starting in the SW¼ sec. 27, T. 18 N., R. 12 W., and proceeding downstream along the South Branch of Salt Creek into the SE¼ sec. 27, Dog Creek Shale through the Blaine Formation. For the upper part of the Flowerpot Shale, SE¼ sec. 23, T. 18 N., R. 12 W., north side of Salt Creek Canyon. For the middle portion of the Flowerpot, NW¼ to the SE¼ sec. 18 and SW¼ sec. 17, T. 18 N., R. 11 W., just north and east of the Boeckman ranch, north of Salt Creek. For the Chickasha Tongue portion, SE¼ sec. 21, T. 18 N., R. 11 W. The lower portion of the Flowerpot Shale is then measured in a series of six sections, proceeding downstream along a creek about 2½ miles north of Salt Creek.

DOG CREEK SHALE (top not exposed; exposed thickness, 113.4 feet) *Feet*

Shale, red, well-indurated 2.0
Shale, green, mottled reddish-brown, dolomitic, well-indurated.. 0.4
Shale, moderate reddish-brown, mottled greenish-gray; with 2-inch purplish silty shale band 2 feet up from base 4.5
Shale, green, mottled reddish-brown, dolomitic 0.5
Shale, moderate reddish-brown, dolomitic 1.0
Shale, green, dolomitic, dense, flaky, well-indurated 0.5
Shale, brown to tan, argillaceous, blocky, well-indurated; mottled greenish-gray; with some ¼-inch dolomite layers and concretions 9.0

Feet

Dolomite, light-gray to greenish-gray, argillaceous, fine-grained, dense, thin-bedded 0.5
Shale, red, well-indurated 0.75
Dolomite, greenish-gray, silty; as above; brown at base..... 0.5
Shale, red, weakly indurated 2.0
Shale, green, dolomitic 0.25
Shale, red; mottled green 2.5
Dolomite, greenish-gray, fine-grained, silty, gypsiferous, thin-bedded; with some ¼-inch greenish-gray selenite layers; and with brownish concretionary gypsum 1.0
Shale, red; with much selenite 1.25
Dolomite; as above; with some red shale laminae 1.0
Shale, red; with some 2-inch greenish-gray bands and some selenite 3.0
Shale, greenish-gray, wavy bedded; with some selenite gypsum 0.6
Shale, brown, mottled greenish-gray, well-indurated, blocky..... 5.0
Dolomite, greenish-gray; with red shale and selenite in middle and with greenish-gray shale at base 1.0
Shale, brown, argillaceous, blocky, well-indurated; mottled greenish-gray; with red and green shale bands near base 3.0

Southard Dolomite Bed:

Dolomite, light-gray to yellowish-gray, fine-grained, compact, dense, medium-bedded to finely laminated, silty; with many small black specks; forms massive yellowish-gray ledge 0.4

Unnamed beds:

Shale, green 0.25
Shale, moderate reddish-brown, mottled greenish-gray, silty, dolomitic, selenitic; with 9-inch red shale n middle 2.0
Shale, brown; with 4 or 5 greenish-gray shale seams 2 to 3 inches thick and with many ¼- to ½-inch satin spar layers....21.0
Shale, green 1.0
Shale, red 4.0
Shale, green, silty; with many ¼- to ½-inch greenish-gray and pink satin spar layers 1.0
Shale, red 5.0
Shale, greenish-gray, gypsiferous, silty; with some ½-inch satin spar layers; with 6-inch red shale seam about 3 inches above base 3.0
Shale, red; with many ¼- to ½-inch satin spar layers and veins 2.0
Shale, green 0.25
Shale, purplish-brown, argillaceous, blocky 2.0

Watonga Dolomite Bed:

Dolomite, light bluish-gray, fine-grained, dense, compact; with lenticular vuggy layers; interbedded with light bluish-gray to moderate reddish-brown dolomitic shale; with ½- to 1-inch satin spar layers at base; forms prominent ledge 4.5
Dolomite; as above; overlain by 1 foot of light-brown siltstone 2.0

Haskew Bed:

Siltstone, light-brown, argillaceous, highly gypsiferous, massive, well-indurated; with greenish-gray layers; with red-dish-brown and greenish-gray shale spots and satin spar layers; forms light-brown ledge 3.0

Unnamed beds:

Shale, red, silty, crinkly bedded, gypsiferous; with two 3- to 6-inch greenish-gray shale layers; with many satin spar layers 11.5

	Feet
Gypsum, greenish-gray, argillaceous, compact, well-indurated, dolomitic	0.75
Shale, red, wavy bedded; with two 4- to 6-inch green layers; with much satin spar; with greenish-gray gypsiferous shale at base	9.5
BLAINE FORMATION (total thickness, 91.75 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, massive, porous to dense; with crinkly upper surface; forms bright-white, massive ledge	15.0
Altona Dolomite Bed:	
Dolomite, light-gray to yellow-gray, fine-grained; with ¼ mm oölites in upper portion and dense basal portion; with *Permophorus* casts; grades upward into gypsum; forms a gray to tan massive ledge	0.75
Unnamed beds:	
Shale, green	0.9
Shale, red; with some ½-inch satin spar layers	9.0
Shale, green; with satin spar	1.0
Shale, red	5.0
Shale, green, gypsiferous	1.0
Shale, red; with green shale streaks	10.5
Shale and impure gypsum, green and red, thin-bedded, crinkly bedded	1.0
Nescatunga Gypsum Member:	
Gypsum, white, finely crystalline, dense, compact, massive to thinly banded; mottled greenish-gray and pink at top	4.5
Anhydrite, light-gray, compact, fine-crystalline, fibrous, massive; weathering light-white and forming a resistant ledge	9.5
Gypsum, white to gray, thin-banded, fine-crystalline	1.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, well-indurated, massive, fossiliferous; with ¼ mm oölites in upper portion and dense portion at base; grading into gypsum above; forms gray to tan massive ledge	0.75
Unnamed beds:	
Shale, red, with 6-inch green shale at top	5.0
Shale, alternating red and green, partly covered	7.0
Kingfisher Creek Gypsum Bed:	
Gypsum, greenish-gray, argillaceous, impure; in several beds	1.5
Unnamed beds:	
Shale, alternating red and green, partly covered	13.0
Medicine Lodge Gypsum Member: (type locality for Ferguson Gypsum)	
Gypsum, white, fine- to coarse-crystalline, massive; mottled moderate reddish-brown to pale-pink at top and greenish-white at base; forms pinkish-gray ledge	5.25
Cedar Springs Dolomite Bed:	
Dolomite, light-gray, fine-grained, dense; missing in many places	0.1
FLOWERPOT SHALE (total thickness, 437 feet)	
(section extrapolated to SE¼ sec. 23, T. 18 N., R. 12 W.)	
Shale, green, well-indurated	5.5
Hematite band, dark reddish-brown, well-indurated	0.01
Shale, highly gypsiferous, well-indurated; red in upper 6 inches; green in lower 2 inches; forms prominent ledge	0.7
Shale, yellow-brown, limonitic, argillaceous, blocky; with many ¼- to ½-inch satin spar streaks	1.8
Gypsum, white, mottled pink; well-indurated; with hematite band at top and greenish-gray shale band at base; forms resistant ledge	0.25
Shale, red; with much satin spar	2.0

	Feet
Shale, greenish-gray, highly gypsiferous, thin-bedded, well-indurated; with much satin spar; forms resistant ledge	1.0
Shale, red, silty; speckled with ⅛- to ¼-inch greenish-gray round specks; with some satin spar streaks	2.0
Shale, green, highly gypsiferous, well-indurated, massive; with selenite streaks; forms ledge	0.25
Shale, red; as above	5.0
Shale, green; as above; forms ledge	0.25
Shale, red; as above	6.5
Shale, green; as above; forms ledge	0.25
Shale, red; as above	2.5
(section extrapolated to south bank of creek)	
Shale, green, highly gypsiferous; as above	0.75
Shale, red, well-indurated; as above	4.0
Gypsum, yellow-white, nodular, vuggy; interbedded with green and red shale	0.5
Shale, red; as above	3.0
Gypsum, yellow-white, nodular, as above	0.25
Shale, red; as above	2.75
Gypsum, yellow-white, nodular; as above	0.25
Shale, red; as above	2.0
Gypsum, greenish-gray to white, nodular; interbedded with greenish-gray shale	0.4
Shale, red; as above	1.75
Gypsum, greenish-gray to white, nodular; as above	0.25
Shale, red; as above	2.5
Shale, green, highly gypsiferous; as above	0.25
Shale, red, silty; with many small greenish-gray spots, and with some 3-4 inch spots; with some veins of greenish-gray shale streaks. Gypsum absent except for a few thin bands in the upper 10 feet	39.0
(section extrapolated to sec. 18, T. 18 N., R. 11 W., to the north)	
Siltstone, greenish-gray, mottled reddish-brown, dolomitic; weathers tan; forms prominent greenish-gray band in countryside	1.5
Shale, red, mottled greenish-gray, silty; with dolomitic streaks	5.5
Shale, red, dolomitic, mottled greenish-gray, well-indurated, blocky	0.7
Shale, red, mottled greenish-gray, silty	3.0
Shale, red, dolomitic, mottled greenish-gray, well-indurated	0.5
Shale, red, silty	11.5
Siltstone, red, dolomitic, mottled greenish-gray, cross-bedded; with asymmetrical ripple marks that strike N 15° E with steep side to southeast; with approximately 15° dip in N 55° W direction on cross-beds	0.2
Shale, red, silty; mottled with greenish-gray spots	3.0
Siltstone, greenish-gray, mottled reddish-brown, dolomitic; forming prominent greenish-gray band in region	3.0
Shale, red; mottled greenish-gray in places	11.0
Siltstone, greenish-gray, argillaceous, weakly indurated; forming 3rd prominent light-colored band below top of formation	2.0
Shale, red; mottled with some black and greenish-gray spots	7.0
Numbered Pf_4 on map:	
Siltstone, greenish-gray, argillaceous, thin-bedded, well-indurated, forming 4th prominent greenish-gray band down from top	1.5
Unnumbered beds:	
Shale, red, silty, thin-bedded; with many 1/16- to ½-inch greenish-gray specks	11.0

	Feet
Siltstone, greenish-gray, dolomitic, argillaceous, mottled moderate reddish-brown, thin-bedded; with symmetrical ripple marks that strike N 25° E	0.5
Shale, red, silty; as above; with greenish-gray layer 2.5 feet below top	12.0
Siltstone, light greenish-gray, mottled moderate reddish-brown, argillaceous, well-indurated; with basal 6 inches cross-bedded; with dip of 16° in a N 60° W direction; forming 5th prominent light band down from top	1.0
Shale, red, silty; as above	2.0
Siltstone, light greenish-gray, dolomitic, argillaceous, well-indurated	0.25
Shale, red, silty; as above	7.0
Numbered Pf_3 on map:	
Siltstone, reddish-brown, mottled greenish-gray, dolomitic, argillaceous, thin-bedded, crinkly; with ¼- to 3-inch greenish-gray spots; forming 6th prominent light band below top of formation	0.25
Unnumbered beds:	
Shale, red, silty	5.0
Gypsum, greenish-gray to white to yellowish, nodular; with ¼-inch pinkish-white selenite at base; forming 7th light band below top	0.3
Shale, red, silty; with occasional 1/16-inch greenish-gray spots	5.5
Siltstone, greenish-gray, dolomitic, argillaceous, thin-bedded, flaky; forming 8th prominent light band below top	2.0
Shale, red, silty; as above	4.0
Gypsum, white, nodular; interbedded with shale	0.5
Shale, red, silty; as above	13.0
(section begins in SE¼ SW¼ sec. 17, T. 18 N., R. 11 W.)	
Siltstone, greenish-gray, argillaceous, dolomitic, mottled reddish-brown, with some white gypsum nodules; cross-bedded with dip of 25° in a N 40° W direction; forming 9th prominent light band below top	1.5
Shale, red, silty, thin-bedded, cross-bedded, well-indurated; mottled with ⅛- to ½-inch greenish-gray spots	6.5
Siltstone, greenish-gray and mottled reddish-brown, argillaceous; forming 10th prominent light band below top	1.0
Shale, red, silty; mottled with some greenish-gray spots	10.5
Chickasha Tongue, marked Pfc_2 on map:	
Siltstone-mudstone conglomerate, mottled reddish-brown and greenish-gray, thin- to medium-bedded, well-indurated; grading into fine-grained quartzose sandstone and siltstone with occasional yellowish-white gypsum nodules in upper part; with 0.1-1.5 cm-sized rock particles in a quartzose siltstone matrix; cross-bedded with dip of 14° to the north; forms ledge; forming 11th prominent light band below top	2.5
Unnumbered Chickasha beds:	
(section extrapolated to SE¼ sec. 21, T. 18 N., R. 11 W.)	
Siltstone, dark reddish-brown, argillaceous, weakly indurated	2.0
Siltstone, moderate reddish-brown, argillaceous; mottled with some greenish-gray spots; with some indurated ½-inch beds	2.0
Siltstone, dark reddish-brown; as above	1.0
Siltstone, moderate reddish-brown; as above	1.0
Siltstone, dark reddish-brown; as above	1.0
Siltstone, mottled greenish-gray and moderate reddish-brown	1.0
Siltstone, dark reddish-brown, blocky; as above	0.5
Siltstone, greenish-gray, cross-bedded; becoming reddish-brown and indurated at top; forming 12th prominent light	

	Feet
band below top of Flowerpot Shale	2.0
Shale, dark reddish-brown, silty	4.0
Siltstone, mottled moderate reddish-brown and greenish-gray	1.0
Shale, red, silty	2.5
Shale, red, silty; mottled with some greenish-gray spots	0.7
Shale, red, silty	0.5
Shale, red, silty, mottled greenish-gray	1.5
Siltstone, greenish-gray, mottled moderate reddish-brown, cross-bedded, well- to weakly indurated	0.25
Shale, red, silty	1.5
Siltstone, greenish-gray, mottled reddish-brown	0.2
Shale, red, silty	2.5
Basal Chickasha bed, marked Pfc_1 on map:	
Siltstone, moderate reddish-brown, mottled light greenish-gray, quartzose, argillaceous, dolomitic, cross-bedded; well-indurated at base; forming 13th prominent light band below top of Flowerpot Shale	2.75
Unnumbered Flowerpot Shale beds:	
Shale, dark reddish-brown, silty	5.0
Siltstone, mottled greenish-gray and reddish-brown; with nodular gypsum	0.2
Shale, dark reddish-brown, silty; with greenish-gray specks	0.75
Siltstone, moderate reddish-brown, mottled greenish-gray	1.0
Shale, red, silty	2.5
Siltstone; as above	0.75
Shale, red, silty; with small greenish-gray specks	1.75
Gypsum, greenish-white, nodular	0.2
Siltstone, mottled greenish-gray and reddish-brown, platy	2.0
Gypsum, white, mottled greenish-gray and moderate reddish-brown; nodular; in discontinuous patches	0.5
Shale, red, silty; with greenish-gray siltstone streaks	11.0
Siltstone, light greenish-gray, argillaceous, dolomitic, cross-bedded; with 17° dip in S 5° W direction; forming 14th prominent light band down from top	2.5
(section extrapolated 2½ miles north, to SE¼ sec. 10, SW¼ sec. 11, NW¼ sec. 11, into NW¼ sec. 12, T. 18 N., R. 11 W.)	
Shale, red, silty	1.25
Siltstone, moderate reddish-brown, mottled greenish-gray, weakly indurated	0.5
Shale, red, silty	3.0
Siltstone, greenish-gray, thin-bedded, well-indurated	0.2
Shale, reddish-brown, silty; speckled greenish-gray	0.8
Siltstone, mottled moderate reddish-brown and greenish-gray	0.3
Shale, red, silty; with occasional 2- to 3-inch greenish-gray round spots with dark-colored centers	7.0
Siltstone; as above; upper 2 inches well-indurated with two sets of asymmetrical ripple marks; the upper set strikes N 55° W with steep side to northeast, and the lower set strikes N 25° E with steep side to southeast; forms 15th prominent light band below top of Flowerpot Shale	0.6
Shale, red, silty; speckled with greenish-gray spots; with some moderate reddish-brown siltstone streaks in upper part	30.0
Siltstone, moderate reddish-brown, mottled greenish-gray, argillaceous, thin-bedded; forms 16th prominent light band below top	0.25
Shale, red, silty; as above	0.75
Siltstone, moderate reddish-brown, weakly indurated	0.1
Shale, red, silty, well-indurated	0.6
Shale, red, silty, platy, weakly indurated	0.2
Shale, red, silty, well-indurated	0.75
Shale, red, silty, partly covered	10.0

	Feet
Shale, red, silty	5.0
(section extrapolated to SW¼, then NW¼, then SE¼ sec. 7, T. 18 N., R. 10 W.)	
Siltstone, moderate reddish-brown, argillaceous	0.7
Shale, red, silty; mottled with some greenish-gray spots	10.0
Siltstone, moderate reddish-brown, thin-bedded; mottled with some 1/16- to ⅛-inch greenish-gray spots; with some fine-grained sandstone; forming 17th prominent light band down from top	0.9
Shale, moderate reddish-brown, platy; with interbedded siltstone	2.75
Shale, red, silty, dolomitic; mottled greenish-gray in middle	0.8
Shale and siltstone, interbedded, moderate reddish-brown	2.0
Sandstone, moderate reddish-brown, fine-grained, wavy bedded	0.2
Shale and siltstone, interbedded, moderate reddish-brown	3.0
Siltstone, greenish-gray, mottled moderate reddish-brown, thin-bedded; forming 18th prominent light band down from top	3.0
Siltstone, moderate reddish-brown, massive, weakly indurated	0.8
Shale, red, silty; with some greenish-gray spots	1.0
Siltstone, greenish-gray, weakly indurated	0.1
Shale, red, silty	0.5
Siltstone, greenish-gray, well-indurated	0.1
Siltstone, moderate reddish-brown, argillaceous, massive; with some greenish-gray specks	0.75
Shale, red, silty	0.75
Siltstone, moderate reddish-brown; as above	0.5
Shale, red, silty	0.25
Siltstone, moderate reddish-brown; as above	0.5
Shale and siltstone, red; as above	2.5
Siltstone, moderate reddish-brown; as above	1.5
Shale, red, silty, partly covered	17.0
Siltstone, mottled greenish-gray and reddish-brown; top 3 inches well-indurated; forming 19th prominent light band down from top	0.5
Siltstone, moderate reddish-brown, argillaceous, weakly indurated	0.5
Siltstone, blocky; as above	0.5
Shale, red, silty	0.7
Shale, red, silty, moderately indurated	0.25
Shale, red, silty, platy	0.75
Shale, red, silty, blocky, well-indurated	0.8
Shale, red, silty, partly covered	4.0
(section taken along creek in SW¼ NW¼ sec. 8, and NE¼ SW¼ sec. 8, T. 18 N., R. 10 W.)	
Siltstone, mottled moderate reddish-brown and greenish-gray, thin-bedded	0.5
Shale, red, silty; mottled with some 1/16- to ½-inch greenish-gray spots; with some 1- to 2-inch moderate reddish-brown platy siltstone beds	8.0
Siltstone, greenish-gray and mottled reddish-brown, dolomitic, wavy bedded, well-indurated; forms thin ledge	0.2
Shale, red, silty; as above	2.0
Siltstone, greenish-gray; as above	0.1
Shale, red, silty; as above	0.7
Shale, red, silty, moderately indurated; as above; forming ledge	1.0
Shale, red, silty, weakly indurated, platy	3.0
Shale, red, silty; as above; with some thin greenish-gray sandy beds	1.5
Shale, red, silty, weakly indurated	1.0

	Feet
Shale, red, silty; with 1- to 2-inch greenish-gray siltstone at top	0.5
Shale, red, silty, weakly indurated	1.5
Shale, red, silty; with light greenish-gray streak near middle	2.0
Shale, red, silty, weakly indurated; with thin greenish-gray band at top	3.0
Shale, red, silty, partly covered	13.0
(section measured in SW¼ sec. 9, T. 18 N., R. 10 W., same as section I.)	
Shale, red, silty; forming small ledge	2.0
CEDAR HILLS MEMBER OF HENNESSEY SHALE	
Siltstone, light greenish-gray, argillaceous, dolomitic, thin-bedded; with 3-inch ledge at base; marked as Pch₈ on map	2.25

XV. Section measured along road in SW¼ sec. 10, T. 18 N., R. 12 W., one mile south of Southard, for Dog Creek portion, continuing into SE¼ sec. 3, NE¼ sec. 10 for Blaine portion along road east of Southard, ending in SW¼ sec. 2, T. 18 N., R. 12 W., south of road, for Flowerpot portion.

DOG CREEK SHALE (top not exposed; exposed thickness, 82.05 feet)	Feet
Shale, mottled reddish-brown and greenish-gray, silty, blocky, crinkly bedded, thin-bedded; with some satin spar and several indurated bands	1.0
Shale, red, silty	0.75
Dolomite, greenish-gray, argillaceous, fine-grained, silty, porous; with some gypsum	0.5
Shale, green, silty	0.25
Shale, red, silty; mottled with some greenish-gray spots and streaks	2.5
Shale, greenish-gray, dolomitic, porous, well-indurated	0.1
Shale, red, silty	0.75
Shale, greenish-gray; as above	0.2
Shale, red, silty	1.0
Shale, greenish-gray; as above	0.1
Shale, red, silty; becoming greenish-gray toward base	1.5
Dolomite, light-gray, fine-grained, dense, well-indurated	0.1
Shale, red, silty	0.3
Dolomite, light-gray; as above	0.1
Shale, red, silty	0.2
Shale, green, silty, dolomitic, well-indurated	0.25
Shale, red, silty	2.0
Shale, green, silty, well-indurated	1.0
Shale, red, silty	0.7
Southard Dolomite Bed: (type section)	
Dolomite, light-gray to yellowish-gray, fine-grained, silty, dense, thin-bedded, well-indurated; with ½-inch vugs; ¼- to 1-inch beds; forms massive tan ledge capping an escarpment	0.3
Unnamed beds:	
Shale, green, silty	1.0
Shale, mottled reddish-brown and greenish-gray, argillaceous, silty, blocky	0.2
Shale, red, silty	1.5
Siltstone, greenish-gray, argillaceous, weakly indurated	0.3
Shale, red, silty, mottled greenish-gray	4.5
Shale, green, silty, dolomitic, well-indurated, mottled reddish-brown	1.5
Shale, red, silty	2.6
Shale, mottled reddish-brown and greenish-gray; as above	1.5
Shale, red, silty	3.0
Shale, green, silty, mottled reddish-brown	1.25

	Feet
Shale, red, silty	5.0
Shale, green, silty at base	0.5
Siltstone, light-brown, massive	3.0
Shale, green, silty; four beds; 2 inches thick; with interbedded reddish-brown shale and siltstone regularly spaced between; with many ½- to 1-inch satin spar layers	5.0
Shale, green, silty; with much pinkish-white satin spar	1.0
Shale, purplish-brown, argillaceous, blocky, silty; with many yellowish-white gypsum nodules	1.75
Shale, green, silty	0.25
Shale, red, silty; with some ⅛-inch spar satin layers	2.5
Shale, green, mottled reddish-brown, silty	1.0
Shale, purplish-brown and mottled greenish-gray, argillaceous, silty, blocky	2.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, well-indurated; capping resistant escarpment	0.1
Shale, argillaceous, blocky; reddish-brown at top; light bluish-gray at base; with ¼- to 1-inch satin spar layers	1.0
Dolomite; as above; ¼- to 1-inch beds	0.4
Shale, silty; as above	0.5
Siltstone, light-brown, platy, crinkly bedded; becoming dolomitic at base	1.75
Dolomite, porous, crinkly bedded; as above; with interbedded shale and satin spar layers	0.2
Unnamed beds:	
Shale, green, silty	0.3
Shale, red, silty	0.25
Haskew Bed:	
Siltstone, greenish-gray, gypsiferous, well-indurated; ¼- to ½-inch beds	0.5
Siltstone, light-brown, gypsiferous, well-indurated, platy, crinkly bedded; forming resistant ledge	3.0
Unnamed beds:	
Shale, greenish-gray, gypsiferous, well-indurated, vuggy; with many nodules and much satin spar	1.0
Shale, red, silty, well-indurated; with many satin spar layers	1.0
Shale, greenish-gray, silty, gypsiferous	0.7
Shale, red, silty; with much satin spar	3.0
Shale, green, silty, gypsiferous	0.6
Shale, green and red, silty, crinkly bedded; with much satin spar; with prominent greenish-gray indurated band about 4 feet below top	12.75
Siltstone, greenish-gray, argillaceous, gypsiferous, well-indurated; forming ledge	0.3
Shale, reddish-brown and greenish-gray, silty, blocky, crinkly bedded; with lower contact impure gypsiferous greenish-gray shale	1.75
BLAINE FORMATION (total thickness, 86.55 feet)	
Shimer Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, banded; the middle portion grading into anhydrite where there are 33 feet or more of natural overburden; forms white ledge	21.0
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, fossiliferous; thin-bedded in upper portion; grading upward into gypsum; forms massive ledge	1.0
Unnamed beds:	
Shale, green, silty	1.0
Shale, red, silty, mottled greenish-gray	8.0
Shale, greenish-gray, gypsiferous, well-indurated; with reddish-brown satin spar; forming ledge	1.0

	Feet
Shale, red, silty; with some ½-inch selenite seams	1.5
Shale, green, silty; with some selenite layers	1.0
Shale, red; as above	3.5
Gypsum and shale, greenish-gray, selenitic, well-indurated; forming ledge	1.0
Shale, red, silty; with ¼-inch selenite veins; mottled greenish-gray at top and base	1.5
Shale, green, silty, mottled dark-reddish-brown	3.5
Shale, red, silty; with satin spar layers	0.75
Shale, green, silty; with many ½-inch satin spar seams	0.25
Shale, red, silty	1.75
Shale, green, gypsiferous, mottled reddish-brown; with satin spar	0.5
Shale, red, silty; with much satin spar	0.8
Shale, green: as above	0.2
Shale, red; as above	0.3
Shale, green, silty, mottled purplish-brown	0.25
Shale, red, mottled greenish-gray, silty	0.5
Shale, green, silty, grading into impure gypsum, crinkly bedded, well-indurated at top	1.5
Nescatunga Gypsum Member:	
Gypsum, white, fine-crystalline, thinly laminated to banded; with upper 1 foot mottled reddish-brown and greenish-gray; forming resistant ledge	5.0
Anhydrite, light-gray, fine-grained, fibrous, compact, well-indurated; grading into fine-grained gypsum; forming resistant white ledge	4.5
Gypsum, white, mottled greenish-gray, fine- to coarse-crystalline, porous, massive; leached in most places	4.5
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, porous, fossiliferous, well-indurated; thin-bedded at top; massive at base; grading into gypsum above; forms massive ledge	0.7
Unnamed beds:	
Shale, green, silty, mottled reddish-brown	0.75
Shale, red, silty; with many small yellowish-white gypsum nodules; and with selenite seams	0.75
Shale, red, silty; with some greenish-gray shale	3.0
Shale, green and mottled reddish-brown, silty	1.5
Shale, red, silty, partly covered; probably includes impure gypsum beds which are the equivalent of the Kingfisher Creek Gypsum	2.75
Shale, green, silty	0.75
Shale, alternating reddish-brown and greenish-gray, argillaceous, silty, blocky	6.0
Medicine Lodge Gypsum Member:	
Gypsum, white, fine- to coarse-crystalline, banded; mottled reddish-brown at top; greenish-gray in middle and at base; wavy bedded in basal 2 feet; forming massive ledge	5.25
Cedar Springs Dolomite Bed:	
Dolomite, greenish-gray, fine-crystalline, dense, porous, well-indurated; grading upward into gypsum; occurring sporadically	0.3
FLOWERPOT SHALE (exposed thickness, 65.8 feet)	
Shale, green, silty, mottled dark reddish-brown	0.3
Shale, red, silty; mottled greenish-gray in places	3.0
Shale, green, silty, well-indurated	2.0
Shale, red, silty, well-indurated	1.0
Shale, green, silty, mottled reddish-brown	1.25
Hematite band, maroon; altered to limonite in places	0.025
Gypsum and shale, greenish-gray, mottled reddish-brown,	

	Feet
well-indurated; with much satin spar; forming a ledge	0.5
Shale, red, silty; with many ¼- to ½-inch satin spar bands	2.5
Shale; as above, more indurated; forming ledge	0.5
Shale, red, silty; as above	2.0
Gypsum and shale, greenish-gray; as above; forms ledge	0.25
Shale, red, silty; as above; with some 1-inch greenish-gray shale seams at top	1.5
Gypsum and shale, greenish-gray; as above; forming ledge	1.0
Shale, red, silty; with some greenish-gray layers and many satin spar layers; with several nodular gypsum layers at base	40.0
(This marks the base of the upper portion of the Flowerpot Shale)	
Shale, red, silty; with some greenish-gray shale layers; and with some gypsum; exposed	10.0 +

XVI. Section measured along State Highway 51, beginning at top in NW¼ sec. 3, T. 18 N., R. 12 W., north and south of highway, continuing into NW¼ sec. 35, T. 19 N., R. 12 W., on highway and north of highway for Blaine-Flowerpot portions, ending in NW¼ NW¼ sec. 25, T. 19 N., R. 12 W.

	Feet
DOG CREEK SHALE (top not exposed; exposed thickness, 99.5 feet)	
Shale, red, silty; with 1- to 2-inch light-gray dolomite near top	10.0
Dolomite, light-gray, fine-grained, dense, thin-bedded; with 8 inches of greenish-gray shale between	1.0
Shale, red, silty, mottled greenish-gray; with three 3-inch greenish-gray shale bands 2, 4, and 6 feet above base	7.0
Siltstone, light-gray, dolomitic, argillaceous; grading into greenish-gray shale in lower 8 inches	1.0
Shale, red, silty	2.0
Shale, green, silty, flaky	0.75
Shale, red, silty	0.5
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, argillaceous, fine-grained, dense, well-indurated; ¼- to 1-inch beds; forms massive ledge	0.3
Unnamed beds:	
Shale, purplish-brown, argillaceous, silty, blocky	0.75
Shale, green, silty, mottled reddish-brown	2.25
Shale, red, silty; mottled with 1- to 3-inch greenish-gray shale spots	3.75
Siltstone, greenish-gray, mottled moderate reddish-brown, porous, well-indurated; 2- to 3-inch beds	1.5
Shale, red, silty	2.6
Shale, green, silty	0.25
Shale, red, silty	1.0
Shale, green, silty	0.25
Shale, red, silty	6.1
Shale, green, silty	0.5
Shale, red, silty	1.0
Shale, green, silty	0.5
Shale, red, silty	2.6
Shale, green, silty	0.5
Shale, red, silty	1.0
Shale, green, silty	0.5
Shale, green, silty, platy to blocky	1.0
Dolomite, light bluish-gray, argillaceous, fine-grained, dense, well-indurated, massive	0.1
Shale, greenish-gray, silty; dolomitic at base	1.25

	Feet
Shale, purplish-brown, mottled greenish-gray, argillaceous, blocky	0.75
Shale, red, silty; with ½-inch seam of dolomite at base	0.75
Siltstone, greenish-gray, mottled reddish-brown, argillaceous	0.7
Shale, red, silty; mottled with 1- to 4-inch greenish-gray shale spots; with several ⅛-inch selenite seams in middle	4.5
Shale, green, silty; with many ¼-inch yellowish-white gypsum nodules	0.5
Siltstone, light-brown, weakly indurated; greenish-gray in upper part; satin spar in lower part; with some mud cracks in upper part	5.75
Shale, green, silty	0.25
Shale, red, silty	1.75
Shale, green, silty	0.75
Shale, red, silty; with some 1/16-inch selenite seams; and with 2-3 inch greenish-gray shale spots	2.2
Shale, green, silty, dolomitic; indurated at base	0.75
Shale, purplish-brown, mottled greenish-gray, argillaceous, blocky, well-indurated	1.0
Shale, red, silty	1.5
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, well-indurated, fine-grained, dense; ¼- to 1-inch beds; forms massive ledge	0.3
Shale, light bluish-gray, mottled reddish-brown, argillaceous, dolomitic, blocky; with many selenite and satin spar layers	0.7
Dolomite, vuggy; as above; with ⅛-inch gypsum layers	0.3
Dolomite, mottled reddish-brown; as above; with interbedded greenish-gray shale and gypsum; with some satin spar layers	0.75
Shale, red, silty; with ¼-inch satin spar layers	0.6
Dolomite, silty; as above; with interbedded greenish-gray shale and satin spar gypsum; forming ledge	1.5
Haskew Bed:	
Siltstone, light-brown, gypsiferous, argillaceous, well-indurated; with many ¼- to 1-inch greenish-gray shale streaks; and with satin spar	1.5
Siltstone, light-brown, mottled greenish-gray, weakly indurated	1.75
Unnamed beds:	
Shale, red, silty, crinkly bedded; with a few greenish-gray layers and many satin spar layers; with a well-indurated greenish-gray gypsiferous 2-foot shale band 11 feet above base	21.0
BLAINE FORMATION (total thickness, 68.3 feet)	
Shimer Gypsum Member:	
Gypsum, white, coarsely crystalline, banded; mottled greenish-gray at top; forms massive ledge; deeply weathered into holes	12.0 +
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, fossiliferous; grading into gypsum above; forms ledge	0.75
Unnamed beds:	
Shale, green, silty, well-indurated	0.5
Shale, moderate reddish-brown and mottled greenish-gray, argillaceous, silty, blocky; with 2-inch greenish-gray shale seam at base	2.75
Shale, red, silty	2.75
Siltstone, greenish-gray, mottled reddish-brown, argillaceous, blocky	2.0
Shale, red, silty, well-indurated	3.0
Shale, green, silty, gypsiferous, platy; with white nodular gypsum at top	0.75
Shale, red, silty	2.5

	Feet
Shale, green, silty, gypsiferous; with 2-inch moderate reddish-brown nodular gypsum band in middle	1.0
Shale, red, silty	1.5
Shale, green, silty, gypsiferous, well-indurated	1.5
Shale, reddish-brown, argillaceous, blocky, silty; thin-bedded, crinkly bedded; alternating with greenish-gray argillaceous gypsum	1.5
Nescatunga Gypsum Member:	
Gypsum, white, fine-crystalline, finely laminated, well-indurated; forms ledge	6.5
Anhydrite, light-gray, fine-crystalline, fibrous, massive, well-indurated; with interbedded fine-grained gypsum; forms bright-white pitted ledge	2.0
Gypsum, white, fine- to coarse-crystalline; becoming greenish-gray in lower 3 inches	3.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fossiliferous, dense, thin-bedded, oölitic; with denser portion near base and oölitic portion toward top; with much satin spar; grading upward into gypsum	1.1
Unnamed beds:	
Shale, green, silty; with yellowish-white nodular gypsum at base	0.5
Shale, red, silty; with some ¼-inch greenish-gray spots and satin spar layers	3.0
Shale, green, silty, mottled moderate reddish-brown	1.25
Shale, red, silty	1.75
Kingfisher Creek Gypsum Bed:	
Gypsum and shale, greenish-gray, platy to blocky, well-indurated; forming ledge	0.5
Unnamed beds:	
Shale, red, silty; with some greenish-gray shale streaks and spots	9.0
Shale, green, silty; with many ¼- to 1-inch reddish-brown shale seams	1.1
Medicine Lodge Gypsum Member:	
Gypsum, white and mottled moderate reddish-brown to pale-pink, fine- to coarse-crystalline, banded; mottled greenish-gray in lower part; forming massive ledge	6.5
Cedar Springs Dolomite Bed:	
Dolomite, greenish-gray, argillaceous, finely crystalline, thin-bedded, crinkly bedded; grading upward into gypsum; occurring sporadically	0.1
FLOWERPOT SHALE (exposed thickness, 68.5 feet)	
Shale, green, silty, mottled moderate reddish-brown	0.25
Shale, red, silty	2.25
Shale, green, silty; with many ¼-inch satin spar seams near base	3.0
Hematite band, maroon, argillaceous, well-indurated	0.025
Gypsum and shale, greenish-gray and reddish-brown, well-indurated, thin-bedded; with many ¼- to ½-inch satin spar layers; forming ledge	1.0
Shale, reddish-brown, silty, well-indurated, gypsiferous; with some greenish-gray layers; with much satin spar; forming ledge	5.0
Gypsum and shale, greenish-gray; as above	1.0
Shale, red, silty, gypsiferous; with much satin spar	2.0
Gypsum and shale, greenish-gray; as above; forming ledge	0.5
Shale, red, silty; with some satin spar	7.75
Gypsum, greenish-white, nodular	0.25
Shale, red, silty; with some satin spar	1.5

	Feet
Dolomite, mottled greenish-gray to tan, argillaceous, well-indurated, dense, massive; weathers tan	0.2
Shale, red, silty; with some 2-inch greenish-gray gypsiferous shale layers	10.5
Shale, green, mottled reddish-brown, silty; gypsiferous at base	1.25
Shale, red, silty; with white nodular 2- to 3-inch gypsum beds at top and in middle; selenite in middle; and greenish-white gypsiferous nodules at base and 2 feet above base; marking base of the upper portion of the Flowerpot Shale	19.0
Shale, red, silty; with many 2- to 3-inch greenish-gray spots and veins	15.0 +

XVII. Section measured in high hill and creek just southeast of hill in SE¼ sec. 21, T. 19 N., R. 12 W., for Dog Creek Shale, continuing into NW¼ sec. 27, then SE¼ sec. 16 for the Blaine portion, ending in the center NE¼ SW¼ sec. 10, T. 19 N., R. 12 W., for Flowerpot portion.

DOG CREEK SHALE (top not exposed; exposed thickness, 95.85 feet)	Feet
Dolomite, light-gray, fine-grained, dense, well-indurated, massive, forming escarpment	0.7
Shale, red, silty	1.0
Shale, green, silty, well-indurated	0.25
Shale, red, silty	2.0
Siltstone, mottled greenish-gray and reddish-brown, massive	2.0
Siltstone, greenish-gray, argillaceous, weakly indurated	0.75
Shale, dark reddish-brown, argillaceous, silty, blocky; with some greenish-gray spots and seams	3.5
Dolomite, light-gray, fine-grained, well-indurated, dense; ¼- to ½-inch beds; forms massive ledge	0.2
Shale, red, silty; with 2-inch greenish-gray shale in middle	6.25
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, argillaceous, fine-grained, dense, vuggy, medium-bedded; forms massive ledge	0.6
Unnamed beds:	
Shale, red, silty; with some greenish-gray beds, especially at top	6.75
Shale, green, mottled reddish-brown, silty	1.0
Shale, red, silty	3.0
Siltstone, greenish-gray, mottled reddish-brown, gypsiferous, argillaceous, well-indurated, massive; with white gypsum nodules in upper portion; forms resistant ledge	0.75
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous, weakly indurated	0.75
Shale, red, silty; with many 1/16-inch selenite layers and some greenish-gray shale seams, especially one 2-inch layer 2 feet below top	7.0
Shale, green, silty; with some ¼- to ½-inch fine-grained dense dolomite beds; and with greenish-white gypsum nodules	1.0
Shale, moderate reddish-brown, argillaceous, silty, blocky; with some ¼- to ½-inch satin spar layers and with a 1-inch greenish-gray shale seam near base	4.0
Shale, red, silty, well-indurated; with 1-inch greenish-gray shale seam in middle	3.0
Shale, green, silty; with 2-inch argillaceous dolomite ledge in middle	2.5
Shale, red, silty; with much paper-thin selenite	0.5
Shale, green, silty, gypsiferous, dolomitic; with some selenite	1.0

	Feet
Shale, red, silty; with some gypsum nodules; and with a 2-inch greenish-gray shale bed in middle	3.5
Shale, green, silty, well-indurated; mottled purplish-brown in some places	0.5
Siltstone, moderate reddish-brown, argillaceous; with many paper-thin selenite and satin spar layers	4.0
Shale, green, silty; with some paper-thin selenite layers	0.5
Shale, red, silty, well-indurated	1.0
Shale, green, silty	0.25
Shale, red, silty; mottled with greenish-gray patches	1.75
Shale, green, mottled reddish-brown, silty, well-indurated	3.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, well-indurated; with ⅛ inch beds; forms resistant ledge	0.25
Shale, red, silty	0.25
Shale, light bluish-gray, argillaceous, blocky	0.5
Dolomite; as above; with gypsiferous band at top	0.75
Shale and gypsum, light bluish-gray, dolomitic, argillaceous, blocky, well-indurated; with some satin spar	1.5
Haskew Bed:	
Gypsum, greenish-black, argillaceous, platy, well-indurated	0.3
Siltstone, light-brown, mottled greenish-gray, gypsiferous, argillaceous, well-indurated, platy; forming resistant ledge	1.25
Shale, green, silty, gypsiferous, selenitic, platy to blocky	2.75
Siltstone, light brown; as above	2.0
Unnamed beds:	
Shale, green, silty, gypsiferous; with much satin spar	0.5
Shale, red, silty; with many greenish-gray shale spots and paper-thin satin spar layers	4.0
Shale, green, silty, gypsiferous; with much satin spar	0.3
Shale, red, silty; as above	5.25
Shale, green, silty, gypsiferous, well-indurated; selenitic with gypsum nodules; forming resistant ledge	1.0
Shale, red, silty; as above; with satin spar, selenite, and gypsum nodules	3.0
Shale, mottled reddish-brown and greenish-gray, argillaceous, silty, dolomitic, crinkly bedded, well-indurated; forming ledge	2.0
Shale, red, silty; with much satin spar and nodular gypsum	1.75
Shale, greenish-gray, argillaceous, gypsiferous, dolomitic, well-indurated; forming ledge	0.5
Shale, red, silty; as above; with much selenite	1.5
Shale, greenish-gray; as above; with undulating bedding	1.5
Shale, red, silty, gypsiferous; with many greenish-gray selenite and shale layers; lower surface undulatory	2.0
BLAINE FORMATION (total thickness, 74.3 feet)	
Shimer Gypsum Member:	
Gypsum, white, coarsely crystalline, selenitic, massive; forms massive ledge	16.0
Altona Dolomite Member:	
Dolomite, ligh-gray to yellowish-gray, fine-grained, dense, oölitic, fossiliferous; with *Permophorus;* grading upward into gypsum; forms massive ledge	1.0
Unnamed beds:	
Shale, green, silty	0.5
Shale, red, silty; with some selenite and 1- to 2-inch gypsum nodules in upper 1 foot	5.25
Siltstone, greenish-gray, mottled moderate reddish-brown, argillaceous	0.75
Shale, red, silty	1.5
Siltstone; as above	0.75

	Feet
Shale, red, silty	1.5
Shale, green, silty	0.2
Shale, red, silty; with some selenite	2.0
Shale, green, silty, gypsiferous, platy, well-indurated	0.5
Shale, red, silty	1.0
Shale, green, silty	1.0
Shale, purplish-brown, argillaceous, silty, blocky; with much selenite	1.0
Shale, green, silty	0.3
Shale, red, silty	1.75
Gypsum, reddish-brown, selenitic, well-indurated	0.2
Shale, red, silty	0.3
Siltstone, mottled moderate reddish-brown and greenish-gray	0.25
Shale, red, silty	1.0
Shale, green, silty, gypsiferous, crinkly bedded, well-indurated	0.75
Nescatunga Gypsum Member:	
Gypsum, white, fine-crystalline, dense, crinkly bedded, finely laminated, well-indurated; mottled reddish-brown at top	6.0
Anhydrite, light-gray, finely crystalline, fibrous, well-indurated; grading into gypsum; forms resistant bright-white ledge with a sharp-pitted surface	4.0
Gypsum, white, fine- to coarse-crystalline, porous; mottled reddish-brown in places; forming ledge	3.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, oölitic, thin-bedded, well-indurated, fossiliferous; forms massive ledge; grading upward into gypsum	0.75
Unnamed beds:	
Shale, green, silty	0.3
Shale, red, silty; mottled with greenish-gray patches	4.0
Shale, green, silty	0.3
Shale, red, silty; with satin spar	2.5
Shale, green, silty	0.75
Shale, red, silty; with some ⅛- to ½-inch satin spar seams	2.5
Kingfisher Creek Gypsum Bed:	
Gypsum and shale, greenish-gray, well-indurated; with much satin spar; forming ledge	0.25
Gypsum and shale, reddish-brown, argillaceous; with much satin spar	0.5
Gypsum and shale, greenish-gray; as above	0.5
Unnamed beds:	
Shale, red, silty; with many greenish-gray shale layers, and with a nodular gypsum near base	4.0
Shale, green, silty, gypsiferous	0.5
Shale, red, silty, gypsiferous	0.5
Medicine Lodge Gypsum Member:	
Gypsum, white, coarsely crystalline, selenitic, wavy bedded; mottled reddish-brown to pinkish-white in upper part and greenish-gray in lower part; forming massive pinkish-white ledge	6.25
Cedar Springs Dolomite Bed:	
Dolomite, greenish-gray, gypsiferous; grading upward into gypsum	0.2
FLOWERPOT SHALE (exposed thickness, 124.2 feet)	
Shale, green, silty, mottled reddish-brown	0.2
Shale, red, silty	2.0
Shale, green, silty	3.0
Gypsum and shale, mottled greenish-gray and reddish-brown, well-indurated; with much satin spar; forming resistant ledge	1.25
Shale, red, silty, well-indurated; with much satin spar	4.5

	Feet
Gypsum and shale; as above	0.25
Shale, red, silty; as above; with much satin spar	2.0
Gypsum and shale; as above	0.5
Shale, red, silty; with some greenish-gray shale seams and much satin spar	7.25
Shale, red, silty	1.5
Dolomite, tan to light-gray, fine-grained, well-indurated; grading into greenish-gray shale	0.25
Shale, red, silty	2.75
Shale, green, silty	1.0
Shale, red, silty; with some selenite	3.5
Shale, green, silty, well-indurated, gypsiferous; with many ¼-inch selenite veins	0.3
Shale, red, silty; with some selenite	4.0
Siltstone, mottled greenish-gray and reddish-brown, argillaceous, gypsiferous, weakly indurated; forming prominent light band	1.0
Shale, red, silty, well-indurated; mottled with small greenish-gray spots; with some selenite	10.0
Gypsum, yellowish-white, nodular	0.3
Shale, red, silty	3.75
Gypsum, yellowish-white, nodular	0.2
Shale, red, silty	0.75
Gypsum, yellowish-white, nodular	0.2
Shale, red, silty	2.0
Gypsum, yellowish-white, nodular	0.2
Shale, red, silty	0.75
Gypsum, yellowish-white, selenitic	0.2
Shale, red, silty	0.8
Gypsum, yellowish-white, nodular; in two bands separated by reddish-brown silty clay shale; marking base of upper part of Flowerpot Shale	0.7
Shale, red, silty; with many ½-inch greenish-gray shale spots and veins	25.0
Siltstone, mottled greenish-gray and reddish-brown, argillaceous	1.25
Shale, red, silty, with some vertical selenite veins and gypsum nodules	15.0
Siltstone, mottled greenish-gray and reddish-brown, cross-bedded; with 19° dip in N 35° W direction on cross-beds. Probably same as 1st light-colored band below top of Flowerpot Shale of section XIV	1.75
Shale, red, silty	5.25
Gypsum, white, nodular	0.5
Shale, red, silty	7.0
Shale, green, silty, mottled reddish-brown; probably same as 2nd light-colored band below top of Flowerpot Shale of section XIV	1.5
Shale, red, silty	2.0
Shale, mottled greenish-gray and reddish-brown, silty	0.8
Shale, red, silty	7.0
Siltstone, greenish-gray, argillaceous, forming prominent light-colored band in region. Probably same as 3rd light-colored band below top of Flowerpot Shale of section XIV	2.0
(section not measured below this point; mostly covered red shale)	

XVIII. Section measured just north and south of road and along road one mile east of Cedar Springs, Major County, beginning at top in basal Marlow Formation along road and proceeding downward in S½ SE¼ sec. 11, NE¼ NE¼ sec. 14, and SW¼ NW¼ sec. 13, T. 20 N., R. 13 W., to the Southard and Watonga Dolomite Beds, to the Shimer Gypsum Member in SE¼ SE¼ SW¼ sec. 13, T. 20 N., R. 13 W. Section then extrapolated to railroad cut in NE¼ SE¼ sec. 29, T. 20 N., R. 12 W., down to Magpie Dolomite, continued to base of Blaine Formation in Lopp quarry in SW¼ NW¼ sec. 21, T. 20 N., R. 12 W., ending in bluff east of Sand Creek in SE¼ NW¼ sec. 20, T. 20 N., R. 12 W., for Cedar Springs Dolomite and Flowerpot sections.

	Feet
MARLOW FORMATION (top not exposed)	
Sandstone, moderate reddish-brown, quartzose, fine-grained, friable, weakly indurated; exposed	10.0 +
Sandstone, greenish-gray, quartzose, fine-grained, friable, weakly indurated	0.5
DOG CREEK SHALE (total thickness 157.2 feet)	
Shale, red, silty, blocky	5.5
Siltstone, mottled greenish-gray and reddish-brown, dolomitic, speckled, well-indurated; forming light greenish-gray ledge	1.2
Shale, red, silty, blocky	10.2
Shale, reddish-brown and greenish-gray, silty, thin-bedded; forming light-colored greenish-gray band	0.25
Shale, red, silty, blocky	2.0
Siltstone, greenish-gray, dolomitic, argillaceous, moderately indurated; forming light-colored greenish-gray band	0.2
Shale, red, silty, blocky; grading into siltstone	10.25
Dolomite, light purplish-brown and mottled greenish-gray, argillaceous, platy, crinkly, weakly indurated	0.4
Shale, red, silty, weakly indurated	4.0
Siltstone, greenish-gray, argillaceous, gypsiferous, weakly indurated; with some indurated layers	0.75
Shale, red, silty, platy, well-indurated	1.0
Shale, greenish-gray and reddish-brown, gypsiferous, silty, well-indurated; with much satin spar	4.0
Shale, blackish-brown, well-indurated, blocky; becoming greenish-gray and platy in upper two feet	5.75
Dolomite, greenish-white, well-indurated, rubbly; grading into blackish-gray shale	0.3
Shale, red, silty, well-indurated; with occasional greenish-gray layers; with much satin spar	4.0
Siltstone, greenish-gray, gypsiferous, argillaceous, well-indurated	1.2
Shale, greenish-gray and reddish-brown, silty, crinkly bedded, thin-bedded	3.2
Siltstone, reddish-brown and greenish-gray, argillaceous, gypsiferous, well-indurated	0.75
Shale, red, silty	1.25
Siltstone, greenish-gray, gypsiferous, weakly indurated	1.5
Shale, red, silty, well-indurated	1.0
Siltstone, greenish-gray, mottled reddish-brown, argillaceous, weakly indurated	2.0
Dolomite, light-gray, argillaceous, fine-grained, crinkly bedded	0.5
Shale, red, silty; mottled moderate reddish-brown in middle	1.8
Siltstone, greenish-gray, mottled reddish-brown, argillaceous	0.75
Shale, red, silty, well-indurated	0.75
Dolomite, light-gray, fine-grained, dense, well-indurated, blocky, even-bedded	0.1
Shale, red, silty, blocky, well-indurated	3.0
Shale, green, silty, platy, weakly indurated	0.5
Shale, red, silty, weakly indurated	0.8

	Feet
Shale, green, mottled reddish-brown, platy	0.5
Dolomite, light-gray to tan, fine-grained, dense, thin-bedded, well-indurated, blocky; with some reddish-brown streaks	0.4
Shale, green, silty, well-indurated; with reddish-brown shale in upper part	2.75
Shale, red, silty	0.75
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, thin-bedded, well-indurated; forming prominent ledge	0.5
Unnamed beds:	
Shale, greenish-gray, silty	3.0
Shale, red, silty, blocky	5.25
Siltstone, greenish-gray, argillaceous	1.75
Shale, red, silty, blocky	2.0
Siltstone, greenish-gray, argillaceous, weakly indurated	0.5
Shale, red, silty, blocky	5.25
Siltstone and shale, greenish-gray and reddish-brown, interbedded	1.5
Shale, red, silty, blocky	1.0
Siltstone, greenish-gray, argillaceous	0.3
Shale, red, silty, blocky	1.1
Siltstone, light brown and mottled greenish-gray, weakly indurated	2.7
Shale, dark reddish-brown, silty, blocky	1.5
Siltstone, light brown and mottled greenish-gray, weakly indurated	10.5
Shale, greenish-gray, blocky	0.75
Shale, red, silty, blocky	3.1
Shale, greenish-gray, platy	1.25
Shale, red, silty, blocky	4.25
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, dense, well-indurated	0.5
Shale, red, silty	0.2
Dolomite, light bluish-gray; as above	0.75
Shale, light bluish-gray to greenish-gray, dolomitic, platy	1.25
Haskew Bed:	
Siltstone, light-brown, gypsiferous, massive, well-indurated; forming ledge	3.0
Unnamed beds:	
Shale, red, silty; with some greenish-gray shale layers; and with much crinkly bedded satin spar (not detailed)	23.0
BLAINE FORMATION (total thickness, 75.6 feet)	
Shimer Gypsum Member:	
Gypsum, white, coarsely crystalline, deeply weathered; forming ledge; absent in many places	13.0
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, well-cemented, fossiliferous, fine-grained, dense, vuggy, oölitic; ¼- to 2-inch beds; with some thin fine-grained non-oölitic layers; weathering light tan; box-work weathering	1.5
(section extrapolated to railroad cut in NE¼ SE¼ sec. 29, T. 20 N., R. 12 W.)	
Unnamed beds:	
Shale, greenish-gray, silty, blocky	0.25
Shale, red, blocky, mottled greenish-gray	4.0
Shale, red, silty; with much selenite	6.75
Shale and gypsum, greenish-gray, crinkly bedded, selenitic, moderately indurated; weathering greenish-gray	0.7
Shale, red, silty, blocky; with much selenite	3.5
Shale and gypsum, mottled reddish-brown and greenish-gray,	

	Feet
selenitic; with satin spar forming reddish-brown ledge	0.75
Shale, red, silty, blocky	1.2
Shale, greenish-gray, blocky; with much paper-thin selenite	0.8
Shale, red, blocky; with some selenite	1.2
Shale and gypsum, reddish-brown, blocky, crinkly bedded, selenitic, well-indurated; in two ledges separated by red-brown shale	1.5
Shale, red, blocky; with much selenite near base	2.0
Nescatunga Gypsum Member:	
Gypsum, reddish-brown, thinly laminated, well-indurated; with many reddish-brown clay seams; with much selenite and satin spar	0.8
Gypsum, greenish-gray, thinly laminated, selenitic; with much satin spar and many greenish-gray shale seams	0.9
Gypsum, white, alabaster-like, fine-grained; mottled with irregular reddish-brown streaks and seams; with 1½ feet of anhydrite in middle portion	15.75
Magpie Dolomitic Bed: (section measured in Lopp quarry SW¼ NW¼ sec. 21, T. 20 N., R. 12 W.)	
Dolomite, light-gray to greenish-gray, fossiliferous, oölitic, fine-grained; ½- to 2-inch beds; forms tan blocks; forms an escarpment	0.7
Unnamed beds:	
Shale, greenish-gray and mottled reddish-brown, blocky	0.4
Shale, red, blocky	0.5
Shale, greenish-gray; as above	0.1
Shale, red, blocky	2.75
Shale, greenish-gray; as above	0.25
Shale, red, blocky; with some satin spar	2.0
Kingfisher Creek Gypsum Bed:	
Gypsum and shale, interbedded, mottled greenish-gray and reddish-brown, crinkly bedded; with much satin spar	1.5
Unnamed beds:	
Shale, red; with occasional greenish-gray shale streaks	2.75
Shale, greenish-gray and reddish-brown, crinkly bedded; with much satin spar	1.0
Shale, red, blocky	0.75
Gypsum and shale, interbedded, reddish-brown, crinkly bedded, blocky, well-indurated; with some satin spar	0.5
Shale, red, blocky; with occasional satin spar	0.5
Gypsum and shale, interbedded, reddish-brown, well-indurated, crinkly bedded	0.5
Medicine Lodge Gypsum Member:	
Gypsum, light-gray and reddish-brown, interbedded, fine-grained, crinkly bedded, well-indurated	1.0
Gypsum, light-gray to white, fine-grained, laminated; with light-gray streaks and occasional reddish-brown streaks	5.25
Cedar Springs Dolomite Bed: (the type section)	
Dolomite, light-gray, fine-grained, dense, oölitic, massive, well-indurated; interbedded with non-oölitic portions; grading upward into gypsum; forming ledge	0.5
FLOWERPOT SHALE (exposed thickness, 104.3 feet)	
Unnamed beds:	
Shale, greenish-gray, blocky	0.2
Shale, maroon to dark reddish-brown, blocky	1.0
Shale, red, blocky	2.0
Shale, greenish-gray to gray, blocky	2.5
Gypsum, white, mottled reddish-brown and greenish-gray, limonitic, argillaceous, crinkly bedded, well-indurated; with much satin spar; forming prominent ledge	0.75
Shale, red, blocky	1.0

	Feet
Shale and gypsum, interbedded, reddish-brown, blocky; with some greenish-gray layers and much satin spar	5.25
Shale, red, blocky; with many crinkly bedded satin spar layers	7.5
Dolomite, light-gray, fine-grained, laminated, wavy bedded, massive; weathering light-tan	0.5
Shale, red, blocky; with many paper-thin selenite layers	2.75
Shale, greenish-gray, blocky, well-indurated; with some thin irregular seams of satin spar	1.6
Shale, red, blocky; with much satin spar and with selenite near top	6.5
Siltstone, greenish-gray, argillaceous, gypsiferous, weakly indurated	2.0
Gypsum, greenish-gray, argillaceous, massive, well-indurated; grading into beds above and below; forming a prominent light-colored ledge in the region. This is Gould's (1902, 1905) "northward disappearing wedge of Ferguson gypsum", which is actually not his same Ferguson gypsum as described on Salt Creek Canyon in Blaine County	1.2
Siltstone, greenish-gray, argillaceous, gypsiferous, weakly indurated; laminated with reddish-brown shale streaks	2.5
Shale, red, blocky	1.75
Shale, red, blocky; with much satin spar and selenite	8.25
Shale, red, blocky; speckled with greenish-gray spots; with some satin spar near top	5.75
Gypsum, white, mottled reddish-brown and greenish-gray, fine-grained, well-indurated; forming prominent band	0.2
Shale, red, silty, blocky	4.0
Gypsum, white, mottled greenish-gray, nodular, fine-grained	0.2
Shale, red, silty, blocky	0.75
Shale, greenish-gray, gypsiferous; well-indurated in places	0.1
Shale, red, silty, blocky	2.6
Shale, mottled reddish-brown and greenish-gray, dolomitic, blocky, well-indurated	0.1
Shale, red, silty, blocky; well-indurated in middle	1.0
Gypsum, white, nodular, selenitic	0.2
Shale, red, silty, blocky	1.5
Gypsum, greenish-gray, argillaceous, selenitic	0.1
Shale, red, silty, blocky	4.0
Gypsum, white, mottled greenish-gray, nodular, well-indurated; forming base of upper gypsiferous portion of Flowerpot Shale	0.75
Shale, red, silty, blocky; with many ⅓- to 1-inch greenish-gray shale spots and with some vertical veins of selenite	4.0
Shale, mottled reddish-brown and greenish-gray, dolomitic, blocky, well-indurated	0.25
Shale, red, silty, blocky	1.75
Shale, greenish-gray; with some satin spar	0.1
Shale, red, silty, blocky	2.1
Gypsum, greenish-white, nodular, selenitic	0.6
Shale, red,, silty, blocky	1.5
Shale and gypsum, greenish-gray, selenitic, nodular	0.2
Shale, red, silty, blocky	9.0
Shale, greenish-gray, gypsiferous, crinkly bedded	0.3
Shale, red, silty, blocky	11.5
Shale, red, silty, blocky, well-indurated; with occasional 1- to 2-inch greenish-gray spots with black centers; forming resistant ledge	3.0
Gypsum, white, nodular, fine-grained	0.5
Shale, red, silty, blocky, well-indurated, exposed	1.0

XIX. Section measured in high hill southwest of Greenfield, beginning at top in sec. 5 and NE¼ sec. 6, T. 14 N., R. 11 W., and ending in Dog Creek Shale in NW¼ sec. 4, T. 14 N., R. 11 W., Blaine County, Oklahoma.

	Feet
MARLOW FORMATION (total thickness, approximately 114 feet)	
Emanuel Dolomite Bed:	
Dolomite, grayish-pink to pale-pink, fine- to coarse-crystalline, arenaceous, crinkly bedded; ¼- to ½-inch beds; with vuggy laminae along weathered arenaceous layers; forms ledge and escarpment	1.1
Unnamed beds:	
Sandstone, pale to moderate reddish-brown, quartzose, fine-grained, medium-bedded, well-indurated; more pinkish toward base	1.0
Sandstone, moderate reddish-brown, mottled grayish-orange, quartzose, fine-grained, silty, argillaceous, cross-bedded, partly covered; subangular to subrounded grains; with some medium-sized well-rounded frosted grains	26.75
Relay Creek Dolomite Bed:	
Dolomite, gray-pink to pale-pink; as above	2.0
Unnamed beds:	
Shale, reddish-brown, argillaceous, silty, blocky; grading into moderate reddish-brown siltstone	1.5
Siltstone, greenish-gray, argillaceous, weakly indurated	0.5
Sandstone, moderate reddish-orange to moderate reddish-brown, silty, argillaceous, quartzose, fine-grained; with some medium-sized well-rounded frosted sand grains; calcareous in middle; mostly massive; forming a prominent escarpment	55.25
Siltstone, reddish-brown, argillaceous, well-indurated; with some ¼-inch greenish-gray spots	6.0
Covered, siltstone and interbedded sandstone and shale, as above	20.0 +
DOG CREEK SHALE (exposed thickness, 110 feet)	
Shale, dark reddish-brown, partly covered; with many 1- to 2-inch greenish-gray shale spots; with 10-15 feet exposed	100.0
Southard Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense, well-indurated, medium-bedded; forming ledge	0.3
Unnamed beds:	
Shale, green, silty	0.3
Shale, red, silty	10.0 +

(The closest section to this one that contains the Southard Dolomite Bed is the one at Roman Nose State Park [section XII] where the Southard is approximately 85 feet above the top of the Shimer Gypsum at the base of the Dog Creek Shale.)

XX. Section measured at type Relay Creek area beginning at top in NW¼ SW¼ SE¼ sec. 19, T. 15 N., R. 11 W., continuing in SE¼ NE¼ SE¼ sec. 19, east into SW¼ NW¼ SW¼ sec. 20, NW¼ sec. 29, T. 15 N., R. 11 W., in prominent hill two miles northwest of Greenfield, just south of Relay Creek.

	Feet
MARLOW FORMATION (total thickness, 112 feet)	
Emanuel Dolomite Bed: (type section)	
Dolomite, grayish-pink to pale pink, coarsely crystalline; with many 1-2 mm fine-grained quartzose layers parallel to the bedding; with vuggy layers; forming prominent ledge	0.75
Unnamed beds:	
Sandstone, pale reddish-brown, dolomitic, quartzose, fine-grained, well-indurated; subrounded to subangular grains;	

Feet

with quartz grains coated with pale reddish-brown iron stains 2.0

Sandstone, dark reddish-brown and grayish-orange, dolomitic, quartzose, fine-grained, well to weakly indurated; subangular to subrounded grains; with some medium-sized well-rounded frosted grains; with symmetrical ripple marks that strike N 25° E four feet below top 25.25

Relay Creek Dolomite Bed: (type section)

Dolomite, grayish-pink, fine- to coarse-crystalline, dense, well-indurated, wavy bedded; with many 2-5 mm light greenish-gray argillaceous vuggy bands; forms resistant ledge 4.5

Unnamed beds:

Sandstone, moderate reddish-brown, quartzose, silty, argillaceous, weakly indurated, fine-grained, dolomitic, light greenish-gray at top; with a few medium-sized grains 4.0

Dolomite, pale pink, fine-crystalline, compact; with many thin argillaceous grayish-green and pinkish-gray laminae with vuggy openings lined with coarsely crystalline calcite; forms ledge 1.0

Sandstone, moderate reddish-orange to moderate reddish-brown, quartzose, weakly indurated, silty, fine-grained; subangular to subrounded grains; with a few medium-sized well-rounded to subrounded grains; with a 2-foot impure dolomitic zone about 20 feet below the top; forming a massive ledge 52.5

Siltstone, reddish-brown, even-bedded; mottled greenish-gray at top 1.2

Siltstone, greenish-gray, mottled reddish-brown, argillaceous, crinkly bedded, well-indurated; with 3-inch shale in middle 1.0

Shale, red, silty, platy; mottled with some greenish-gray streaks 2.0

Sandstone; as above; with some greenish-gray streaks 1.5

Shale, red, silty, well-indurated 2.0

Sandstone, mottled greenish-gray; as above; with many medium-sized grains 0.25

Sandstone, medium-grained to fine-grained, weakly indurated; as above; with some greenish-gray streaks 1.75

Sandstone, greenish-gray, medium-grained, friable; as above 0.25

Shale, red, silty, weakly indurated 4.25

Sandstone, fine-grained; as above 0.5

Shale, red, silty, weakly indurated 2.0

Sandstone, vuggy, well-indurated; as above 0.5

Shale, red, silty, platy; with some greenish-gray streaks 0.5

Sandstone, light greenish-gray, argillaceous, silty, calcareous, quartzose, fine-grained; with many medium- and a few coarse-sized grains, well-rounded to subrounded, frosted, white, poorly cemented; well-indurated in middle 9 inches 4.25

Dog Creek Shale (exposed thickness, 76.2 feet)

Shale, dark reddish-brown, blocky, well-indurated; mottled with some 1- to 2-inch greensh-gray spots 14.75

Shale, chocolate-brown, well-indurated, blocky; with 1-inch greenish-gray layer at top and at bottom 0.75

Shale, reddish-brown; as above 37.75

Siltstone, greenish-gray, arenaceous, massive, weakly indurated 2.5

Shale, reddish-brown; as above 2.0

Shale, green, weakly indurated 0.75

Shale, reddish-brown; as above 2.0

Shale, reddish-brown, dolomitic, nodular; as above 0.2

Shale, reddish-brown; as above 3.0

Feet

Siltstone, light greenish-gray, argillaceous; with some fine-grained quartzose sandstone 2.5

Shale, red, well-indurated; exposed 10.0 +

XXI. Section measured west of Watonga, beginning at top in creek in N½ NW¼ sec. 30, T. 16 N., R. 12 W., continuing downstream into SW¼ SW¼ sec. 20 and N½ sec. 29, and ending in the Dog Creek Shale in S½ NE¼ sec. 20, T. 16 N., R. 12 W.

Feet

Rush Springs Sandstone

Sandstone, moderate to dark reddish-brown to moderate reddish-orange, fine-grained, quartzose, calcareous, well- to weakly indurated, cross-bedded; with many medium-sized well-rounded frosted grains 10.0 +

Marlow Formation (total thickness, 93 feet)

Emanuel Dolomite Bed:

Dolomite, maroon, arenaceous, vuggy, crinkly bedded, well-indurated; mottled with many black specks; with vugs filled with calcite 0.05

Unnamed beds:

Sandstone, silty, partly covered; as above 20.0

Relay Creek Dolomite Bed:

Dolomite, maroon, argillaceous; absent in most places; appearing as a maroon discoloration of sandstone but persistently at the same level 0.025

Unnamed beds:

Sandstone, partly covered; as above; not cross-bedded 35.0

Sandstone, moderate reddish-brown to moderate reddish-orange, fine-grained, quartzose, well- to weakly indurated, calcareous; with some medium-sized well-rounded frosted grains; with light greenish-gray layers at top and at bottom 1.0

Sandstone; as above; with no light-colored layers 11.0

Sandstone, mottled light greenish-gray and moderate reddish-brown, weakly indurated; as above; forms light-colored band 3.75

Siltstone, shale, and some sandstone, moderate reddish-brown to dark reddish-brown, weakly-indurated, partly covered 17.0

Sandstone, moderate reddish-brown to moderate reddish-orange; as above; speckled with many 1/16-inch greenish-gray spots 5.0

Sandstone, dolomitic, slabby, crinkly bedded; as above 0.3

Sandstone; as above; speckled with many greenish-gray spots 1.2

Sandstone, light greenish-gray, quartzose, fine-grained; mottled with moderate reddish-brown spots; with many medium-sized and a few coarse-sized well-rounded frosted white grains; well-indurated in places; forms prominent light-colored band; with basal 3-4 inches crinkly bedded 2.5

Dog Creek Shale (exposed thickness, 54.4 feet)

Shale, red, well-indurated; with some lenticular greenish-gray beds and many 2- to 3-inch greenish-gray shale spots 28.0

Shale, red; as above; with some 1- to 2-inch greenish-gray dolomitic shale layers at top; and with some 2-inch greenish-gray shale layers beneath 10.0

Siltstone, greenish-gray, vuggy, argillaceous; dolomitic in upper portion, forms light-colored band 0.75

Siltstone, speckled greenish-gray and reddish-brown, argillaceous, platy, weakly indurated 0.7

Shale, chocolate-brown, silty, platy, weakly indurated 0.25

Siltstone, platy; speckled as above; with ripple marks in middle 0.5

Shale, red, silty 7.75

Feet

Siltstone, well-indurated; speckled as above ... 0.3

Shale, moderate reddish-brown and greenish-gray, silty, massive, weakly indurated ... 0.9

Siltstone, greenish-gray, argillaceous, crinkly bedded, thin-bedded, weakly indurated ... 0.25

Shale, red, silty, well-indurated; exposed ... 5.0 +

XXII. Section measured northwest of Eagle City to Canton dam area, beginning at top in the Cloud Chief Formation in high hill in S½ SE¼ sec. 1, T. 17 N., R. 14 W., and N½ NE¼ sec. 12, T. 17 N., R. 14 W., Dewey County, continuing eastward into SW¼ SW¼ sec. 6 and C sec. 6, T. 17 N., R. 13 W., Blaine County, to Relay Creek Dolomite in creek in N½ NW¼ NW¼ sec. 5, T. 17 N., R. 13 W. Section then extrapolated to SE¼ NW¼ SW¼ sec. 27, T. 18 N., R. 13 W., in road cut, for Relay Creek interval, continuing into NE¼ NW¼ sec. 27, for Marlow Formation to Dog Creek, ending just south of Canton dam, in NE¼ NE¼ SE¼ sec. 32 and SW¼ SW¼ NW¼ sec. 33, T. 19 N., R. 13 W., for Dog Creek portion.

CLOUD CHIEF? FORMATION (exposed thickness, 100.75 feet) — Feet

Dolomite, pinkish-gray to white, fine-crystalline, compact, thin-layered; with occasional black manganese? specks; with vugs along layers lined with dolomite crystals; some portions are streaked pale pink and moderate red, are finely to medium crystalline, and are lenticular; other portions are light gray with a salt-and-pepper texture, and are medium to coarsely crystalline; forms undulatory ledge ... 4.0

Sandstone, moderate reddish-brown, fine-grained, cross-bedded, crinkly bedded, quartzose, calcareous, silty; with some medium- and coarse-sized well-rounded frosted grains; with many carbonate stringers throughout; well-indurated where highly calcareous ... 26.0

Dolomite, pinkish-gray to white, mottled grayish-orange, fine- to medium-crystalline, compact; speckled with many black manganese oxide spots; with interbedded pale- to moderate-red wavy lenticular coarsely crystalline arenaceous laminated dolomite; showing definite thinning and thickening of bedding; with vugs along arenaceous layers. Some portions are light olive gray, crystalline, compact; have a salt-and-pepper texture; are interbedded with pinkish-gray coarsely crystalline laminated dolomite that has vugs filled with calcite crystals. Forms undulatory ledge ... 3.0

Sandstone, moderate reddish-brown, calcareous, silty, slightly cross-bedded; as above; with indurated dolomitic streaks 15 feet and 32 feet above base ... 67.0

Weatherford? Dolomite Member:

Dolomite, white, fine-crystalline, compact; with many thin wavy light-red to grayish-pink arenaceous layers; with occasional ⅛- to ½-inch black manganese oxide spots; becoming vuggy along the arenaceous layers; with coarse-crystalline dolomite lining the vugs; forms pale reddish-brown to light-brown resistant ledge ... 0.75

RUSH SPRINGS SANDSTONE (total thickness, 180 feet)

Sandstone, moderate to dark reddish-brown, silty, cross-bedded, quartzose, fine-grained, weakly-indurated; with occasional medium-sized well-rounded grains; with occasional dolomitic vugs where well-indurated ... 32.0

Dolomite, pinkish-gray to white, mottled moderate reddish-

Feet

orange to reddish-brown, arenaceous, fine-crystalline, layered; with calcite-filled vugs along layers; with many small black manganese oxide spots; grading into a dolomitic sandstone; appearing to be deposited in patches; forms light-brown to pale reddish-brown ledge ... 1.0

Sandstone, moderate reddish-brown to light-brown, gypsiferous, medium-grained, highly cross-bedded; well-rounded to subrounded frosted quartz grains; with dip of cross-bedding in S 25° W direction ... 3.5

Sandstone, moderate reddish-brown, fine-grained, quartzose, silty, calcareous, highly cross-bedded; with many medium-sized well-rounded frosted grains; with dip on cross beds same as above; cross-beds in 4- to 6-foot intervals; parallel to bedding at base; forming an acute angle with the bedding-plane above; lower 18 feet not cross-bedded; weakly indurated except where highly calcareous; with symmetrical ripple marks 2 inches wide that strike N 50° W ... 35.0

Sandstone, moderate reddish-brown to moderate reddish-orange, silty, calcareous, fine-grained, cross-bedded; with some medium-sized grains; weakly indurated except where highly calcareous ... 108.0 +

MARLOW FORMATION (total thickness, 100 feet)

Emanuel Dolomite Bed:

Dolomite, maroon, crinkly bedded; mottled with many black manganese oxide spots; ⅛- to ¼-inch beds; forming small ledge ... 0.1

Unnamed beds:

Sandstone; as above; covered in places ... 20.0 +

Relay Creek Dolomite Bed:

Dolomite, maroon; as above ... 0.1

Unnamed beds:

Sandstone, silty, argillaceous, weakly indurated; as above ... 26.75

Shale, dark reddish-brown, silty; forming a line ... 0.01

Sandstone; as above ... 8.25

Sandstone, highly dolomitic, crinkly bedded; as above; forming ledge ... 0.1

Shale, red, silty; with many ½- to 1-inch dolomite nodules and geodes ... 2.75

Sandstone, silty; as above ... 3.25

Sandstone; as above; with many medium-sized grains ... 3.75

Shale, chocolate-brown, silty, well-indurated, blocky ... 0.1

Sandstone, mottled greenish-gray, medium-grained; as above ... 3.0

Siltstone, moderate reddish-brown to orange-brown, argillaceous, arenaceous, weakly indurated ... 2.0

Sandstone; as above; upper 6 inches dolomitic ... 5.75

Siltstone, greenish-gray, argillaceous, arenaceous, vuggy ... 0.05

Sandstone, massive, silty, weakly indurated; as above; mottled with occasional ⅛-inch greenish-gray spots ... 21.75

Sandstone, greenish-gray, mottled moderate reddish-brown, fine-grained, quartzose, weakly indurated, massive ... 2.5

(section extrapolated to Canton Dam area to north)

DOG CREEK SHALE (exposed thickness, 49.20 feet)

Siltstone, moderate reddish-orange, medium-bedded, speckled greenish-gray with many vuggy areas lined with quartz crystals ... 0.5

Shale, red-brown, silty, blocky, well-indurated ... 0.25

Siltstone; as above; weathering moderate reddish-orange ... 0.2

Siltstone, greenish-gray and reddish-orange; as above; weathering greenish-gray ... 0.2

Shale, reddish-brown, blocky ... 1.5

Siltstone, greenish-gray and moderate reddish-orange; as above 0.1

Shale, red-brown; as above ... 2.0

	Feet
Siltstone, orange-brown; as above; weathering reddish-brown	0.2
Shale, red-brown; as above	1.5
Siltstone, reddish-orange and greenish-gray, well-indurated; as above; with many small greenish-gray spots	0.5
Shale, red-brown, blocky	12.75
Siltstone, reddish-brown, argillaceous, thin-bedded; well-indurated; with some ¼-inch greenish-gray spots; forming a ledge	0.25
Shale, red-brown, blocky	2.0
Shale, red-brown, silty, well-indurated, with many 0.5- to 1-inch greenish-gray spots; forming a resistant ledge	0.5
Shale, red-brown; with some 1- to 2-inch greenish-gray spots	14.75
Shale, red-brown; with many 0.5- to 1-inch satin spar layers; and with several 0.25-inch greenish-gray siltstone layers in basal 1-foot	8.0
Siltstone, mottled greenish-gray and reddish-brown, arenaceous, well-indurated; with some 0.5- to 1-inch beds of satin spar	2.0
Shale, red-brown; exposed to water level of North Canadian River	2.0 +

XXIII. Section examined from cuttings taken every 5 feet from exploratory water well drilled by the Watonga Chamber of Commerce on the Dr. Bohlman place, NW¼ NW¼ sec. 26, T. 16 N., R. 13 W., about 10 miles west of Watonga; completed September 3, 1956. Elevation 1,775 feet; total depth 587 feet; spudded in the Rush Springs Sandstone.

	Feet
RUSH SPRINGS SANDSTONE (partial thickness, 125 feet)	
Sandstone, moderate reddish-brown to tan to moderate reddish-orange, fine-grained, quartzose; subrounded to subangular grains, ranging in size from 0.025 to 1 millimeter	125.0
MARLOW FORMATION (total thickness, 100 feet)	
Sandstone; as above; with maroon and black specks; probably representing the Emanuel and Relay Creek Dolomites in part	20.0
Sandstone; as above; with some coarse-grained sandstone in upper 15 feet; with many 0.8- to 1.2-millimeter grains	55.0
Siltstone, shale, and fine-grained sandstone, moderate to dark reddish-brown; probably interbedded	25.0
DOG CREEK SHALE (total thickness, 180 feet)	
Shale, dark reddish-brown, silty, well-indurated; with occasional satin spar flakes and greenish-gray shale specks	55.0
Shale; as above; with many greenish-gray shale layers	25.0
Shale; as above; with dolomitic shale or argillaceous dolomite layers	15.0
Southard Dolomite Bed:	
Dolomite, light-gray, fine-grained, dense, argillaceous	0.3
Unnamed beds:	
Shale; as above; with many greenish-gray dolomitic shales present	20.0
Shale; as above; with some greenish-gray shale layers	30.0
Watonga Dolomite Bed:	
Dolomite, light bluish-gray, fine-grained, argillaceous, dense	5.0
Unnamed beds:	
Shale; as above; with much satin spar; highly gypsiferous at base	30.0
BLAINE FORMATION (total thickness, 95 feet)	
Shimer Gypsum Member with Altona Dolomite Bed at base:	
Gypsum, white, fine-grained; with much anhydrite; becoming dolomitic at base	15.0

	Feet
Unnamed beds:	
Shale, dark reddish-brown, silty; with much satin spar and greenish-gray shale beds	30.0
Nescatunga Gypsum Member with Magpie Dolomite Bed at base:	
Gypsum and anhydrite, white, fine-grained, well-indurated; with greenish-gray dolomitic layer at base	22.0
Unnamed beds, including Kingfisher Creek Gypsum Bed:	
Shale, red, silty; with occasional greenish-gray shale layers, and with some anhydrite and gypsum chips	21.0
Medicine Lodge Gypsum Member including Cedar Springs Dolomite Bed:	
Gypsum and anhydrite, white; with some reddish-brown shale above	7.0
FLOWERPOT SHALE (drilled thickness, 87 feet)	
Shale, dark reddish-brown, silty, blocky; with some greenish-gray shale layers; with much gypsum; being cavernous in upper part	60.0
Shale; as above, but with no gypsum	27.0
Total depth	587.0 feet

XXIV. Sunray Mid-Continent Baker No. 1 Relief core hole. Beginning at top in basal part of Rush Springs Sandstone, at ground elevation 1,566 feet, in NW¼ SE¼ SW¼ sec. 36, T. 14 N., R. 13 W., the first 397 feet to Blaine top was drilled, the next 373 feet into the Flowerpot Shale was cored (3-inch cores), and the last 230 feet was drilled to a total depth of 1,000 feet. The Emanuel, Relay Creek, Southard, and Watonga Dolomite Beds are extrapolated from surface information, supplemented by examination of cuttings.

	Feet
RUSH SPRINGS SANDSTONE (base locally exposed)	
Sandstone, red-brown, fine-grained, quartzose	1.0
MARLOW FORMATION (total thickness, 153 feet)	
Emanuel Dolomite Bed:	
Dolomite and shale, red-brown and mottled dark-red, arenaceous, platy, crinkly bedded, well-indurated; forming ledge	0.1
Unnamed member:	
Sandstone, red-brown to moderate reddish-orange, fine-grained, quartzose	19.8
Relay Creek Dolomite Bed:	
Dolomite and shale, red-brown; as above	0.1
Unnamed member:	
Sandstone, red-brown; as above	133.0
DOG CREEK SHALE (total thickness, 243 feet)	
Shale, red-brown, silty, blocky	98.0
Southard Dolomite Bed:	
Dolomite, light-brown to light-gray, well-indurated, fine-grained; appearing as light-brown specks in cuttings	0.5
Unnamed member:	
Shale, red-brown, silty, blocky; with some anhydrite	71.5
Watonga Dolomite Bed:	
Siltstone, greenish-gray, dolomitic, well-indurated; with some anhydrite; including Haskew Member at base	8.0
Unnamed member:	
Shale, red-brown, silty, blocky; with much satin spar and three prominent thick beds of anhydrite; with anhydrite stringers throughout	65.0

	Feet
BLAINE FORMATION (total thickness, 108.5 feet)	
Shimer Gypsum Member:	
Anhydrite, red-brown, argillaceous	1.7
Anhydrite, gray, massive	6.0
Shale, greenish-gray	2.0
Shale, red-brown; with anhydrite bands	3.0
Anhydrite, gray, massive	4.5
Altona Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, oölitic; extremely fossiliferous with many *Permophorus*	1.0
Unnamed members:	
Shale, greenish-gray, blocky	1.5
Shale, red-brown; with occasional greenish-gray layers	30.3
Shale, red-brown, blocky	15.0
Nescatunga Gypsum Member:	
Anhydrite, gray, massive	2.0
Anhydrite, gray, massive; with clear drusy halite filling holes about one-inch in diameter	4.0
Anhydrite, gray, massive	3.0
Magpie Dolomite Bed:	
Dolomite, light-gray to yellowish-gray, fine-grained, dense to oölitic	1.0
Unnamed member:	
Shale, red-brown, silty, blocky	15.5
Kingfisher Creek Gypsum Bed:	
Anhydrite, gray, mottled red-brown, massive	2.0
Unnamed member:	
Shale, red-brown, blocky; with greenish-gray streaks	12.5
Medicine Lodge Gypsum Member:	
Anhydrite, gray, massive, mottled reddish-brown	3.25
Cedar Springs Dolomite Bed:	
Dolomite, light-gray to red-brown, fine-grained, dense, thin-bedded, wavy bedded	0.25
FLOWERPOT SHALE (base not determinable)	
Shale, red-brown, blocky	3.0
Anhydrite, gray, massive	0.5
Shale, red-brown, silty, blocky; with some thin greenish-gray siltstone and shale beds, and with occasional anhydrite nodules	23.0
Shale, red-brown, blocky; as above	88.0
Shale, red-brown, blocky; with anhydrite nodules	8.0
Shale, red-brown, mottled greenish-gray, salty	10.0
Shale, red-brown; with occasional greenish-gray shale layers	13.0
Chickasha Tongue:	
Siltstone, greenish-gray, well-indurated, salty	5.0
Siltstone, moderate reddish-orange; with interbedded red-brown shale	20.0
Shale, red-brown; with occasional greenish-gray spots	11.0
Shale, red-brown, blocky; with anhydrite nodules	3.0
Siltstone, greenish-gray, mottled moderate reddish-orange, cross-bedded, salty; with occasional red-brown shale stringers	30.0
Siltstone, greenish-gray; interbedded with red-brown blocky shale	10.0
Mudstone conglomerate, red-brown, mottled greenish-gray	1.0
Shale, red-brown; with small anhydrite nodules	4.0
Siltstone, greenish-gray; with occasional red-brown shale layers	2.0
Siltstone, red-brown, argillaceous, salty, blocky; with occasional greenish-gray spots	7.0
Mudstone conglomerate, red-brown, mottled greenish-gray, silty	2.0

	Feet
Siltstone, red-brown, argillaceous, blocky; with occasional greenish-gray shale patches	9.0
Siltstone, greenish-gray, argillaceous, salty	15.0
Siltstone and shale; as above; drilled. The projected base of the Chickasha Tongue from the outcrop would be somewhere in this part of the section, and the base of the Flowerpot Shale would be about another 180 feet farther down	230.0
Total depth	1,000.0

INDEX

A

(**Boldface** indicates main references.)

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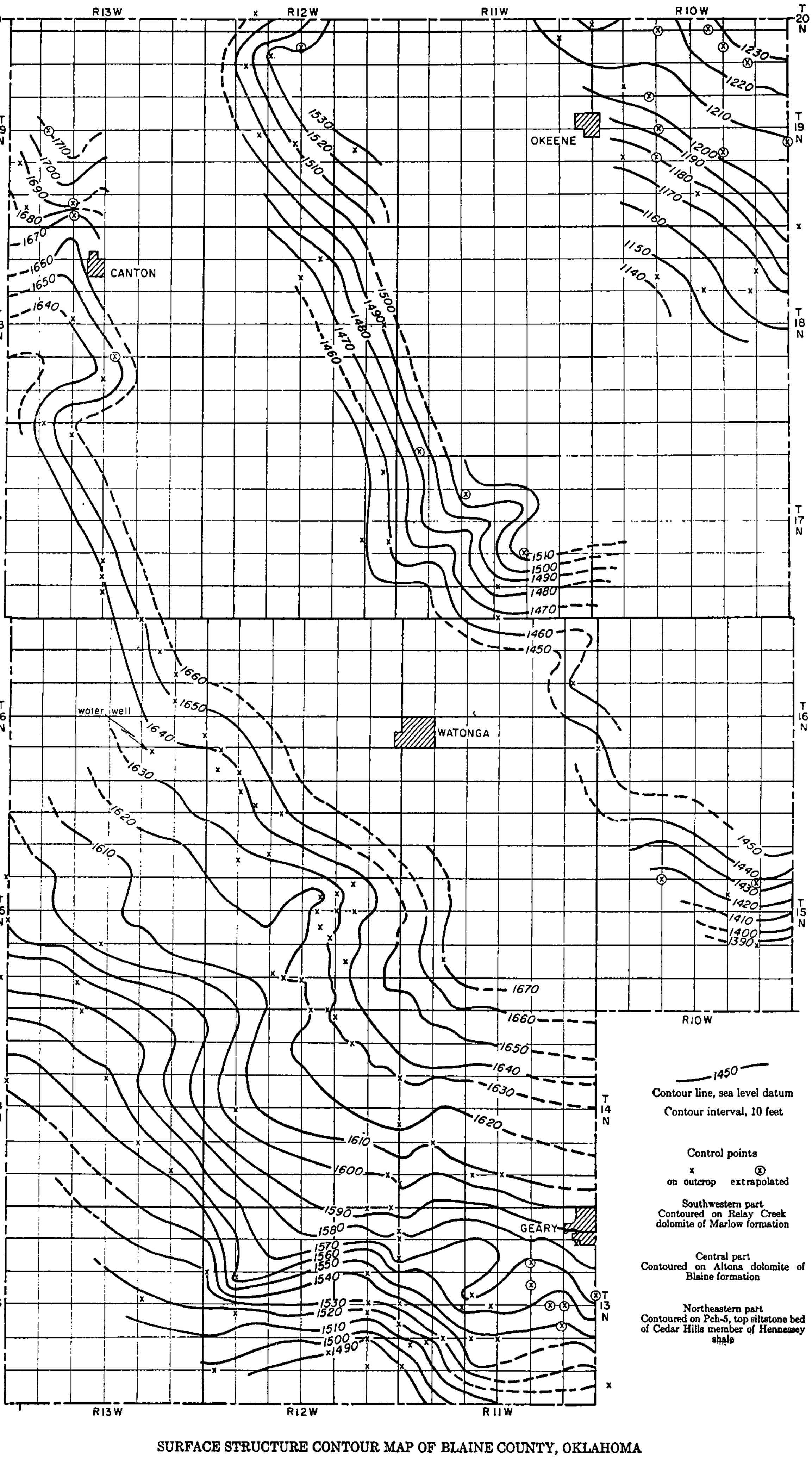
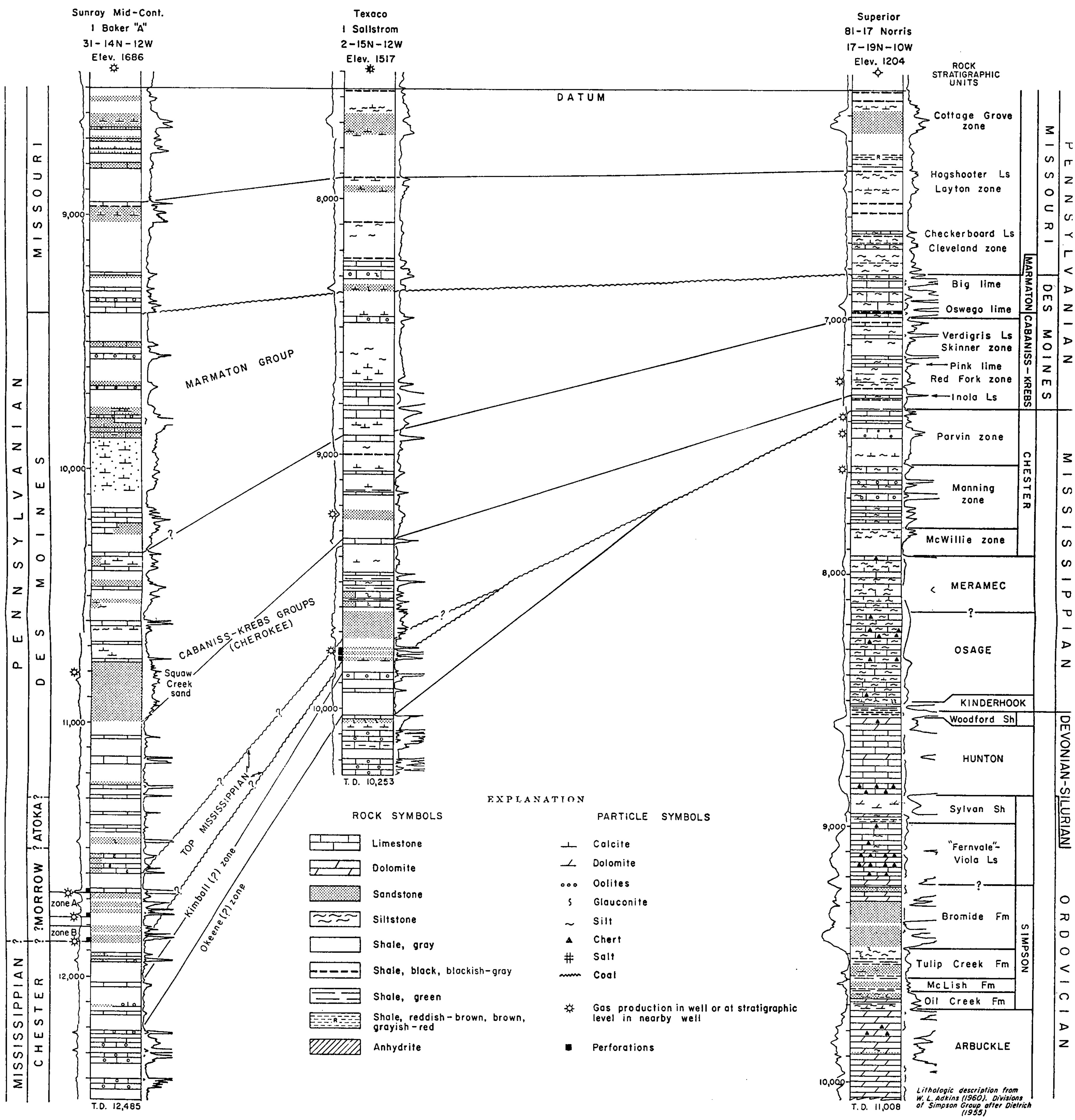
N

O

P



SURFACE STRUCTURE CONTOUR MAP OF BLAINE COUNTY, OKLAHOMA



SOUTHWEST - NORTHEAST STRATIGRAPHIC CROSS SECTION
LOWER PART OF PENNSYLVANIAN AND OLDER ROCKS
BLAINE COUNTY, OKLAHOMA

by
Louise Jordan
1962