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GEOLOGY AND GYPSUM RESOURCES OF THE CARTER AREA OKLAHOMA

By

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Geology and Gypsum Resources of the Carter Area, Oklahoma

BY

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Abstract

As mapped for this report, the Carter area includes 166 square miles along North Fork of Red River in semiarid southwestern Oklahoma, mostly in the southeastern part of Beckham County. All the exposed bedrock is in the Guadalupe and Leonard series of Middle Permian age. The strata consist principally of red shales, sandstones, and beds of gypsum, and have an aggregate thickness of 650 feet.

Most of the outcropping rocks are in the El Reno group, which is fully represented and consists in ascending order of the Duncan sandstone, Flowerpot shale, Blaine formation, and Dog Creek shale. Strata of this group have a total thickness of 400 feet.

Underlying the El Reno group is Hennessey shale, the oldest exposed rock, the upper beds of which crop out in the southern part of the map area. The youngest rocks overlie the El Reno group and consist of red sandstones in the Whitehorse group.

The Blaine formation in southwestern Oklahoma is here redefined as extending from the base of the Haystack gypsum member to the top of the Van Vacter gypsum member. Both boundaries are new. The thin Chaney and Kiser gypsum members are excluded from the Blaine and are placed with similar gypsiferous beds in the underlying Flowerpot shale; and a previously unrecognized thick gypsum, here called Van Vacter, is added at the top. The Van Vacter gypsum member lies directly upon the Mangum dolomite. In earlier work by Gould the top of the Blaine was placed at the top of the Mangum.

As here redefined, the Blaine formation in the Carter area is 130-140 feet thick, of which approximately 90 feet or 70 percent is massive-bedded gypsum.

The four gypsum beds in the Blaine formation are nearly flat-lying and contain large-tonnage reserves of high-purity white gypsum. Although these beds have not been worked, they are suitable for making plasters, wallboard, tile, retarder for portland cement, and for agricultural soil conditioner. Estimated reserves are 375,000,000 short tons, distributed as follows: Collingsworth member, 180 million tons; Cedartop and Haystack members, 120 million tons; and Van Vacter member, 75 million tons. The workable area of gypsum covers more than 7,500 acres or 12 square miles, wherein the beds have an average workable thickness of 13 feet and a range of 10 to 35 feet.

The gypsum ledges crop out as stair-step benches in an escarpment and as gently rolling plains above the escarpment, and they could be worked in open cuts after removal of shale-soil overburden one to 30 feet thick. Theoretical gypsum content of seven analyzed channel outcrop samples ranges from 95.39 to 97.83 percent and averages 96.86 percent. Anhydrite, calcite, halite, and magnesite, together with silt and clay, make up the remaining percentage.

Even greater reserves of high-purity anhydrite are inferred from outcrop observations and from past experience in working the Blaine gypsums elsewhere. To a depth of 130 feet, anhydrite reserves in the Carter area are estimated to be 1,140,000,000 short tons, which could be worked partly by underground room-and-pillar methods or entirely in open-face quarries. This anhydrite offers a potentially new integrated industry manufacturing sulfuric acid or ammonium sulfate fertilizers and portland cement.

Structurally the Carter area is characterized as a homoclinal gently north-dipping element on the south limb of the Anadarko basin. A northwest-trending flexure zone marked by small surface faults and by local dips as steep as 9° is probably the southeastern extension of the Beckham County fault described by Gouin. It probably overlies a subsurface belt of strongly deformed early Paleozoic rocks at the edge of a wave-cut platform cut on granitic rocks of the Wichita Mountain system.

Introduction

General statement. As here mapped and described, the Carter area includes 166 square miles along North Fork of Red River in southwestern Oklahoma, in the southeastern part of Beckham County and in adjoining small parts of Greer, Kiowa, and Washita Counties (Figure 1). The largest town is Carter, population 545, from which the name of the mapped area is taken.

The critical position of this area, in terms of its stratigraphic and economic geology, was recognized by Dr. Ham during reconnaissance work in 1949. It was then realized that large reserves of high-purity gypsum in the Blaine formation, Middle Permian in age, were accessible to rail transportation and could be worked as a source of plasters, wall board, and cement retarder. The rocks previously had not been mapped in detail and the stratigraphic classification had not been thoroughly investigated, but the Blaine formation and certain related rocks are so completely exposed in the bluffs along North Fork that opportunities for direct observation are excellent. Of stratigraphic interest is the occurrence within the Carter area of a change in lithologic facies whereby gypsum beds grade eastward into shales and other clastic sediments of the Permian delta in the southeastern part of the Anadarko basin. The need for new and comprehensive information in this strategically located area has resulted in a program of mapping and evaluation on which the present report is based.

Mapping with aerial photographs, scale 1:20,000 (approximately 3 inches per mile), was begun by Scott in 1953 and completed in 1955. This field investigation, undertaken as a Master of Science thesis in the University of Oklahoma (Scott, 1955), was supervised by Ham as a project for the Geological Survey. During the course of field work, in addition to the geological mapping and measurement of stratigraphic sections, channel samples from representative beds of gypsum, anhydrite, and shale were cut and analyzed for quality control of potentially economic deposits.

Assistance in various forms has made the final report possible and is gratefully acknowledged. Roy D. Davis of the Geological Survey drafted Plates I and II and most of the line drawings in the text; Dr. T. W. Amsden took the photographs in Plates IV and V B; Robert O. Fay took the photographs in Plates III, V A, VI, VII A, and VIII A; and T. E. Hamm, A. L. Burwell, and R. O. Slate made the chemical analyses in Table I.

The field work was greatly facilitated by helpful cooperation of farm and ranch owners, particularly the owners of the Van Vacter ranch in the central part of the area, for which a newly recognized rock unit is named. Finally, the writing of Scott's thesis was under the direction of Dr. P. A. Chenoweth, Associate Professor of Geology in the University of Oklahoma.

Geographical setting. The Carter area is part of the semiarid redbed plains of western Oklahoma. It lies roughly midway between the High Plains to the northwest and the Wichita Mountains to the south and east. Cutting through the area along a southeasterly course is North Fork of Red River, on the north side of which is one of the most prominent escarpments in the region.

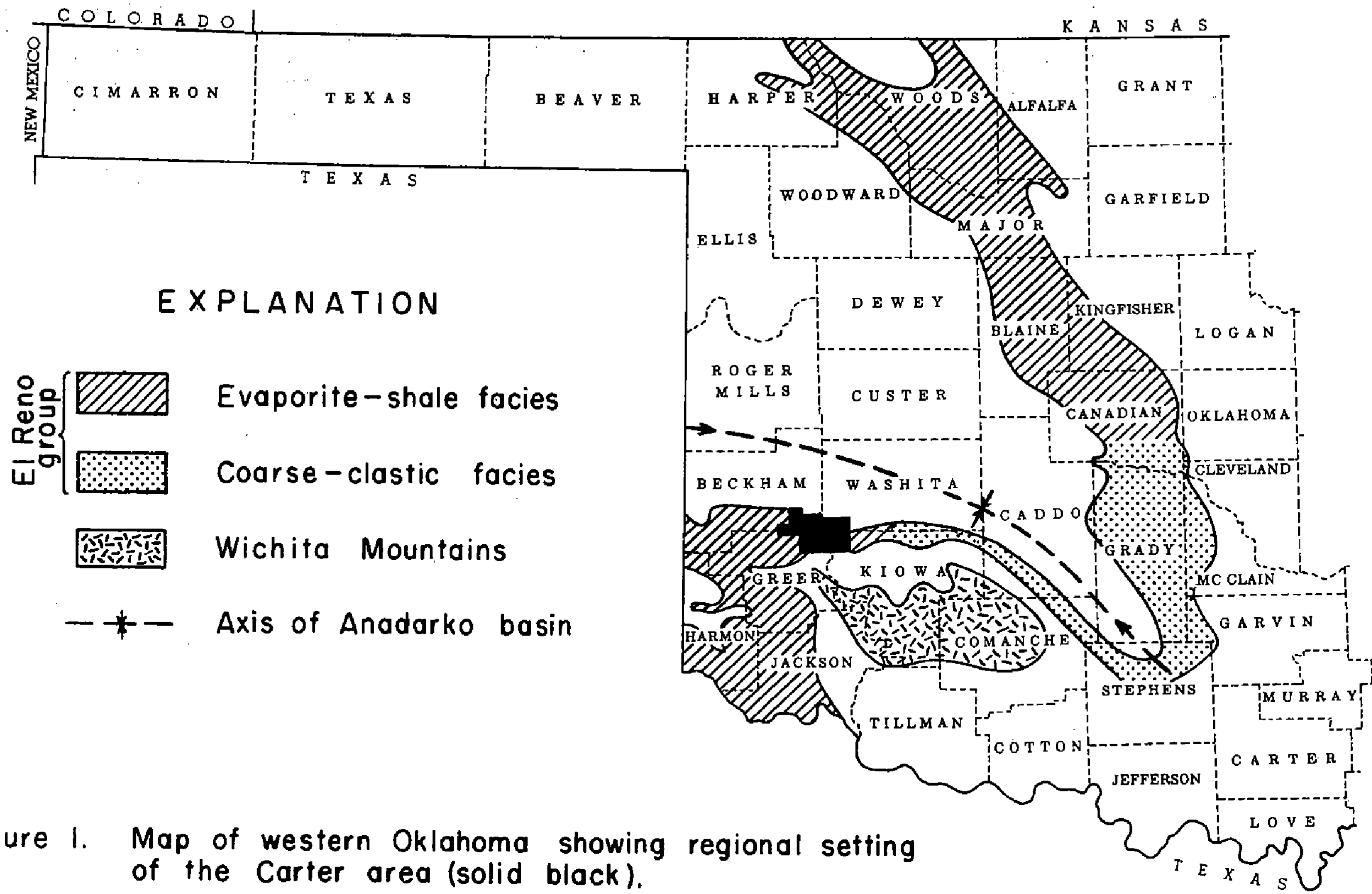


Figure I. Map of western Oklahoma showing regional setting of the Carter area (solid black).

Above the escarpment is a dissected hill country of low relief, 1,850-1,900 feet above sea level between Carter and Retrop. The hills are developed on red sandstone of the Whitehorse group. The escarpment itself is 100-200 feet high and follows a sinuous band 1-1.5 miles wide. It is supported by massive gypsum beds and thin dolomites of the Blaine formation.

Southward from the Blaine escarpment are the plains that border North Fork. They descend from an elevation of about 1,800 feet near Carter to 1,650 feet in the southeastern part of the area, where the river bed has an elevation of 1,575 feet. The largest plain is south of the river and consists of alluvium and terrace deposits that have been locally excavated by wind into elongated blow-outs and the sand piled into low sand dunes. North of the river, between it and the escarpment, are sparsely vegetated plains and badlands cut predominantly on red shales of the Flowerpot, Duncan, and Hennessey formations.

Warm dry climate characterizes the Carter area and governs both the native vegetation and the kinds of agricultural crops grown. According to records of the U. S. Weather Bureau at Elk City, the nearest large town, the mean annual temperature is 60.3° F., divided between a mean temperature of 73.4° in summer and 47.3° in winter. The highest temperature ever recorded was 113° and the lowest was —11°. Average annual precipitation is 21.95 inches.

Under this semiarid climate mesquite trees, short mesquite grass, bunch grass, and prickly pear cactus grow on the shale plains, the grass supporting a small beef cattle industry. Elm, cottonwood, tamarisk, and willow grow in the alluvium of North Fork and its tributaries; and scattered "cedars" (*Juniperus*) grow locally on gypsum and dolomite outcrops of the Blaine escarpment.

The upland plain and the plain in the eastern part of the area are largely in cultivation. Cotton, wheat, and sorghum are the chief crops.

Stratigraphy

Except for a broad band of surficial sediments in the central part of the area that was deposited by North Fork in Pleistocene and Recent time, all the rocks of the Carter area are clastic sediments and evaporites of Middle Permian age. It is with these Permian rocks that the present report is concerned.

Permian System

All the exposed bedrock of the Carter area is of the Guadalupe and Leonard series of Middle Permian age. It consists principally of red shales, sandstone, and beds of gypsum, and has an aggregate thickness of 650 feet.

Most of the outcropping rocks are in the El Reno group, which is fully represented and consists in ascending order of the Duncan sandstone, Flowerpot shale, Blaine formation, and Dog Creek shale. Rocks of this group have a total thickness of 400 feet. The Blaine formation is of particular interest because of the vast reserves of potentially valuable gypsum that it contains.

Overlying the El Reno group are red sandstones of the Whitehorse group, middle Guadalupean in age, which are poorly exposed in the northern part of the area. They consist of undifferentiated Marlow sandstone and Rush Springs sandstone. The oldest exposed rocks are Hennessey shale, of probable late Leonardian age, the uppermost part of which crops out below the Duncan sandstone in the southern part of the mapped area.

These Permian rocks are part of a thick sequence of evaporites and red clastic sediments, generally unfossiliferous, that maintains rather similar characteristics from north Texas through western Oklahoma into southwestern Kansas (see Figure 2). The most pronounced facies change is in rocks of the El Reno group. Where strata of the El Reno group crop out around the southeastern margin of the Anadarko basin, east of the Carter area in Caddo, Comanche, Stephens, and Grady Counties, they show a marked facies change into a sandstone complex that contains virtually no evaporites. This is the up-dip or shoreward phase, present only in the eastern outcrop area of the basin where downfolding has preserved these clastic rocks from erosion. Evaporites in the Blaine reappear on the outcrop in Blaine County and extend northwestward well into Kansas (Figure 1).

The disappearance of evaporites around the up-dip part of the Anadarko basin separates the gypsum outcrops into two principal areas and thereby makes difficult the correlation of individual members.

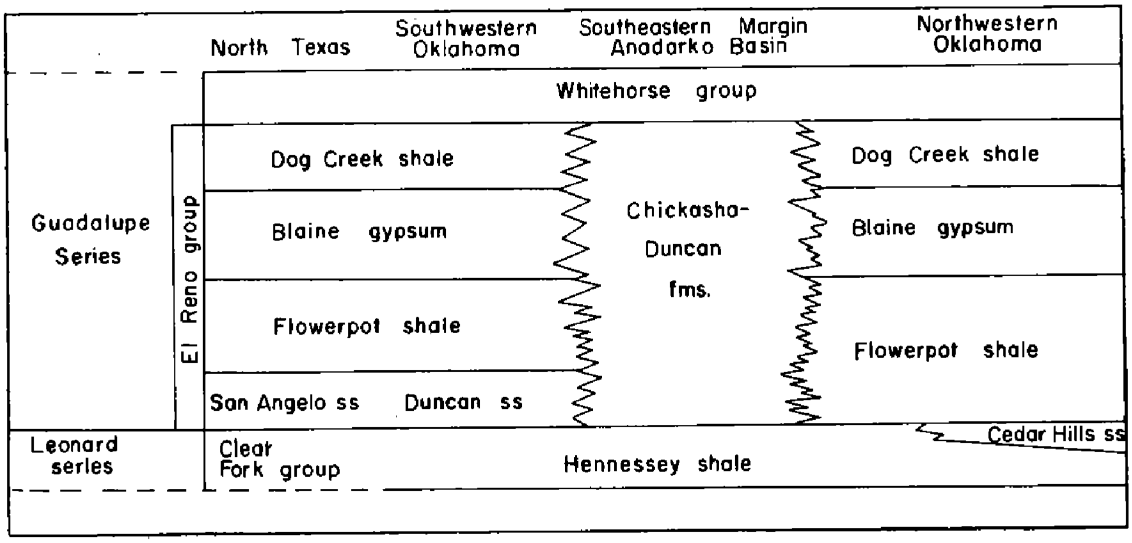


Figure 2. Stratigraphic diagram of outcropping middle Permian strata in north Texas and western Oklahoma.

Hennessey Shale

History of nomenclature. Rocks currently assigned to the Hennessey shale were originally placed by Gould (1905, p. 39) within the Enid formation, which included all strata from the base of the Permian to the base of the Blaine formation. The term Hennessey shale was first used by Aurin, Officer, and Gould (1926, p. 786-799) in central Oklahoma when they gave group standing to the Enid formation, and subdivided this new group into the Chickasha, Duncan, Hennessey, Garber, Wellington, and Stillwater formations. Anderson (1927, p. 10) traced the Hennessey across McClain County toward the apex of the Anadarko basin.

Sawyer (1929, p. 9) assigned the rocks above the Wellington and below the Duncan sandstone in Kiowa County a Garber-Hennessey age. Later reports by Becker (1930, p. 47), Green (1936, p. 1465), and Brown (1937, p. 1546) refer to the presence of and to the character of the Hennessey shale in this area.

According to present usage (Miser, 1954) the Hennessey shale in southwestern Oklahoma is underlain by the Wichita formation and is overlain by the Duncan sandstone, or by the Flowerpot shale where the Duncan is absent. In the Carter area the upper part of the Hennessey crops out in the southern sections of the mapped area, and the Duncan sandstone is everywhere present at the top.

Character and thickness. The Hennessey is 300-600 feet thick in central Oklahoma, but only the uppermost 40 to 50 feet is exposed in the Carter area. Here it is predominantly yellowish gray to buff unfossiliferous shale. A few thin gray, gray-blue, or buff silty fine-grained calcareous sandstone stringers occur in the section, as do thin beds of bright red, brown, maroon, orange, yellow, and blue shales. Selenite crystals as much as one inch in diameter weather out of the shale. Red, rusty, and yellowish rounded concretions up to two inches in diameter occur in the thin beds of red, maroon, orange, and yellow shale. The thin sandstone beds and the buff shale closely resemble both in color and character the sandstone and shale in the overlying Duncan formation.

The Hennessey formation is easily eroded, typically into rounded low hills which slope back to the escarpment of the overlying Duncan sandstone.

Stratigraphic relations. The rusty concretions and the yellow and reddish shale streaks may represent zones of oxidation and weathering on a temporarily emergent surface. Further possible evidence of emergent conditions and of a regional disconformity at the Hennessey-Duncan contact is available from a study of the Duncan sandstone and will be discussed under that heading.

El Reno Group

The name El Reno formation was proposed by Becker (1930, p. 55) for those strata above the Hennessey shale and below the base of the Whitehorse group. Schweer (1937, p. 1553) suggested that "El Reno formation" be changed to El Reno group, and this classification has been followed in subsequent work.

The outcrop pattern of this group shown on the Geologic Map of Oklahoma (Miser, 1954) is a large "V" with the apex in Stephens County. One limb passes along the north side of the Wichita Mountains, including the Carter area, and the other limb swings northwestward through west-central Oklahoma and thence into Kansas. This outcrop pattern results from synclinal folding of the Anadarko basin, first noted in 1924 when both Sawyer (1924, p. 319) and Gould (1924, p. 323) published papers describing it.

Within the apex or southeastern margin of the Anadarko basin is a pronounced change in facies that has led to the recognition of numerous stratigraphic problems and to much discussion by geologists (Wegemann, 1915; Greene, 1920; Sawyer, 1924; Gould, 1924; Gould and Willis, 1927; Sawyer, 1929; Becker, 1930; Evans, 1931; Green, 1936; Brown, 1937; Schweer, 1937; and Davis, 1955). It is now generally believed that the Chickasha-Duncan sandstone complex in this apex region is the near-shore coarse-clastic equivalent of the shale-gypsum-anhydrite-dolomite strata comprising the El Reno group on both sides of the basin to the north and west. The fact that the two evaporite areas are separated by non-evaporite sediments has resulted in the establishment of a dual nomenclature, one set of names being applied to the gypsum members of the Blaine in the northwestern belt, and another set in the Carter area and elsewhere in southwestern Oklahoma.

The present work in the Carter area has resulted in revision of the older stratigraphic concept of the Blaine formation, extending the upper boundary to include a thick bed of gypsum, hitherto unrecognized in print, which is here called the Van Vacter member. This bed lies next above the Mangum dolomite, at the top of which the upper boundary of the Blaine was placed by earlier workers.

An unconformity with local truncation separates the rocks of the El Reno group from those of the overlying Whitehorse group, and a possible disconformity is present at the base of the group, between the Duncan sandstone and underlying Hennessey shale.

In the Carter area strata comprising the El Reno group are divided, in ascending order, into the Duncan sandstone, Flowerpot shale, Blaine formation, and Dog Creek shale. Composite thickness of these strata in the central part of the area is 400 feet.

Duncan Sandstone

History of nomenclature. The first reference to the Duncan sandstone was by Wegemann (1915, p. 43-50) who referred to it as an escarpment-forming sandstone which could be traced from the vicinity of Duncan to the north flank of the Wichita Mountains.

The formation was named by Gould (1924, p. 325) and the type locality designated as Duncan, the county seat of Stephens County, Oklahoma (Gould, 1925, p. 89). Gould gave a thickness of 250 feet for the formation. Traced north and northwestward along the south flank of the basin, the Duncan thins and the escarpment generally becomes less noticeable.

Gould, Gouin, Sawyer, Becker, and Green have referred to the presence of the Duncan sandstone in the area of this report.

Distribution. The Duncan sandstone forms a prominent escarpment above the Hennessey shale across T. 7 N., R. 20 W. Owing to its resistance to erosion and to its low northward dip, it forms a gentle south-facing cuesta across all the central part of the township. The Duncan-Hennessey contact enters the map area across the southeast corner and trends northwestward to Crooked Creek where it swings back to the southwest near the North Fork of Red River. From this point the contact extends northward in bluffs along the river, then turns northwest and passes under terrace sand and flood plain alluvium. Across North Fork the Duncan is exposed in three small inliers. The Duncan-Flowerpot contact extends northwestward across the north half of T. 7 N., R. 20 W.

Character and thickness. The Duncan is a grayish-brown to buff, indurated, highly cross-bedded, ripple-marked, silty to very fine-grained, dolomitic sandstone with much interbedded buff to gray silty and non-silty shale. Neither the sandstones nor the shales are fossiliferous. Blue-green malachite-impregnated sandstone nodules are widely disseminated throughout the formation. A thickness of 28 feet was measured in the NE¼ sec. 24, T. 7 N., R. 21 W. At this locality, there are four ledge-forming cross-bedded sandstones and siltstones aggregating 10 feet; the other 18 feet is composed of less indurated buff-silty sandstone, silty shale, and shale. Sawyer (1929, p. 9) gives an approximate thickness of 40 feet for the Duncan over most of Kiowa County.

An interesting conglomeratic siltstone bed is exposed in the bluff along North Fork of Red River in the NE¼ sec. 13, T. 7 N., R. 21 W., two feet above the base of the formation. It is cross-bedded and has a gray, knobby, irregular surface at the outcrop. The matrix and dominant constituent is gray calcareous quartzose silt. Scattered irregularly throughout the silt are rounded flattened granules and pebbles of green shale which range from

1 to 7 millimeters in long dimension. Two pieces of angular quartz, 1.5 millimeters in diameter, were found in a hand sample. Many small, irregular, soft, highly-weathered gray, rusty, and yellowish pebbles of uncertain original composition also occur. Most of the shale pebbles are oriented parallel to bedding.

Ripple marks are common on the upper surfaces of sandstone beds beneath thin beds of shale. The ripple crests are rounded and the slopes are asymmetrical, indicating that they are current ripple marks (Twenhofel, 1950, p. 570).

Cross-bedding is well displayed in the Duncan across all the area covered by this report. In general, the cross-bedding falls into two categories. Cross-bedding placed in the first category is inclined at angles ranging from 8 to 20 degrees and is in beds 1 to 5 feet thick, which are concave upward. The horizontal extent of these beds ranges from several feet to 40 feet. The individual laminae within such beds thin and feather out downward. At the thin terminus the dip is nearly horizontal, and as a result these beds display a general foreset and bottomset arrangement. This category is well displayed in the bluff in the NE¼ sec. 13, T. 7 N., R. 21 W., and can be seen at many localities along the Duncan outcrop. The cross-bedding dips in many directions, but northwestward dip appears to predominate.

Cross-bedding of the second category is characterized by thin laminae ranging from 1 to 5 inches long, and dipping 10° to 40°. Each lamina thins and decreases in dip near its lower end. Flat or gently inclined bedding planes, many current-rippled, cut across the top of these laminae, and other such planes, which may or may not be parallel with the first, pass under the laminae. Inclined laminae such as these, called foresets, are produced by current rippling. According to Twenhofel, 1932, p. 623, "The laminations are made on the lee sides of the asymmetrical ripples and their upper ends are truncated with ripple advance. The direction of cross lamination made in ripples records the directions of the currents, the inclinations in all cases except those of antidunes and rapid deposition being in the directions of current movement."

At virtually every outcrop, several different directions of dip are displayed by different sets of these inclined foresets. A statistical study would probably reveal predominating dip directions and thus reveal the principal current directions of Duncan time.

Stratigraphic relations. The Duncan sandstone is believed to have a gradational or interfingering contact with the overlying Flowerpot shale, and may be separated from the underlying Hennessey shale by a regional disconformity. Physical evidence of unconformity in the Carter area is meager, consisting chiefly of the occurrence of clay gall conglomerate in the lower part of the Duncan, and the presence in the upper Hennessey of rusty-yellow weathered-appearing concretions.

Any unconformity which may exist at the base of the Duncan probably has its greatest magnitude in the southern apex of the Anadarko basin, near Duncan and elsewhere in Stephens County where the sandstone attains its maximum thickness of approximately 250 feet. From this thickness it grades northwestward to only 40 feet in the Carter area; and southwestward from the Carter area the Duncan is hardly recognizable as a sandstone, so that an unconformity, if present, would lie wholly within shale strata.

History of nomenclature. The name Flowerpot shale was first used by Cragin (1896, p. 1-48) in Kansas. The following year he stated that the Flowerpot shale is a member of the Glass Mountain formation in northwestern Oklahoma (p. 351-363). Gould (1924, p. 325, 329-330) named the beds above the Duncan sandstone and below the Blaine formation the Chickasha formation. Sawyer (1929, p. 9) preferred the name Flowerpot shale over Chickasha formation for western and northwestern Oklahoma. Becker (1930, p. 55) agreed with Sawyer. Since that time, Green, Schweer, and King have used "Flowerpot shale" in preference to "Chickasha formation" in papers pertaining to western and northwestern Oklahoma; and in current nomenclature the Flowerpot shale is recognized as overlying the Duncan sandstone, where it is present, and underlying the Blaine formation.

Distribution. The Flowerpot shale extends diagonally across the area, entering the mapped area in T. 7 N., R. 20 W. and trending northwestward across T. 8 N., R. 21 W. and T. 8 N., R. 22 W. It is also exposed in the southwest corner of T. 8 N., R. 22 W., and parts of the adjoining townships.

Character and thickness. As described by Sawyer (1929, p. 9) the Flowerpot shale in this area consists of 150 feet of red shales, together with minor amounts of gray shale, and has no sharp boundary with the underlying Duncan sandstone. In reasonable accord with Sawyer's thickness is the 165 feet measured for the present investigation in sec. 2, T. 7 N., R. 21 W., and the 162 feet measured by McLaughlin (1955) farther west in the vicinity of Haystack Butte, sec. 23, T. 7 N., R. 23 W. Normal thickness of the Flowerpot shale in this region thus is 160 feet. Three measured sections are shown graphically in Plate II and are described in the appendix (Measured Sections II, VIII, and IX).

The Flowerpot consists mainly of red, brown, and maroon blocky shales with much interstratified green and light gray shale, thin impure gypsum beds, and thin brown fine-grained dolomites. Satin spar gypsum extends vertically and horizontally throughout the section, especially along joint planes. Most of the gypsum and dolomite beds are persistent, as is shown in Plate II.

Lenticular gray to brown, current-rippled, cross-bedded, fine-grained, very silty, dolomitic sandstone occurs in the Flowerpot, about 50 feet above the base in the NE¼ sec. 2, T. 7 N., R. 21 W. The interbedded grayish buff shales, current-rippling, cross-bedding, color, and worm burrows all resemble similar features in the Duncan sandstone. It is believed, in view of the eastward gradation of the Flowerpot into the Duncan-Chickasha facies, that the above sandstone-buff shale sequence thickens eastward and gradually merges with the Duncan sandstone. This part of the Flowerpot is covered in T. 7 N., R. 20 W. and the rate of thickening cannot be determined. Small poorly preserved gray-brown fossil fragments, possibly of pelecypod valves, were found in a dolomitic phase of this sandstone.

Two persistent gypsum members occur in the upper part of the Flowerpot shale. The lower bed, the Chaney member, generally 42 to 50 feet below the top of the Flowerpot formation, is typically a gray to white massive gypsum 1 to 3 feet thick. At some localities it is gray to greenish and is shaly.

The upper gypsum bed is called the Kiser member and is about 25 feet below the top of the Flowerpot. Across the area covered by this report it ranges in thickness from 2 to 5 feet, and in lithology it is greenish to reddish very shaly well-bedded gypsum.

These members were named by Gould (1902, p. 42) and included in his Greer formation (western area), the base of which was placed at the base of the Chaney. When the Greer (western area) was renamed, these members became a part of the Blaine formation (Gould, 1924, p. 325-334). For reasons that are discussed later in this report under Blaine formation, both the Kiser and Chaney are here classified with the Flowerpot shale rather than with the Blaine.

The Chaney derives its name from the Chaney Salt Plain on Elm Fork of Red River, four miles east of the Texas line, and the Kiser is named from the Kiser Salt Plain on Elm Fork, Greer County, where it is well exposed (Gould, 1902, p. 55).

Stratigraphic relations. The Flowerpot shale lies conformably upon the Duncan sandstone and is overlain conformably by the Blaine formation.

Blaine Formation

The Blaine formation in the Carter area consists of four massive white gypsum beds with three interstratified well-defined units of red and green shale, together with several thin beds of gray medium-grained dolomite or dolomitic limestone. It lies conformably upon the Flowerpot shale and is conformably overlain by the Dog Creek shale. Average thickness of the formation is consistently about 130-140 feet across T. 8 N., Rs. 21 and 22 W., where the strata are well exposed in bluffs, but in the eastern part of the area where exposures are poor the thickness could not be accurately determined. In the eastern area the gypsum beds are much thinner as a result of gradation into shales, but the formation itself apparently maintains a nearly constant thickness. Eastward from the mapped area the gypsum beds of the Blaine formation become very thin and disappear.

History of nomenclature. In early reconnaissance work on gypsum-bearing Middle Permian rocks of western Oklahoma, it was generally believed that there were two stratigraphic sequences—the Blaine formation in the northwestern district, and the younger Greer formation in the southwestern district (Gould, 1902, 1905). A nomenclature was erected for beds of the Blaine formation in the northwestern counties, using excellent outcrops in Blaine County for the type section, and bringing such names as Shimer and Medicine Lodge into Oklahoma from Kansas. At the same time prominent beds in the Greer formation were named for southwestern localities. The persistent gypsum beds in the Carter area and southwestward therefrom were placed in the western area of the Greer formation, and the little understood but thick gypsums of Washita and Custer Counties were placed in the eastern area of the Greer.

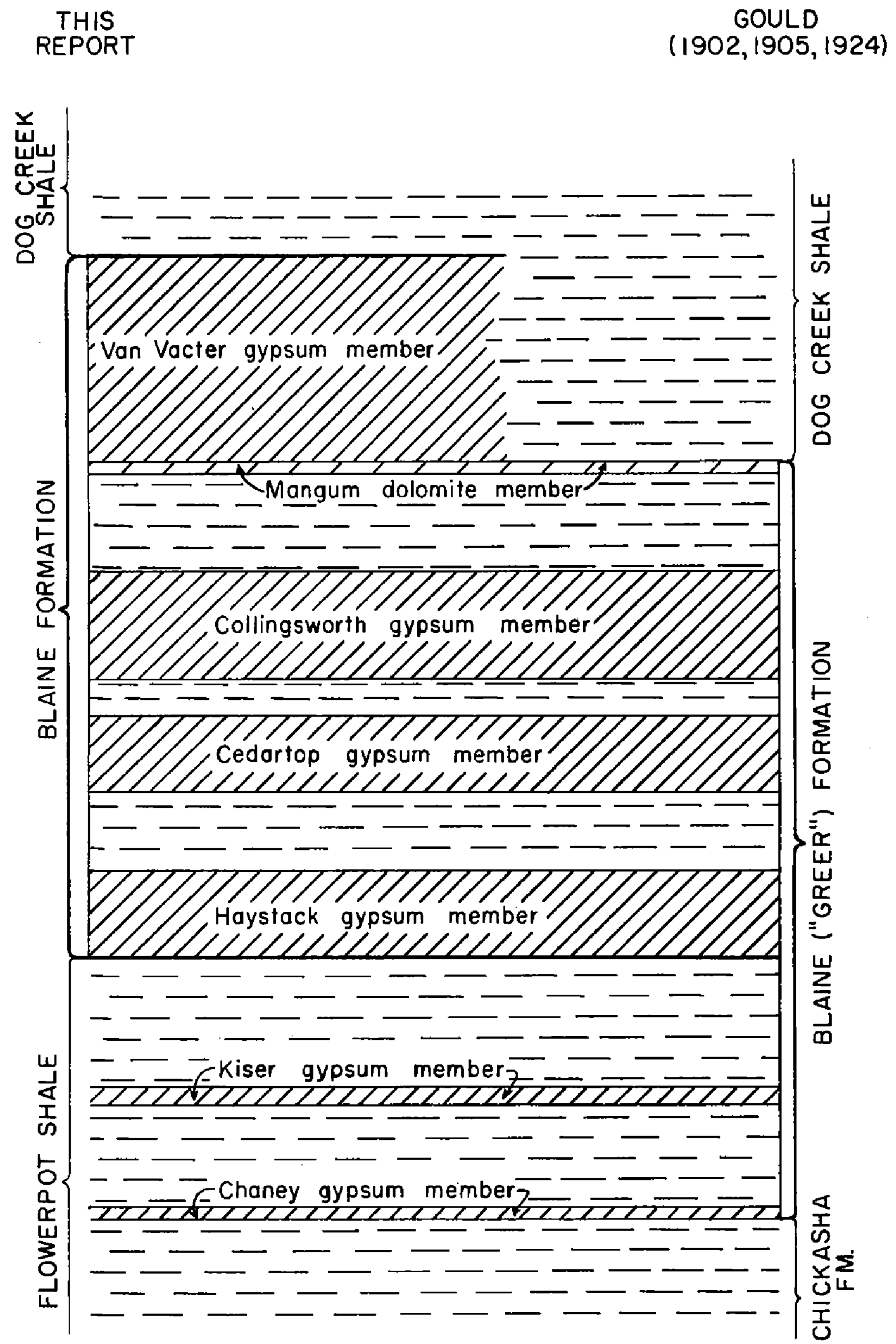


Figure 3. Classification of the Blaine formation in southwestern Oklahoma. Minor dolomite beds not shown.

It was not until western Oklahoma had been mapped in some detail that accurate stratigraphic relations were established. The two keys to the new interpretation were (a) the recognition of a large northwest-plunging syncline, called the Anadarko syncline (Gould, 1924, p. 323), and (b) the recognition of important changes in facies whereby thick gypsum sequences graded into coarse clastics on a major scale. Under the new concept it was shown that the "eastern area of the Greer formation" was in the trough of the syncline and contained the youngest of all gypsum-bearing Permian strata in Oklahoma. This formation was named Cloud Chief.

Of even greater stratigraphic importance was the demonstration by surface mapping that the gypsum of the Blaine formation of northwestern counties is essentially equivalent to gypsum beds in the "western area of the Greer formation," the two being on opposite flanks of the Anadarko basin and being separated along the outcrop by a wedge of non-gypsiferous sediments between them. The term "Greer formation" was dropped and the Blaine formation was extended, with slight modification, throughout western Oklahoma from Kansas to Texas. Because the northwestern and southwestern districts of the Blaine gypsum are separated for 100 miles along the outcrop by a complex of sandstones and shales without gypsum, thus dividing the Blaine into two separate regions between which individual beds can not be directly correlated, the dual nomenclature established by Gould in 1902 has been retained to the present time.

In the standard section given by Gould for southwestern Oklahoma the Blaine formation was defined as extending from the base of the Chaney gypsum to the top of the Mangum dolomite, and including within it the Kiser, Haystack, Cedartop, and Collingsworth gypsums.

From results of the present work, including the discovery of a new thick gypsum bed above the Mangum, it can be shown that the boundaries given above are illogical and that a reclassification is needed. Accordingly the Blaine formation in the Carter area and elsewhere in southwestern Oklahoma is here redefined as extending from the base of the Haystack gypsum member to the top of the Van Vacter gypsum member. Both boundaries are new. The thin Chaney and Kiser gypsums are excluded from the Blaine and are placed with similar gypsiferous beds in the underlying Flowerpot shale; and a previously unrecognized thick gypsum, here called Van Vacter, is added at the top.

As thus redefined, the Blaine formation includes all strata, characterized by thick beds of gypsum, that lie above the Flowerpot shale and below the Dog Creek shale. In the new classification (Fig. 3) the Blaine formation consists in ascending order of the Haystack gypsum member, Cedartop gypsum member, Collingsworth gypsum member, Mangum dolomite member, and Van Vacter gypsum member. The three intervening beds of shale are unnamed. In the Carter area the formation is 130-140 feet thick, of which approximately 90 feet or 70 percent is massive gypsum.

Correlation with the type section. Under a new program by the Oklahoma Geological Survey of mapping gypsum beds in western Oklahoma, much attention is currently being given to details of the Blaine formation in the northwestern district, particularly in Harper County, which has been mapped by Arthur J. Myers, and in Blaine County, which is being mapped by Robert O. Fay. Discussions with these men regarding their respective areas, a trip to Blaine County with Mr. Fay, and a trip by Fay to the Carter area, all have strengthened the opinion that certain correlations can be made with confidence. These correlations are shown in Figure 4.

In central Blaine County, the type locality, three persistent gypsum members are present and a fourth gypsum bed occurs as a thin northward-disappearing tongue. Using a number of control beds in the Dog Creek, Blaine, and Flowerpot formations, Fay was able to trace the persistent gypsum beds of the Blaine into Kansas and thus establish the basal bed as Medicine Lodge, the top bed as Shimer, and the middle bed as Nescatunga. This classification will now replace the older nomenclature, which was based on early miscorrelations as well as on an incomplete knowledge of the gypsum beds themselves. The thin gypsum tongue between the Medicine Lodge and Nescatunga has been called "Alabaster" (Green, 1936, p. 1468) but it has been neither formally described nor given a type locality.

On the interregional correlation chart shown in Figure 4, great emphasis is here placed on the lithology, thickness, fossil content, and stratigraphic position of dolomite beds. First, it has been established that dolomites of the Dog Creek formation are unlike those of the Blaine, and this

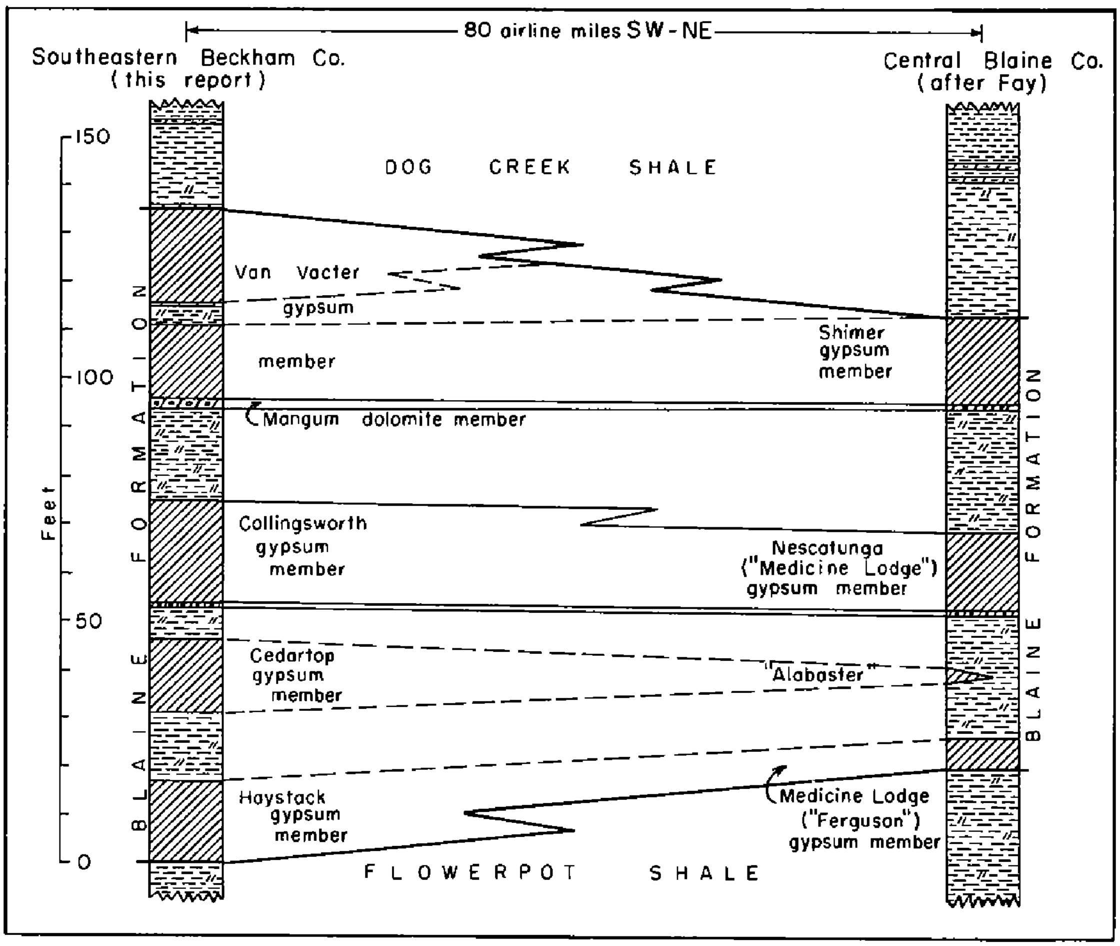


Figure 4. Correlation of the Blaine formation from the Carter area to the type locality in central Blaine County.

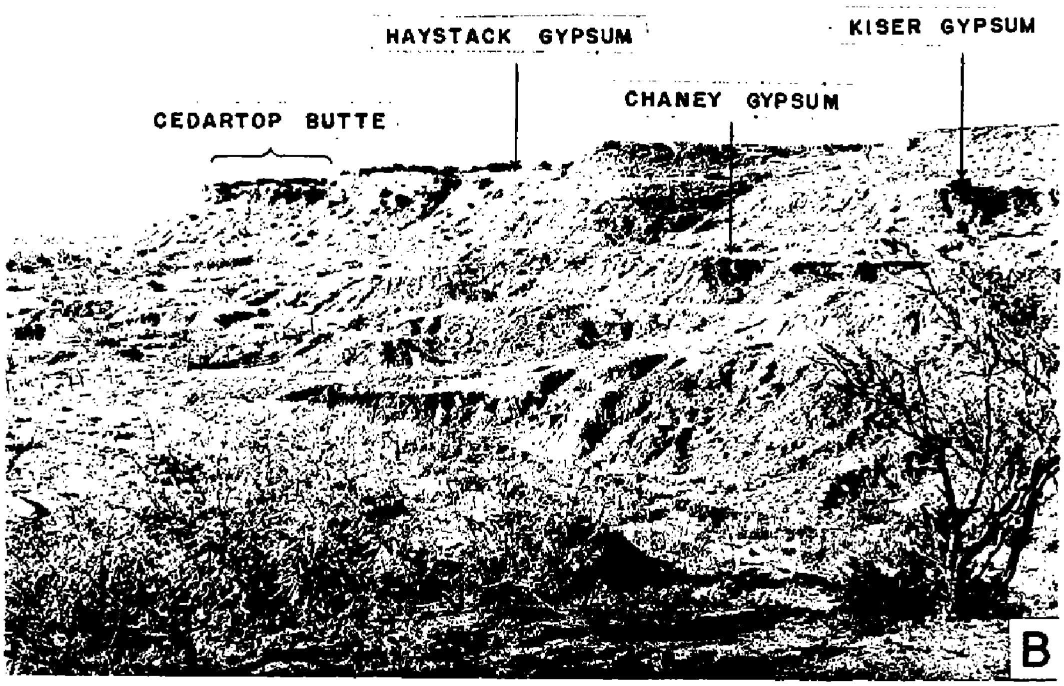
distinction serves to mark the approximate boundary between them. Dog Creek dolomites typically are grayish green, laminated, and uniformly silt-sized. They are 1 inch to as much as 4 feet thick, and they weather into thin plates or slabs. Thus far fossils have been observed at only one locality. In many places they contain impressions of hopper-shaped crystals of halite or common salt (Plate VIII, B), a fact which demonstrates the saline environment of deposition of the dolomites and explains why invertebrate fossils are so rare.

By contrast, the Blaine dolomites that occur at the base of the upper two gypsum beds are commonly oolitic and fossiliferous; and, except for one locality, they have not been found to contain salt casts. Fossils in the Blaine dolomites are well known and consist almost exclusively of pelecypods of the genus *Schizodus*. In the outcrop area connecting Blaine County with Beckham County the gypsum members thin and disappear before reaching the southeastern extremity of the Anadarko basin (Figure 1), but the dolomites continue well beyond the gypsum facies. Strikingly persistent are the Mangum dolomite at the base of the Van Vacter gypsum, and the dolomite at the base of the Shimer gypsum (Altona of Gould, 1902, p. 48-49). Each is 1-2 feet thick. Because of their lithologic and faunal similarity, their stratigraphic position as the highest oolitic dolomite bed of the Blaine, and their great lateral persistence, these beds are correlated and are used as the datum for Figure 4. On this basis the Shimer gypsum is shown to be equivalent to the lower part of the Van Vacter gypsum; and the top of the Van Vacter or top of Blaine is shown to be stratigraphically higher than the top of the Blaine in the type locality.

The lower oolitic dolomite of the Blaine underlies the Collingsworth gypsum in Beckham County and the Nescatunga gypsum in Blaine County. That these two dolomite beds are correlative is again strongly indicated by their oolitic character, presence of pelecypods, constant thickness of about 1 foot, and a constant interval of 40 feet below the Mangum. From these data it is clear that the Collingsworth and Nescatunga gypsum beds are equivalent. In Blaine County the dolomite below the Nescatunga ("Medicine Lodge" of Gould) was called the Magpie dolomite in the earliest publications (Gould, 1902, p. 48); and in Jackson County what may be the same bed was called Creta by Suffel (1930, p. 32). Until a clearer concept of the Creta is available the term should not be adopted and it is not used in the Carter area.

Correlation of the Haystack and Cedartop gypsums with gypsums of the type area of the Blaine is less secure, but from Figure 4 it is believed and here suggested that Haystack is equivalent to Medicine Lodge, and that Cedartop is equivalent to "Alabaster." It is not clear whether the base of the Haystack is precisely the same as the base of the Medicine Lodge or is stratigraphically lower, but for practical classification each marks the base of the Blaine in its respective area.

Distribution. The Blaine formation crops out in a south-facing escarpment across the area of this report. The outcrop has a west-northwest trend in the western half of the area where the escarpment is near North Fork and attains its greatest height, and a generally eastward trend in the



Blaine Escarpment

A. Escarpment 200 feet high capped by lower three gypsum members of Blaine formation and by Mangum dolomite (upper left). View east-southeast across nearly dry channel of North Fork Red River into southern part of T. 8 N., R. 21 W.

B. Detail of Flowerpot shale in face of the dissected escarpment, showing upper shale and siltstone strata and the Kiser and Chaney gypsum members. Caprock is Haystack gypsum at base of Blaine formation. View southwest toward Cedartop Butte, NE¼ NE¼ sec. 2, T. 7 N., R. 21 W.

eastern half where the escarpment gradually diminishes and grades into a plains country interrupted by low dolomite-capped cuestas. Average width of the Blaine outcrop is about 1½ miles (Plate I).

Thickness. Normal thickness of the Blaine formation across the Carter area is 140 feet. It maintains approximately a constant thickness across T. 8 N., Rs. 21 and 22 W. (Plate II). Eastward from these townships the gypsum members thin and the shales thicken, and the thickness of the formation is difficult to measure because the upper gypsum member is generally covered and the Blaine-Dog Creek contact is not exposed.

Southwest of the mapped area, in sec. 29, T. 7 N., R. 24 W., the formation is 125 feet thick.

Members. One dolomite bed and four gypsum beds are named members and are mapped for this report (Plate I). In ascending order they are Haystack gypsum member, Cedartop gypsum member, Collingsworth gypsum member, Mangum dolomite member, and Van Vacter gypsum member (new). Three unnamed beds of shale separate the gypsum members.

Haystack gypsum member. Gould (1905, p. 69) described the Haystack member as follows: "The upper part of the Greer (Blaine) formation consists of three layers of massive gypsum and one of dolomite, interstratified between beds of red clay shale. The lowermost of the three thicker layers, the third gypsum member from the bottom of the formaton, consists of the typically massive gypsum, almost pure white or occasionally grayish in places, with a few thin bands of gypsiferous sandstone. This ledge is often cut by joints which separate the rocks into rectangular blocks. These blocks frequently weather out and roll down the slope and in places render it conspicuously white for miles. The Haystack varies locally from 18 to 25 feet in thickness, and so far as known is the thickest gypsum member in the western area of Greer. It is exposed along all the bluffs on North Fork and Elm Fork and is particularly conspicuous on Haystack Creek and in the vicinity of Haystack Butte, whence the name."

The type locality at Haystack Butte, in sec. 23, T. 7 N., R. 23W., is about 6 miles southwest of Moravia and hence just outside the mapped area.

The Haystack crops out in a steep bluff where the Blaine is in close proximity to North Fork of Red River. Commonly the entire thickness of the Haystack is exposed as a vertical ledge. As the outcrop swings away from the river eastward into Washita County, the escarpment becomes much less pronounced. In Kiowa County the Haystack outcrop is covered and its areal distribution is largely inferred.

The thickness of the Haystack ranges from 17 to 24 feet across the two townships in Beckham County. Plate II shows thicknesses measured at various localities. From the east side of sec. 31, T. 8 N., R. 20 W., Washita County, to the east edge of the map, the base of the Haystack is not exposed.

From the west side of the map area to the vicinity of Cedartop Butte, a distance of approximately 12 miles, the Haystack gypsum member is uniform in thickness and character. A band of gray to dark gray shaly gypsum about one foot thick occurs at the base. A thin dolomite bed 1 to 5 inches thick and approximately 7 feet above the base can be identified at most localities. The gypsum is white to gray, somewhat laminated in the lower 8 feet, compact, massive, and aphanitic to fine-crystalline.

In the SW¼ sec. 36, T. 8 N., R. 21 W., 4 feet of green shale lies 2.5 feet below the top of the Haystack. Eastward about 150 yards a gray slabby medium-grained gypsiferous dolomite, 1-1½ feet thick, appears in the middle of this shale. The dolomite is absent across secs. 31 and 32, T. 8 N., R. 20 W., but is correlated with a similar dolomite which crops out across the NE¼ NE¼ sec. 10, T. 7 N., R. 20 W.

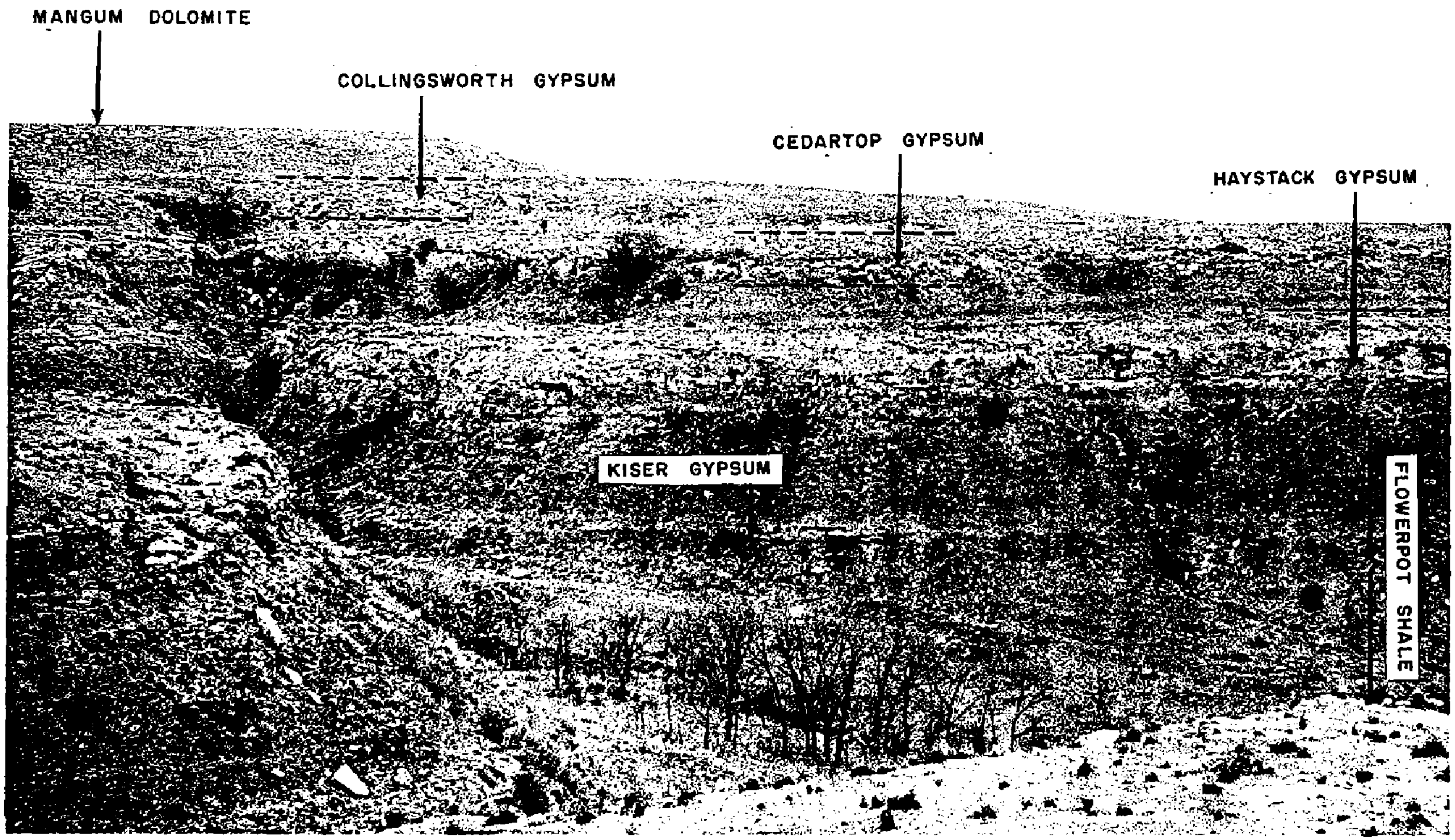
No gypsum is exposed in the Haystack member as mapped across T. 7 N., R. 20 W. Its outcrop across this portion of the mapped area is inferred by the presence of the dolomite referred to above and by its proximity to the other members of the Blaine formation.

Measured section 2, Plate II, is at Haystack Butte, the type locality of this member. The correlations clearly indicate that the Haystack of the type locality and the Haystack as used in this report are the same. Field work in the vicinity of measured sections 1 and 2 (type locality) convinced the writers that these sections were properly correlated with the measured sections in the area of this report.

The Haystack gypsum ledge can be mapped with ease from the west side of the area of this report to the vicinity of measured section 9 (Plate II) near Cedartop Butte. This butte is capped by the Haystack gypsum (Plate III, B). Cedartop Butte was given as the type locality of the Cedartop gypsum member by Gould (1902, p. 56). It is therefore concluded that the names "Haystack" and "Cedartop" as originally used at their type localities refer to the same gypsum ledge. A new type locality for the Cedartop gypsum is assigned elsewhere in this report.

Cedartop gypsum member. Concerning this member Gould (1902, p. 56) stated: "The Cedartop is a massive white gypsum, very similar in appearance to the Haystack. It has a constant thickness of 18 to 20 feet throughout the region of outcrop. It is very conspicuous on North Fork, Haystack, and Elm Fork, and forms the caps of a number of buttes and bluffs throughout the region. It is called "Cedartop," from a prominent butte on the North Fork of Red River, in the extreme southeastern corner of Roger Mills County (now Beckham County). This rock forms the upper ledge of this butte, and may be seen from a great distance up and down the river and even from Headquarters Mountain at Granite, 15 miles away."

As previously shown, the Haystack gypsum caps Cedartop Butte, and since all rocks younger than Haystack have been eroded away, this butte can not be the type locality for what is here called Cedartop gypsum. The writers have therefore changed Gould's type locality of the Cedartop gypsum, placing it in the excellent bluff exposures about 250 yards north of Cedartop Butte, in the SE¼ SE¼ sec. 35, T. 8 N., R. 21 W., where the member is 10.5 feet thick (Plate V, A). At the newly selected type locality, the Cedartop gypsum member is separated from the underlying Haystack gypsum member by 12.5 feet of red and gray-green shale, and from the overlying Collingsworth gypsum member by 13.5 feet of shale. A thin yellowish to brown, platy, medium-crystalline limestone occurs at the base of the Cedartop.



Typical Outcrop of the Blaine Formation

View in west-central part of Carter area, NE¼ sec. 23 and SE¼ sec. 14, T. 8 N., R. 22 W., showing outcropping ledges of the Haystack, Cedartop, and Collingsworth gypsum members, separated by shale, and the Mangum dolomite capping the mesa at upper left. Van Vacter gypsum at top of Blaine crops out back of escarpment on dip slope, out of view. Flowerpot shale and Kiser gypsum member exposed in valley wall below Haystack.

The outcrop of this member closely parallels that of the Haystack. It can be traced from the west side of T. 8 N., R. 22 W. into Washita County where good outcrops disappear about one mile west of the Crooked Creek fault. Southeast of this fault, in Kiowa County, there are no outcrops of this gypsum, and its contacts as shown on the map are inferred from its relations to overlying and underlying members. It is possible that in this area the gypsum has graded entirely into shale.

Plate II shows the correlation of the Cedartop through the area of this report into southwestern Beckham County. The maximum thickness is in T. 8 N., R. 22 W., where the member is 18 to 20 feet thick. The minimum thickness of 7 feet is in T. 8 N., R. 20 W. As this gypsum thins eastward the overlying shale thickens, indicating that the upper part grades eastward into shale.

At the outcrop the Cedartop gypsum has a gray, highly weathered surface. Fresh exposures reveal a white to slightly pink, massive to slightly honeycombed, fine-crystalline gypsum. A yellowish to brown, slabby, fine-crystalline dolomitic limestone 0.5 to 2 inches thick underlies the Cedartop, and at many localities a similar limestone occurs 2.5 feet up in the gypsum.

An anhydrite bed 26 inches thick is exposed just above the middle of the Cedartop gypsum along the steep escarpment in the NE¼ sec. 23, T. 8 N., R. 22 W. (Plate V, B). It is gray, laminated, compact, coarse-crystalline, exhibits a pitted, ragged surface, and breaks away from the ledge in large rectangular blocks. Owing to greater resistance of these blocks to chemical and mechanical erosion, they constitute a large percentage of the talus at the foot of the escarpment. This anhydrite bed has an outcrop length not exceeding 2.5 miles, disappearing both eastward and westward, probably by gradation into gypsum. Two such localities are in the SE¼ SE¼ sec. 16, T. 8 N., R. 22 W. and at the NE cor. sec. 28, T. 8 N., R. 21 W.

Collingsworth gypsum member. Gould's (1902, p. 56) original description of this member is as follows: "This (Collingsworth) is the upper gypsum ledge of the Greer formation, and it does not differ materially in lithological appearance from the Haystack or Cedartop. Like them, it is massive and white throughout, and like them, also, it is cut by a series of master joints into rectangular blocks. Where exposed, the thickness varies from 18 to 20 feet, being approximately that of the Cedartop and not so great as the Haystack. As it is the upper gypsum member it has often been eroded, and for that reason does not always appear in a section. Near the heads of the various creeks, however, it is the prominent ledge, and it is also exposed on a number of the conspicuous bluffs, as along North Fork. It is named from Collingsworth County, Texas, just west of Greer County, Oklahoma, where the gypsum is well exposed."

Since publication of the original description, the formation name has been changed from Greer to Blaine, and the Van Vacter gypsum member has been added at the top, so that the Collingsworth is now the second gypsum below the top of the Blaine formation rather than the uppermost member.

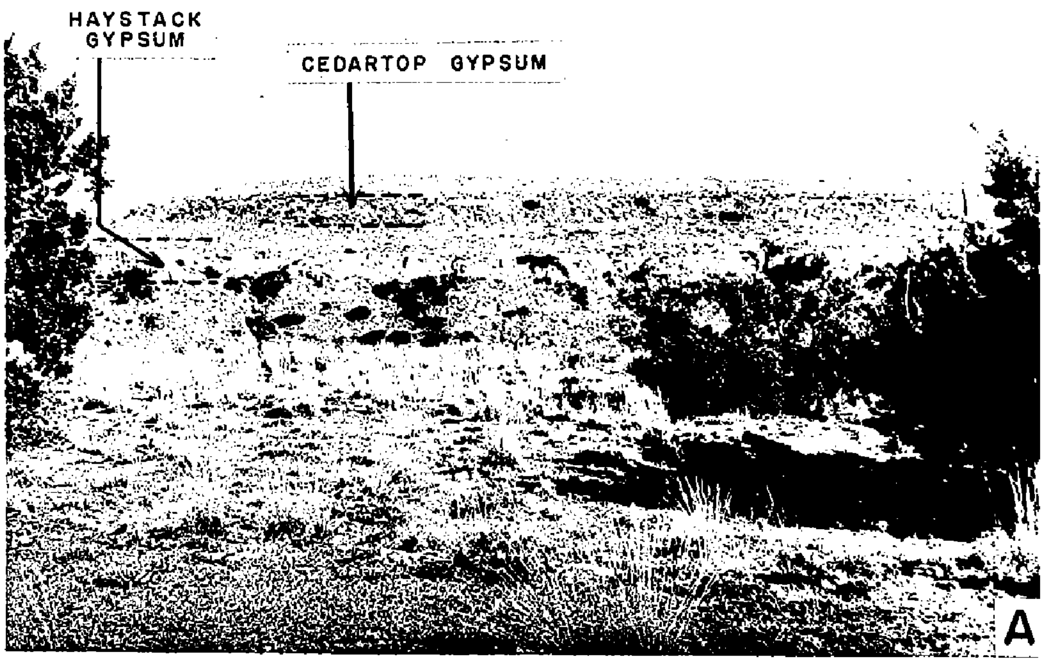
The Collingsworth gypsum member can be traced along the escarpment north of North Fork from the west side of T. 8 N., R. 22 W., east and southeast to the fault along Crooked Creek (Plate I). Where the overlying Mangum dolomite and Van Vacter members have been stripped away the Collingsworth caps the escarpment. At several localities this gypsum is either covered or is removed by erosion or solution. At such places the Collingsworth horizon is recognized by the dolomite at its base, which thickens eastward and resembles the overlying Mangum dolomite at many localities. This dolomite is picked up on the downthrown side of the Crooked Creek fault and is traced eastward to the edge of the mapped area. Over most of this distance it forms a small ledge along the face of the larger escarpment capped by the Mangum dolomite.

From Crooked Creek eastward, no gypsum crops out above this dolomite. Near a road cut along the east side of sec. 21, T. 7 N., R. 20 W., a 50-foot sequence from the dolomite up to the Mangum dolomite was measured (measured section 13, Plate II). Only red and greenish shales are present in this interval; no gypsum is exposed. Three explanations are offered for the absence of the gypsum. First, the gypsum was not deposited this far east. The second is that it was removed at the outcrop by solution accompanied by contemporaneous shale filling of solution cavities. The presence of several solution cavities along Crooked Creek that are completely filled with shale supports this possibility. Inasmuch as most of the shale in sec. 13 is not well-bedded this possibility may have considerable merit. A third possibility is that the gypsum is actually present near the outcrop but is covered by shale slumping down from the overlying Mangum escarpment.

The Collingsworth gypsum member thins westward toward southwestern Beckham County. Across the North Fork area, however, the thickness is rather constant, ranging from 18 to 22 feet.

The Collingsworth has a dirty gray caliche-like appearance at the weathered outcrop. Like the Cedartop, however, it is white to slightly pink on fresh surfaces. Some gray and brown discoloration accompanied by small irregular cavities and vugs attests to the dissolving effect of surface water. The gypsum is generally fine-grained and soft. At many localities, however, it is highly crystalline and consists of closely packed and intergrown selenite crystals up to 1 inch in diameter, giving the outcrop a rough, ragged appearance. At one locality, SW¼ NW¼ NE¼ sec. 17, T. 8 N., R. 21 W., the Collingsworth is made up of massive coarsely crystalline anhydrite.

The dolomite at the base of the Collingsworth across the eastern half of the area is about one foot thick. Its texture and color vary considerably. In general it can be described as gray to gray-brown, massive to slabby, honeycombed in part, compact to soft, fine- to coarse-crystalline, locally oolitic, locally fossiliferous, and calcareous. In color, composition, and texture it is similar to the Mangum dolomite and is described under that heading.



Cedartop Gypsum

A. Type locality of Cedartop gypsum, SE¼ SE¼ sec. 35, T. 8 N., R. 21 W., looking north from Cedartop Butte. Caprock on skyline is dolomite at base of Collingsworth gypsum, all of which has been eroded away.

B. Anhydrite bed 26 inches thick in middle of Cedartop gypsum, NE¼ NW¼ sec. 23, T. 8 N., R. 22 W. Hammer handle rests at base of banded anhydrite.

The possibility exists that this unnamed dolomite can be correlated with the Creta dolomite in Jackson and southern Greer Counties. A section measured by Snider near Mangum, Oklahoma (Suffel, 1930, p. 32), shows the Creta dolomite as one foot thick and to be separated from the overlying Mangum dolomite by 26 feet of shale. On the basis of the stratigraphic interval a tentative correlation could be made.

Mangum dolomite member. Gould's (1905, p. 71) description is as follows: "Above the Collingsworth and separated from it by about 20 feet of red clay shale is a very persistent 3-foot bed of more or less dolomitic limestone. In places it is true dolomite; while at others it contains only a small per cent of magnesia and is a magnesian limestone. The character of the rock varies considerably. In places it is arenaceous and soft, in other localities cavernous or honeycombed. Often, however, it is firm and solid and forms an excellent building stone. Its color is white, drab, or sometimes yellowish. The underlying clays have often been eroded and the rock frequently covers slopes at a considerable distance below its original position. While the thickness averages three feet, it varies from one foot to five feet. This member is exposed on the hills north of North Fork, in Roger Mills County (later Beckham), and on practically all the divides of Elm Fork and Haystack, Bull, and Fish Creeks in Greer County. The name of Mangum is that of the county seat of Greer County, near which the dolomite is well exposed."

With the exception of three miles along Crooked Creek, near the southwestern and southeastern boundaries of Beckham and Washita Counties respectively, the Mangum is well exposed as the upper ledge of the Blaine escarpment (Plate IV). Elsewhere, the Mangum outcrop is easily traced on the aerial photographs, as the underlying 15 to 20 feet of red shale forms a small escarpment which is darker in tone than the underlying gypsum escarpment. The Van Vacter gypsum member overlies the Mangum across the area of this report. Near the front of the steep Flowerpot-Blaine escarpment the Van Vacter gypsum has been stripped away by erosion and solution, and when viewed from near the base of the escarpment it appears that no gypsum occurs above the Mangum. The Mangum is about 1.5 feet thick across all the area.

The appearance and texture of the Mangum vary along the outcrop. Where the overlying gypsum has been stripped away, exposing the dolomite to prolonged weathering, it is thoroughly honeycombed with solution channels and vugs and has a gray to brown sandy-appearing surface (Plate VII, A). At such localities it is composed of dense, fine- to medium-crystalline limestone with irregular small patches of ellipsoidal medium-grained oolites. Red to pinkish, compact, dense calcite veins cut the rock along joint planes. These veins are more resistant to erosion than is the rock they cut across, producing at some localities a pitted cross-hatched appearance where the softer limestones and dolomite are eroded below the surface of the veins.

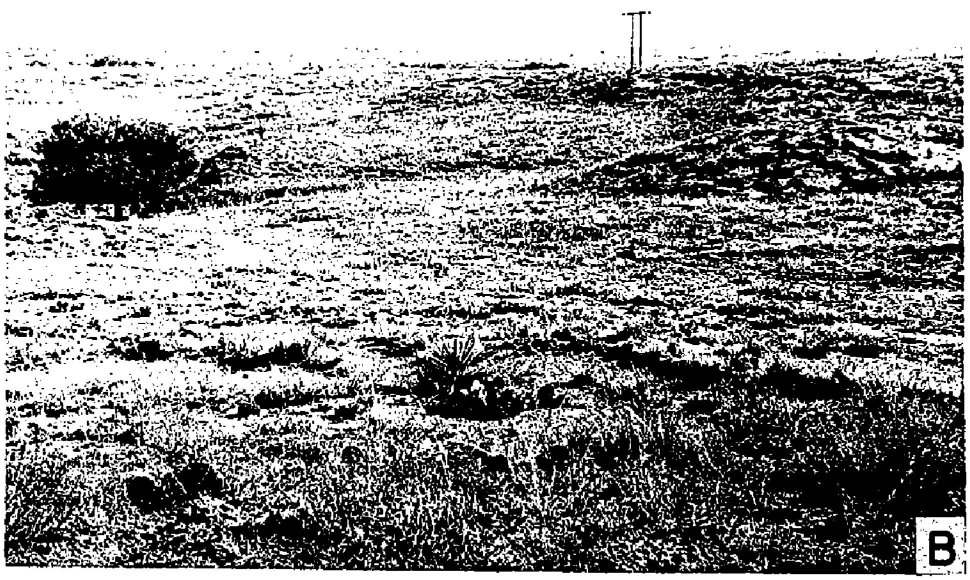
The appearance and texture of the Mangum is considerably different where it is not so highly weathered. It is massive, light gray to gray, and is much softer than the weathered variety. Ripple marks with an amplitude of one-third inch and a wave length of 3 to 4 inches are present at many localities. They are poorly preserved and appear to be oscillation ripples. A hand lens reveals fine- to medium-grained, rounded, spherical to elongated oolites, many of which are hollowed out, apparently in the process of being dissolved (Plate VII, B). Small rusty brown spots are widely scattered. Pelecypod molds and casts are common. A few thin, delicate fragments of the original valves are present. The unweathered Mangum is found beneath the Van Vacter gypsum along the small creeks which cut across the Blaine formation.

The Mangum is similar in many respects to the dolomite at the base of the Collingsworth gypsum. The Mangum is but a little thicker; and both weather gray-brown at the outcrop. Both have the red calcite veining, and the lower dolomite is at many places massive like the Mangum. Both are gray, soft, oolitic, and fossiliferous in fresh exposures. There are exposures of these dolomites where portions of the soft unweathered oolitic dolomite is enclosed in darker, gray, dense, medium-crystalline, vuggy limestone. It appears that both dolomites were originally deposited as oolitic calcitic dolomite, and later altered to a crystalline dolomitic limestone. The pink dense calcite which filled fracture planes is probably a still later feature deposited by surface waters. The alteration of these dolomites is discussed at length by Suffel (1930, p. 64).

It is difficult if not impossible to distinguish between the two dolomites on the basis of lithology alone. Of more use in the field is the slight difference in thickness and the difference in weathering at the outcrop. The Mangum weathers out in honeycombed blocks, whereas the lower dolomite commonly weathers into slabby layers.

Van Vacter gypsum member (new). The top of the Blaine formation in southwestern Oklahoma as previously defined by Gould (1924, p. 332) was at the top of the Mangum dolomite member. The present investigation has shown that above the Mangum dolomite, rather than shale which was classified by Gould as Dog Creek, occurs a thick sequence that consists principally of gypsum. Some shale is present in this sequence, and the shale appears to thicken eastward at the expense of the gypsum. Green (1937, p. 1522) has noted the presence of these beds.

The original purpose in establishing the Blaine formation was to classify into one stratigraphic unit all thick beds of closely related gypsum. This usage has been uniformly followed, as is shown by the frequent use in speech and in print of the term "Blaine gypsum" instead of "Blaine formation." Clearly the presence of a thick gypsum bed immediately above the Mangum dolomite would place this gypsum in the same category with the Haystack, Cedartop, and Collingsworth gypsums, thus making all of them logical members of the Blaine formation. Accordingly this upper bed is here named the Van Vacter gypsum and is made the top member of the Blaine formation in the Carter area. It has a maximum thickness of 50 feet and thus it is the thickest gypsum member of the Blaine formation as newly defined, including the outcrops in all parts of southwestern, west-central, and northwestern Oklahoma.



Contrasting Outcrops of Gypsum

A. Bold face of Haystack gypsum, produced by jointing in caprock on east side of Cedartop Butte, NE¼ NE¼ sec. 2, T. 7 N., R. 21 W. Banded gypsum above hammer handle rests on gypsiferous shale of the Flowerpot formation.

B. Dissected plain developed on Van Vacter gypsum in type area, NE¼ SE¼ sec. 10, T. 8 N., R. 22 W. Gypsum is poorly exposed as a result of surface solution and irregular soil cover.

The name Van Vacter is taken from a well known local ranch along North Fork in T. 8 N., Rs. 21 and 22 W. The entire thickness of this member can not be found on the ranch, but can be seen in reasonably good exposures to the north along Boggy Creek, especially its western branch, and along the two unnamed creeks three miles farther east.

The type area is here designated as the outcrops along the west branch of Boggy Creek, cen. E½ sec. 10 and cen. W½ sec. 11, T. 8 N., R. 22 W., about 2 miles northwest of the Van Vacter ranch house (Plate I). In the type area the Van Vacter member is 36.5 feet thick and consists of a lower and upper division of massive white and pink granular gypsum, respectively 14 and 18 feet thick, separated by 4 feet of red shale. A dolomite bed approximately 0.5 foot thick lies above the middle shale at the base of the upper gypsum (measured section V). The Van Vacter member is underlain by the Mangum dolomite and is overlain by the Dog Creek shale.

Outcrops of this gypsum can be found above the Mangum dolomite from the west side of T. 8 N., R. 22 W. to the vicinity of the fork in the road between secs. 21 and 22, T. 8 N., R. 21 W. Eastward in Washita and Kiowa Counties no outcrops occur and the top and bottom of the member are largely inferred. Its presence across most of this area, however, is indicated by many small sink holes. A large depression, the origin of which is attributed to solution of this member, and possibly of underlying gypsums as well, is in secs. 3 and 4, T. 7 N., R. 20 W. A large block of gypsum has been plowed up in the vicinity of the depression.

Without detailed investigations the presence of the Van Vacter could easily be overlooked across the two townships of Beckham County included in this report. Looking northward along the top edge of the steep Blaine escarpment, it appears to an observer that the beds of the Blaine are horizontal and that only a residual soil covers the Mangum dolomite. Actually, the Mangum dips beneath the overlying Van Vacter gypsum, the top surface of which has been leveled by erosion and is mostly covered. Down dip the Van Vacter thickens beneath an irregular soil cover; and only near the Dog Creek contact is the gypsum well exposed along intermittent subsequent creeks. Although reasonably good exposures are available north of the Van Vacter ranch, the member's true thickness is difficult to measure as it is mostly dissolved and slumped. The Dog Creek-Van Vacter contact is well exposed at only one locality in the area of this report and there a dip change occurs, accompanied by small faults (Plate I). At other localities, especially in T. 8 N., Rs. 21 and 22 W., the contact appears to be along a zone of flexure.

The four beds that make up the Van Vacter gypsum member are, in ascending order (1) lower gypsum bed, (2) shale bed, (3) dolomite bed, and (4) upper gypsum bed. The lower gypsum is 12 to 15 feet thick and is white, massive, fine-crystalline gypsum. The shale is 3 to 4.5 feet thick, red near the base and greenish near the top, and contains satin spar and selenite. The dolomite bed ranges from 3 to 8 inches in thickness, is gray to brown, medium-crystalline, and locally argillaceous and gypsiferous. A thickness of 18 feet for the upper gypsum bed was measured near the junction of Boggy Creek with its western tributary. No Dog Creek shale is present here over the eroded gypsum bed so the section is incomplete. No locality was found where the base of this bed and the base of the overlying Dog Creek shale are close together and well exposed. It is therefore believed that the thickness of this upper bed across the area of this report is at least 18 feet and may be as much as 25 feet. This upper bed may contain layers of shale, as it does at section 1 (Plate II) in northwestern Greer County, but owing to slumping and poor exposures they are not apparent. Thickness of the Van Vacter gypsum increases westward. In measured section I (NE¼ sec. 29, T. 7 N., R. 24 W.) the Van Vacter is 51 feet thick; and near the Texas line southwest of Erick, McLaughlin (1955, personal communication) measured 80 feet of gypsum between the Mangum dolomite and the Dog Creek shale.

Stratigraphic relations. The Blaine formation is conformable with the underlying Flowerpot shale and with the overlying Dog Creek shale. Plate II suggests that shale in the lower part of the Dog Creek grades westward into gypsum, as discussed in more detail under the heading Dog Creek.

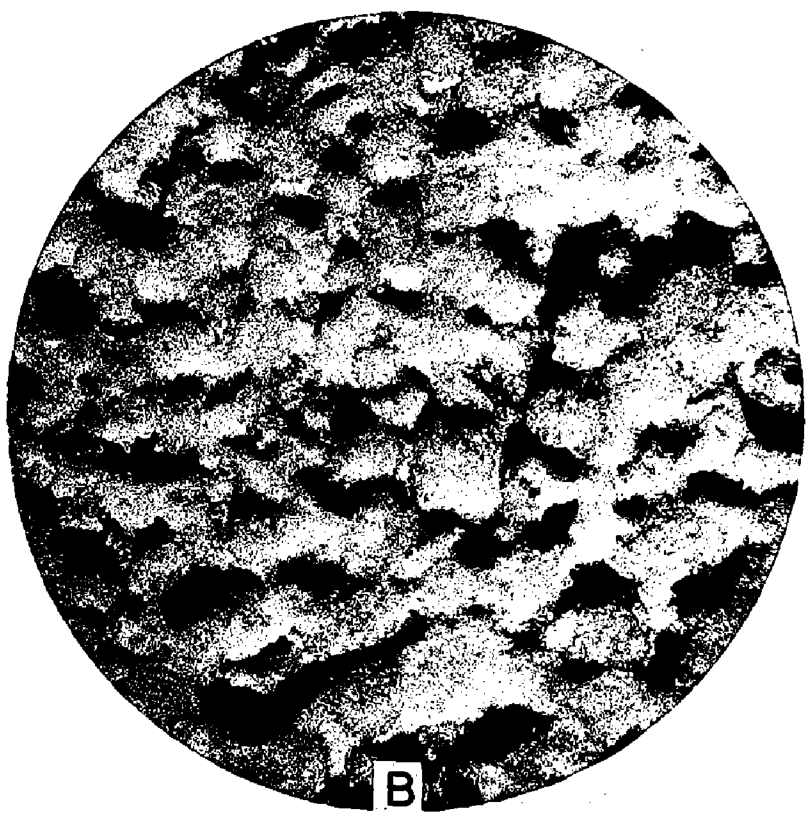
Dog Creek Shale

History of nomenclature. The Dog Creek shale was named and originally described by Cragin (1896, p. 39). The type locality is at Dog Creek, in western Barber County, Kansas. Cragin described it as being about 30 feet thick, consisting of dull red shales, laminated in the basal part, and containing one or more dolomite beds in the upper part. He noted that the coloring of the Dog Creek shales resembles more closely that of the shales of the underlying strata than that of the overlying strata. Cragin placed the Dog Creek stratigraphically below the Red Bluff (later Whitehorse group) and above the Cave Creek gypsums (later Blaine formation). Although originally named the "Dog Creek shales", the plural form is no longer used.

In the Carter area the beds comprising the Dog Creek shale were originally placed in the lower part of the Quartermaster formation by Gould (1902, p. 57) and described as follows: "In the lower part of the formation the rocks are chiefly shales, typically red, but sometimes containing greenish bands and layers." Sawyer (1924, p. 312) correlated this shale unit with the Dog Creek of northwestern Oklahoma. Gould, Gouin, Sawyer, Becker, and Green lated used this classification.

As classified for this report, the Dog Creek shale overlies the Van Vacter gypsum member of the Blaine formation and underlies the Marlow formation of the Whitehorse group.

Distribution. The Dog Creek crops out in a narrow band ranging in width from 100 yards to half a mile, and strikes in a west to northwestward direction (Plate I). It typically forms a valley between the Blaine cuesta to the south and the Whitehorse cuesta to the north. Thin dolomites locally form small cuestas and hogbacks along the Dog Creek outcrop in T. 8 N., R. 22 W. and in the western part of T. 8 N., R. 21 W. (Plate VIII, A). From the central and eastern part of the latter township to the Crooked Creek fault, bedrock exposures are poor and formation contacts



Mangum Dolomite

A. Block of Mangum dolomite showing calcite vein-filling in joints which on weathering typically produce boxwork pattern. SE¼ NE¼ sec. 12, T. 8 N., R. 20 W.

B. Cut surface of Mangum dolomite, X20, showing oolitic texture.

are partly inferred. By studying road cuts, soil composition, and vegetation, however, the Dog Creek-Whitehorse contact can be placed with a fair degree of accuracy. Just east of the Crooked Creek fault the Dog Creek-Whitehorse contact is well exposed, and lower in the section near the bridge across Crooked Creek, good outcrops of the Dog Creek dolomite can be seen. Eastward from this vicinity one of the dolomites forms a small escarpment which extends eastward to the edge of the map (Plate I).

Character and thickness. Gouin (1927, p. 8) reported a thickness of 90 feet for the Dog Creek in southeastern Beckham County. For the present investigation a thickness of 80 feet was measured in the NW¼ sec. 17, T. 8 N., R. 21 W. (Measured section VII). The Dog Creek is composed of locally gypsiferous red, brown, and green blocky shales and contains many thin interbedded light gray, dense to fine-crystalline dolomites. Thin beds of gray siltstone, fine-grained sandstone, and silty dolomite occur locally. A zone of red, ellipsodial dolomitic concretions, 5 to 10 inches in diameter, occurs at several localities 40 feet above the base of the formation.

Thin dolomite beds are the most conspicuous elements of the Dog Creek shale. As many as 8 dolomite beds are present, ranging in thickness from 1 inch to nearly 2½ feet, but in most of the Carter area they are not sufficiently thick nor are they well enough exposed for mapping except in the southeastern corner, where a bed about 1 foot thick in the lower part of the formation has been mapped (Pdcd of Plate I) for 3 miles. These beds are believed to be lenticular and therefore not to be reliable for long-distance mapping. The fine-grained, even-bedded, gray to greenish-gray character of the dolomite beds, however, is distinctive of the Dog Creek, and this type of dolomite does not ordinarily occur in the underlying Blaine formation.

Several of the dolomite beds exhibit unusual pyramidal forms (Plate VIII, B). Merritt (1936, p. 604-607) has termed such specimens "castellated dolomites", and has described similar forms from the Dog Creek in Major County, Oklahoma. His description of these interesting features is quoted as follows: "The castellated dolomites vary in size from one half inch to five inches along an edge. They are gray on fresh surfaces and a brown gray on weathered planes, the latter color being due to a slight iron oxide coating. The forms are of three types, namely (1) single pyramidal-like forms; (2) pyramidal forms of the first type but aggregated together in groups of two, three or four with the individuals meeting at a common central point; and (3) cube-like forms, many of which exhibit hopper-shaped depressions." Concerning the origin of these structures Merritt states: "The presence of NaCl in some of the specimens and the cube-like forms with hopper depressions indicate that the original mineral was halite. . . . The cube has six hoppers and the filling of these would give rise to six hopper casts all meeting at a common center. By weathering these could be separated into single forms or aggregates of two, three, four or five casts."

Stratigraphic relations. The Dog Creek is conformable with the underlying Blaine formation. Correlations of measured sections shown in Plate II indicate that the lower part of the Dog Creek grades westward into gypsum. On the north side of the Anadarko basin Evans (1931, p. 412-414) found that gypsums in the Blaine formation thicken westward in the subsurface across Ellis County, as does gypsum in the Dog Creek shale. He states: "In this connection it might be said that the Dog Creek formation is very closely allied with the Blaine and farther west may merge with the Blaine to make a very considerable thickness of gypsum. As the Dog Creek is supposed to lose its identity westward and southwestward from northwestern Oklahoma, this seems a logical explanation of what happens to the Dog Creek."

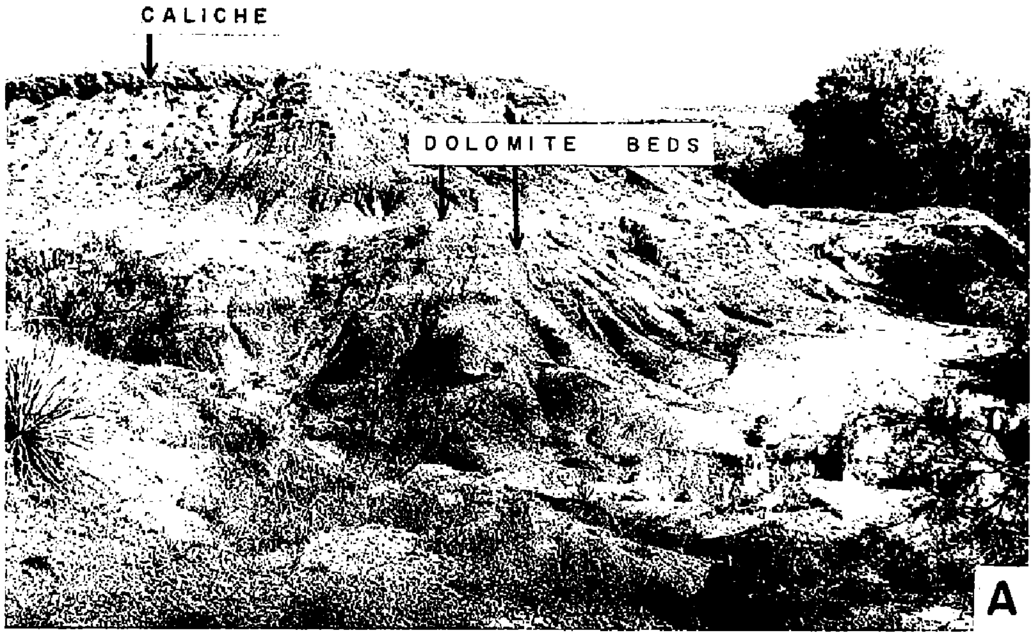
A survey of the many sections of the Flowerpot-Blaine-Dog Creek sequence makes the general lithologic differences between the formations obvious, although it does not demonstrate that the defined contacts in the several sections are synchronous. If the lower part of the Dog Creek shale grades westward into gypsums, as suggested by the cross section (Plate II), the Blaine-Dog Creek contact obviously lies at a high stratigraphic level toward the west. Similarly, the base of the Blaine may be stratigraphically low to the west of the Carter area if the Kiser and Chaney gypsums increase notably in thickness.

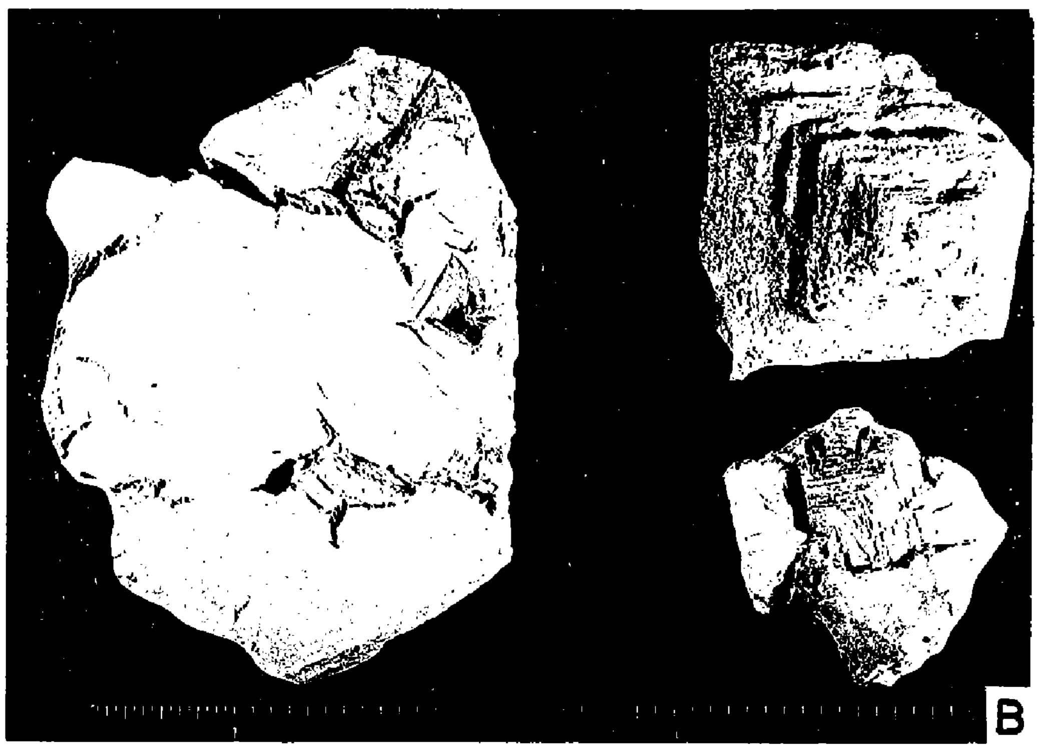
A regional unconformity is believed to exist between the Dog Creek and the overlying Whitehorse group. The principal local evidence of unconformity is the contrast in lithologies above and below the contact and the presence of a thin shale-pebble or clay-gall conglomerate in the basal Whitehorse sandstone.

Whitehorse Group, Undifferentiated

History of nomenclature. Rocks now recognized as the Whitehorse group were first described by Cragin (1896, p. 40) in western Kansas and named the Red Bluff sandstone. As this name was preoccupied, Gould (1905, p. 55) proposed the name Whitehorse sandstone, after Whitehorse Springs in northwestern Woods County, Oklahoma, and gave it member standing within his Woodward formation. Reeves (1921, p. 47) and Clapp (1921, p. 156-164) described the Whitehorse in the Cement area of Caddo County, Oklahoma. In 1924 Gould (p. 335-337) and Sawyer (p. 312-321) described the Whitehorse regionally, omitting the name Woodward and regarding the Whitehorse as a formation.

Since 1924 there has been much discussion about stratigraphy and nomenclature of the Whitehorse sandstone, as shown by the papers of Gould, 1926, p. 152; Gould and Lewis, 1926, p. 9; Gould and Willis, 1927, p. 431-442; Becker, 1927, p. 11; Sawyer, 1929, p. 11; Becker, 1930, p. 111; Evans, 1931, p. 405-439; Roth, 1937, p. 445-447; Green, 1937, p. 1525-1533 and Schweer, 1937, p. 1553. The present status is expressed





Dog Creek Shale and Castellated Dolomite

A. Outcrop of variegated shale and thin dolomite strata in upper part of Dog Creek formation, SE¼ NE¼ sec. 17, T. 8 N., R. 21 W.

B. Castellated dolomite, showing casts of hopper-shaped salt (halite) crystals. From upper dolomite bed illustrated in A, above. Scale is in inches.

by Davis (1955, p. 62), who used the term Whitehorse as a group name ". . . applied to all Permian strata above the El Reno group and below the Cloud Chief formation. The group is divided into two formations: the Marlow formation at the bottom and the Rush Springs sandstone at the top."

The boundaries of the Whitehorse as used in this report are the same as those of Davis. Because of poor outcrops across most of the area, no attempt was made to differentiate the Rush Springs and the Marlow formations.

Distribution. The Whitehorse group is exposed across all the north side of the area of this report, striking in a general west by northwest direction. The best outcrops are along the creeks and gullies in the northwestern part of the area (Plate I). Elsewhere the outcrop is covered with loose buff to red sandy soil.

Character and thickness. Despite the poor exposures and the small area of outcrop, a section of the Whitehorse group was measured across parts of sec. 12, T. 8 N., R. 22 W. and sec. 6, T. 8 N., R. 21 W., giving a thickness of 387 feet (measured section XVIII). Dip and strike control was not fully reliable and this measurement may be as much at 10 percent in error.

The best outcrops occur in the lower part of the group, probably because it is better indurated and more gypsiferous than the overlying friable sandstone. The lower 30 to 40 feet, above the gray basal sandstone, is typically a red to pink, massive, very fine-grained, well sorted sandstone, silty and gypsiferous in part. The next 80 feet is composed of red and pink, shaly, silty, very fine-grained sandstone. It contains many irregular, lenticular indurated ledges of red sandstone with a tight dense gypsiferous cement. Many of these ledge exhibit highly contorted laminae, which indicate penecontemporaneous slumping. Parts of this sequence consist of slabby, gypsiferous silty sandstones, with numerous satin spar veins. This lower 120 feet probably correlates with the Marlow formation, as in its type area in Stephens County the Marlow is quite gypsiferous and even-bedded, and contains ledges of hard gypsiferous sandstone

The upper 267 feet is dominantly a pink, red, massive, quite friable, shaly and silty in part, very fine- to fine-grained sandstone. Some cross-bedding is present. Several hard red gypsiferous sandstone ledges occur near the top, 40 feet beneath the massive white gypsum 5 to 10 feet thick that marks the base of the Cloud Chief formation.

Just north of the area of this report a brownish oolitic dolomite approximately four inches thick crops out near the section line in a road cut along the east side of sec. 19, T. 8 N., R. 20 W. This dolomite lies within the Whitehorse group, but its exact stratigraphic position and lateral extent are undetermined.

The base of the Whitehorse is characterized by two or more feet of light gray, well sorted, very fine-grained, porous, poorly indurated quartz sandstone consisting of subrounded and frosted grains. A few very fine, frosted, well-rounded red quartz grains are scattered throughout. Scattered black sand-sized particles occur and are considered to be small iron concretions.

A thin, irregular, sandy, red shale pebble conglomerate is present above the gray basal sandstone along the east bank of the easternmost creek in sec. 17, T. 8 N., R. 21 W. Above the conglomerate are several thin streaks of orange shale associated with interbedded sandstone exhibiting small ripple marks and cross-bedding.

Stratigraphic relations. The Whitehorse lies unconformably upon the Dog Creek shale. At the head of the Anadarko basin it onlaps the Chickasha formation, cutting out the upper part of the El Reno group.

Quaternary System

Terrace deposits and alluvium cover the Permian sediments in much of the area south of North Fork of Red River, and occur as scattered deposits in the area north of the river. The alluvium is silt, sand, and clay that is being transported and deposited by North Fork and by its larger tributaries.

South of North Fork, and near it on the north side, the terrace deposits are composed by light-colored unconsolidated sand, locally containing quartz and quartzite gravels. Near Cedartop Butte these deposits are somewhat consolidated and are slightly cemented by calcium carbonate.

The terrace deposits along Crooked Creek and capping the ridge in sec. 35 and 36, T. 8 N., R. 20 W. are gray, loamy, and fine-grained, and probably originated by reworking of the Whitehorse sandstone.

Several terrace levels appear as faint remnants partly obscured by wind-blown sand. The top of the highest level is at least 100 feet above the present stream bed. The various levels probably represent stages of river flow during the Pleistocene epoch.

Structural Geology

Regional Setting

A few miles south of the area of this report the Precambrian granitic rocks of the Wichita Moutains rise above the surrounding Permian red beds. The mountain system trends north approximately 50° west and passes into the Texas panhandle where it is covered by Permian sediments.

On the northeast flank of the mountains in southwestern Oklahoma, the surface of the granite is buried at comparatively shallow depths in a belt about 9 miles wide. According to Tanner (1954, p. 6) this buried granite surface is marked by at least two rather flat wave-cut erosion surfaces, one above the other. The lower surface is in the northern part of the belt and is about 500 feet above sea level, whereas the upper surface is near the mountains and is about 1,000 feet above sea level. Elevation of the surface Permian rocks is about 1,750 feet.

These surfaces, cut by late Pennsylvanian and early Permian seas, are covered with Pontotoc "granite wash" and Permian shales and evaporites. Permian strata which overlie the granite platform dip northward at angles generally less than one degree, and at many places they appear to be virtually horizontal.

Paralleling the buried and exposed portions of the Wichita Mountains on the north is a large syncline, named the Anadarko basin by Gould (1924, p. 324). As a result of deep drilling and seismic exploration, it is known that this basin is bounded on the south, near the deepest part, by high angle faults and possibly by thrust faults (Tulsa Geol. Society, 1937, p. 339). Along the uplifted south side of the faults the Paleozoic rocks have been stripped away, exposing the Precambrian granite. North of the fault zone the granite basement may be as deep as 30,000 feet.

The Beckham County fault, described by Gouin (1927, p. 11-12) as a normal fault trending about 14° north of west, has its eastern terminus near the bend of North Fork in sec. 12, T. 8 N., R. 23 W. The north side is downthrown, with a displacement of 300 to 500 feet. Possibly this fault coincides with the flexure zone in the Carter area described below.

Local Structural Features

Northeast Moravia dome. A study of formation tops in drilled wells reveals a domal structure northeast of Moravia, the apex of which appears to be near sec. 25, T. 8 N., R. 22 W., and sec. 30, T. 8 N., R. 21 W. On the surface this feature is suggested by strike and dip changes in the Blaine formation, which crops out along the north flank of the structure.

Inliers along Crooked Creek. Two small inliers which expose the shale beneath the basal Collingsworth dolomite are in secs. 31 and 32, T. 8 N., R. 20 W. (Plate I). About 400 yards southeast of the inliers the Cedartop gypsum dips eastward at a greater angle than the creek gradient. There is a possibility that west of these inliers, under the soil cover, the Blaine dips slightly west of north. If this is true a small northwestward-plunging anticline trends through these inliers.

Flexure zone. A rather narrow belt, in which the strata are characterized by steeper dips than those in adjoining areas, as well as by local faulting, extends across the Carter area and is referred to as a "flexure zone". Across T. 8 N., Rs. 21 and 22 W., this zone follows the Dog Creek outcrop (Plate I). In the NE¼ T. 7 N., R. 20 W., the flexure is marked by the Mangum dolomite cuesta. Small step faults with about one foot displacement are exposed in the NW¼ sec. 17, T. 8 N., R. 21 W. A displacement of at least 30 feet is indicated in the SE¼ sec. 17. Small faults probably occur across sec. 11, T. 8 N., R. 22 W. The possibility that this zone of steeper dips and faulting results from extensive solution and collapse in the underlying Blaine gypsum is considered and rejected as unlikely.

A study of granite tops reported from oil wells in this area indicates that this flexure zone may lie along the edge of the granite "platform". In the SW¼ sec. 12, T. 8 N., R. 22 W., near the flexure zone, granite was reached at 2,628 feet. Less than two miles to the north a well reached a depth of 10,500 feet in the Viola limestone. If the flexure zone does overlie the edge of the granite, then it overlies a complex fault zone, north of which the sediments of the Anadarko basin subsided, while to the south Precambrian granites were uplifted.

Any movement along this buried fault system should cause some folding and faulting in the Permian above the fault zone. Differential compaction between the basin sediments and the solid granite should add to the dip along the flexure zone. It is quite possible that this zone links up with the Beckham County fault which Gouin (1927, p. 11) projected to sec. 12, T. 8 N., R. 23 W.

Crooked Creek fault. The Crooked Creek fault is named after the creek of the same name which flows along the fault trace in sec. 4, T. 7 N., R. 20 W. This fault strikes northward, cutting obliquely across and offsetting the Flowerpot, Blaine, and Dog Creek formations and the Whitehorse group. Displacement is estimated to be about 100 to 200 feet.

Jointing. The following joint directions predominate: north 42° east, north 45° west, and north-south. Less prominent directions are due east-west, and north 13° west. These are averaged directions, observed on aerial photographs and in the field.

Economic Geology

Mineral resources of the Carter area include petroleum and natural gas, ground water, sand and gravel, shale, and gypsum. Petroleum is produced in small quantities and ground-water is used locally, but the other mineral resources are undeveloped. The outstanding resource for potential development is high-purity gypsum, available in enormous quantities from four thick beds in the Blaine formation. This gypsum offers promise of establishing a major industry in the region.

Gypsum

From general considerations of the Blaine gypsum in the Carter area, as discussed in preceding sections of this report, it appeared probable that large reserves of gypsum are available for commercial exploitation. In this chapter the economic aspects are investigated through chemical analyses, physical properties, topographic expression, facility of quarrying, and probable character underground. As a result of these investigations it is here concluded that the gypsum beds, having a gross total thickness of 88 feet, could be worked by open pit quarry methods over at least 7,500 acres or about 12 square miles. Average composition is 96.86 percent theoretically pure gypsum, $CaSO_4.2H_2O$. The gypsum beds are white and sufficiently pure to be used for the manufacture of gypsum products such as plasters, wallboard, and tile. The deposits are accessible to the Missouri, Kansas and Texas Railroad, which crosses the belt of outcrop in the western part of the area.

The four gypsum beds of the Blaine formation lie virtually flat and range in thickness from 10 to 35 feet. They are separated by shales 7 to 19 feet thick, so that the beds could be worked in open cuts or in stair-step benches after removal of shale overburden. Average workable thickness of each of the four beds is about 13 feet, and workable reserves of easily accessible gypsum in the Carter area are calculated to be approximately 375,000,000 tons.

As there are no quarries in the area and no drill-hole information is available, these estimates are based on outcrop observations and on the general relation, established elsewhere, that the Blaine gypsum beds grade into anhydrite where covered by more than 30 feet of shale overburden. Anhydrite reserves to a depth of 130 feet, calculated on this general relation, are estimated to be 1,140,000,000 tons, or three times greater than the gypsum reserves given above.

Chemical composition. Seven chemical analyses show the gypsum beds in the Blaine formation of the Carter area to be essentially the same in chemical composition. They are uniformly of high purity and are fully suitable for calcining to make plasters, wallboard, and tile, and for use as a soil conditioner or as a retarder in manufacturing portland cement. The color is generally white or light gray, so that the calcined products likewise would be white and therefore competitive with the best grades of commercial gypsum products.

Chemical analyses were made from channel samples cut with a pick from each of the four gypsum beds at localities of completely exposed outcrop. Each inch of the full thickness of an outcropping bed was taken and made into a composite sample, fully representative of the gypsum at the sampled locality. A geographic spread was obtained by sampling in the western part of the area, near the Van Vacter ranch house, and by sampling in the eastern part, near Cedartop Butte (Plate I). Chemical analyses of these samples shown in Table I include two each of the Haystack, Cedartop, and Van Vacter gypsums, and one of the Collingsworth gypsum.

The theoretical gypsum content in the seven analyzed samples ranges from 95.39 to 97.83 percent and averages 96.86 percent. The remaining percentage consists of anhydrite, calcite, halite, and magnesite, together with SiO_2 and Al_2O_3 that are present in the form of silt and clay. In the amounts shown these impurities are not deleterious in gypsum-manufacturing processes.

Anhydrite is the most abundant impurity in most samples analyzed, ranging from 0.58 to 2.35 percent and averaging 1.46 percent. Except at two localities in the mapped area, anhydrite is so inconspicuous and so disseminated in the gypsum beds that it cannot be observed even with a hand lens. This anhydrite probably represents the last traces remaining from original anhydrite beds that, through hydration, have been converted into gypsum.

Calcite, $CaCO_3$, is the next most abundant impurity. It is absent in one sample but in all others analyzed it ranges from 0.21 to 1.59 percent and averages 0.67 percent. Magnesite, $MgCO_3$, averages 0.03 percent in the Haystack, Cedartop, and Collingsworth gypsums, and 0.50 percent in the Van Vacter gypsum.

Water-soluble common salt, the mineral halite, averages 0.27 percent in the seven samples analyzed. It is a common constituent in evaporite beds such as gypsum and anhydrite, having been introduced from sea water in the original site of deposition.

All the gypsum beds of the Blaine formation in the Carter area are low in clay and silt impurities. Alumina (Al_2O_3) and silica (SiO_2) together range from 0.18 to 0.78 and average 0.52 percent. Separation of the gypsum deposits from underlying and overlying shale beds is sharply defined, and thus little shaly material is present in the gypsum. The low content of clastic impurities is indeed remarkable, and contributes notably to the chemical purity of the gypsum beds.

Reserves. Areal distribution of workable gypsum beds in the Carter area is shown in Figure 5. These beds lie in a northwestward-trending belt that extends for 12 miles through T. 8 N., Rs. 21 and 22 W., southeastern Beckham County. Eastward from the area of Figure 5 the gypsum beds probably are too thin to yield large tonnage, and westward they are covered by alluvium of North Fork.

TABLE I

CHEMICAL ANALYSES OF GYPSUM, ANHYDRITE, AND SHALE FROM THE BLAINE FORMATION

	GYPSUM							ANHYDRITE
Member	Haystack	Haystack	Cedartop	Cedartop	Collingsworth	Van Vacter	Van Vacter	Cedartop
Laboratory number	10183	10186	10184	10187	10185	10189	10190	10191
Sample description	White massive finely crystalline gypsum	White very finely crystalline gypsum	White, gray, and pink massive gypsum	White, pink and pale yellow massive gypsum	White, gray, and pink massive granular gypsum	White to pink massive granular gypsum	White to pink massive granular gypsum	Gray coarse-crystalline massive anhydrite lens in middle of Cedartop gypsum
Location	NW¼ NW¼ NW¼ 23-8N-22W	SE¼ SE¼ SE¼ 23-8N-21W	NW¼ NW¼ NW¼ 23-8N-22W	SE¼ SE¼ SE¼ 35-8N-21W	SW¼ SW¼ SE¼ 14-8N-22W	NW¼ NE¼ SW¼ 11-8N-22W	NW¼ NW¼ SW¼ 11-8N-22W	SE¼ NW¼ NW¼ 23-8N-22W
Thickness of channel sample (feet)	25	18	18	10	22	Lower 15 feet	Upper 16 feet	2
Analyst	T. E. Hamm	T. E. Hamm	T. E. Hamm	T. E. Hamm	T. E. Hamm	A. L. Burwell	A. L. Burwell	T. E. Hamm
SiO_2	0.05	0.05	0.15	0.24	0.03	0.12	0.12	0.27
Al_2O_3	0.46	0.56	0.61	0.54	0.61	0.06	0.07	0.04
Fe_2O_3	0.05	0.20	0.07	0.18	0.10	0.03	0.02	0.21
CaO	32.63	32.81	32.85	33.14	32.80	32.83	32.70	37.74
MgO	0.01	0.04	0.01	0.01	0.01	0.25	0.23	1.14
CO_2	0.10	0.36	0.62	0.70	0.18	0.27	0.41	0.27
SO_3	46.28	45.73	45.78	45.11	45.88	46.86	46.74	53.95
Free H_2O	0.02	0.03	0.02	0.02	0.01	0.02	0.02	0.00
Combined H_2O	20.42	20.31	20.15	19.95	20.46	20.23	20.32	6.85
NaCl	0.38	0.35	0.28	0.35	0.38	0.08	0.08	0.06
Total	100.40	100.44	100.54	100.24	100.46	100.75	100.71	100.53
	Calculated Mineral Components							
Gypsum, $CaSO_4 \cdot 2H_2O$	97.64	97.12	96.35	95.39	97.83	96.67	97.10	32.75
Anhydrite, $CaSO_4$	1.41	0.90	1.58	1.21	0.58	2.35	2.21	65.77
Calcite, $CaCO_3$	0.21	0.73	1.39	1.59	0.39	---	0.36	---
Magnesite, $MgCO_3$	0.02	0.08	0.02	0.02	0.02	0.52	0.48	0.52
Halite, NaCl	0.38	0.35	0.28	0.35	0.38	0.08	0.08	0.06

	SHALE		
Stratigraphic position	Above Collingsworth gypsum and below Mangum dolomite	Above Haystack gypsum and below Cedartop gypsum	Above Cedartop gypsum and below Collingsworth gypsum
Laboratory number	10192	10193	10194
Sample description	Silty maroon and pale green gypsiferous shale	Silty maroon and gray-green gypsiferous shale	Silty maroon and green gypsiferous shale
Location	SE¼ SE¼ SW¼ 13-8N-22W	SW¼ SE¼ SW¼ 13-8N-22W	SE¼ SE¼ SW¼ 13-8N-22W
Thickness of channel sample (feet)	19	11	7.5
Analyst	T. E. Hamm	T. E. Hamm	R. O. Slate and T. E. Hamm
SiO_2	51.96	47.34	47.96
Al_2O_3	13.80	15.49	13.97
Fe_2O_3	4.95	5.40	5.30
MnO_2	0.04	0.04	0.04
TiO_2	0.46	0.47	0.50
P_2O_5	---	---	0.08
CaO	5.84	6.29	9.45
MgO	5.22	5.13	3.12
K_2O	2.73	2.94	2.95
Na_2O	0.81	1.34	1.10
CO_2	2.29	1.62	5.89
SO_2	3.55	4.35	2.09
H_2O at 100° C	3.93	4.96	3.87
H_2O combined	4.98	4.71	3.80
Total	100.56	100.08	100.12
Calculated gypsum / Calculated $CaCO_3$	7.63	9.35	4.50
$CaSO_4 \cdot 2H_2O$	5.21	3.68	13.40

Three belts of gypsum are indicated: (c) Collingsworth, (b) Cedartop and Haystack, and (c) Van Vacter. In each belt the shale overburden averages about 10 feet in thickness and ranges from less than 1 foot to a maximum of 30 feet. Calculated reserves of gypsum over the 7,500 acres considered workable are 375,000,000 short tons.

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.

Collingsworth gypsum. The Collingsworth gypsum, owing to the topographic position of its outcrop, has the greatest workable area and the largest reserves of all the gypsum beds of the Blaine formation in the Carter area. It covers 4,000 acres in a sinuous belt about 0.5 mile wide that extends entirely across the area. This gypsum bed is consistently 19-22 feet thick and as shown in Table I it is of high chemical purity, containing 97.83 percent theoretical gypsum. At one locality in the NE¼ NW¼ SE¼ sec. 17, T. 8 N., R. 21 W., deep in a gully exposure, the Collingsworth consists of coarsely crystallized anhydrite. Here the bed has not been exposed long enough for hydration to gypsum. At all other exposures the Collinsgworth is medium-grained or coarse-crystalline white gypsum, and this is the type of rock expectable within the boundaries indicated in Figure 5.

Workable thickness of the Collingsworth gypsum ranges from 5 to 22 feet, the thinnest part being at the southern outcrop edge where the uppermost beds have been eroded. The full thickness could be worked in the northern two-thirds of the belt where overlying shale has protected the gypsum from erosion. Plate V illustrates this general outcrop character of the tapering eroded margin and preservation of the full thickness under the overlying shale, which is capped by Mangum dolomite.

As the average workable thickness of the Collingsworth gypsum is 15 feet and the total area is 4,000 acres, its expectable reserve is 180,000,000 tons. Overburden ranges in thickness from about 1 foot to 30 feet.

Cedartop and Haystack gypsums. For the purpose of estimating reserves the Cedartop and Haystack gypsum beds are here considered a unit, because they crop out together in the bluff face and because both probably grade into anhydrite within a short horizontal distance downdip from the outcrop.

The probable area in which these gypsums could be worked is shown in Figure 5 as a belt curving southward around promontories and northward into stream valleys. It lies immediately south of the Collingsworth belt and in most places it is 500-1,000 feet wide. The northern limit of the Cedartop-Haystack belt is placed at the outcropping base of the Collingsworth gypsum, on the assumption that anhydrite is present in excessive amounts in the underlying evaporite beds. This boundary, however, is based on past experience elsewhere and has not been confirmed by drilling in the Carter area. It is thus possible that both the Cedartop and Haystack members extend as gypsum well to the north of the indicated boundary, and accordingly the reserves calculated for these beds would be substantially increased.

The Haystack gypsum makes prominent and nearly continuous outcrops in the escarpment along North Fork. It is well exposed in almost all parts of the area as a solid gypsum ledge 18-25 feet thick. At no outcrop in the Carter area has anhydrite been observed in this member. It consists of white gypsum that is partly fine-grained, closely resembling alabaster, and partly medium-crystalline. Light gray subparallel wavy layers are characteristic, particularly in the lower part (Plate VI, A). Two analyses of the Haystack show its average theoretical gypsum content to be 97.38 percent.

Above the Haystack member, and separated from it by 14 feet of shale, is the Cedartop member. Although seen at most outcrops as a bed of white pure gypsum, the Cedartop contains in its middle part a 26-inch bed of anhydrite (Plate V, B) that extends as a lens for about 0.5 mile in secs. 14 and 23, T. 8 N., R. 22 W. This anhydrite lens disappears westward beyond Oklahoma Highway 34 and the M-K-T tracks but reappears at numerous localities in southwestern Beckham County, thus indicating discontinuous though considerable lateral extent. The discovery of anhydrite in the Cedartop gypsum, in outcropping bluff faces where weathering and hydration are pronounced, is a contributing reason for precaution in estimating gypsum reserves.

The Cedartop gypsum, like the Haystack and Collingsworth, is white virtually pure gypsum. From two analyses the average theoretical gypsum content is calculated to be 95.87 percent. In thickness the bed ranges from 10 to 19 feet and averages 14 feet.

Over the area where the Haystack and Cedartop members are considered to be workable gypsum, the full thickness of neither bed could be quarried. Erosion has so stripped away the upper part of each bed that the average workable thickness is 12 feet for the Haystack and 10 feet for the Cedartop. If worked in benches beginning with the upper bed, shale overburden 1 to 7 feet in thickness must be stripped to expose the Cedartop; then as much as 14 feet of shale must be removed to expose the Haystack. The total workable thickness of gypsum in the two beds is 22 feet and the area covered by them is 1,820 acres, yielding an estimated reserve of 120,000,000 tons.

Conceivably the Haystack could be mined by underground room-and-pillar methods, provided that the bed extends into the hills as gypsum rather than as anhydrite. Near the railroad, in secs. 13, 14, 23, and 24, T. 8 N., R. 22 W., the member has an average thickness of 23 feet, which would allow a 20-foot working face under a gypsum roof 3 feet thick. For reasons considered above, however, underground reserves of gypsum in the Haystack are not estimated in this report.

Van Vacter gypsum. Being the uppermost and thickest gypsum bed in the Carter area, the Van Vacter in some respects has the greatest economic attraction of all the gypsum members of the Blaine formation. Its maximum thickness is 35 feet and the average theoretical gypsum content is 96.89 percent. The most abundant impurity is anhydrite, which averages 2.28 percent; but the combined total of silica, alumina, and iron oxide is the lowest in the area, averaging only 0.21 percent.

The member crops out in an east-trending belt of low rolling hills and plains that lies above and northward from the Blaine escarpment on North Fork. For about 4.5 miles in the central part of the belt (Figure 5) the Van Vacter has an outcrop one-half mile wide, within which the only overburden is a thin covering of soil. Here the average workable thickness is 15 feet, ranging from approximately 5 feet at the southern edge to 35 feet at the northern edge, where the Dog Creek shale, owing to its steep local dip and its outcrop in the face of an escarpment, in a short distance covers the gypsum with excessive overburden. The workable outcrop covers 1,750 acres and the gypsum reserves are estimated to be 75,000,000 tons.

Gypsum could easily be mined in surface pits, first removing soil about 5 feet thick from the eroded gypsum surface. Probably this surface is highly irregular, as ground water has locally dissolved the gypsum to form caves, which later develop into collapsed sinks.

Van Vacter outcrops eastward from sec. 17, T. 8 N., R. 21 W. are so uncommon and widely scattered that most of the member is believed to have graded into shale, and accordingly no reserves are estimated for that area.

Anhydrite in gypsum members of the Blaine formation. The occurrence of anhydrite, $CaSO_4$, in gypsum beds of the Blaine formaton is well known at many places in western Oklahoma. In Blaine County the formation contains three thick evaporite beds, each of which is quarried for commercial gypsum. The quarries have been actively operated for 60 years, and during this time much has been learned about the occurrence of gypsum and the relation of gypsum to anhydrite, which is not wanted for making plasters because, being anhydrous, it can not be calcined. Anhydrite therefore is considered an impurity and is avoided wherever possible.

Through quarrying operations in Blaine County it has been established that outcropping beds of gypsum grade into anhydrite where they are covered by 30 feet or more of shale overburden, this line marking the economic limit for gypsum quarrying. From these field relations and from supporting study of thin sections, it is believed that anhydrite was the original deposit and that gypsum has been derived from it by hydration during surface weathering.

In the Carter area the gypsum beds have not been quarried, but the gypsums themselves and the topographic expression of the outcropping beds appear to be identical with those of Blaine County. Moreover, the gradation of gypsum into massive anhydrite has been observed in the Collingsworth member in sec. 17, T. 8 N., R. 21 W. of the Carter area, where the entire thickness of the member, as exposed at the bottom of a ravine under approximately 30 feet of shale and soil overburden, is made up of coarsely crystallized, rough-weathering anhydrite. Other similar occurrences in the Haystack and Cedartop gypsums have been observed west of the Carter area, in southwestern Beckham County, and therefore it is considered probable that anhydrite is widely distributed and constitutes most of the material of the evaporite members of the Blaine formation where they are present back from the outcrop under thick shale cover.

The inferred relations as applied to the Carter area are illustrated in the idealized section of Figure 5, which shows that the Cedartop and Haystack members have comparatively small reserves of workable gypsum yet large reserves of anhydrite, whereas the Van Vacter and Collingsworth members have large reserves of gypsum and comparatively small reserves of anhydrite. This ratio depends primarily on topographic position and resulting availability of the evaporite beds to surface weathering and hydration.

Total reserves of anhydrite in the Carter area are believed to be enormous. The Cedartop and Haystack members have average thicknesses respectively of 15 and 17 feet and could be worked by surface or underground methods along a width of at least 1 mile. Rock anhydrite weighs about 175 pounds per cubic foot or 3,500 tons per acre-foot. Hence in the 12-mile length shown in Figure 5 the reserves of anhydrite in the Cedartop and Haystack are 860,000,000 tons. Along the same length, inferred anhydrite in the Collinsgworth member has an average thickness of 21 feet and a width of one-half mile, and an estimated reserve of 280,000,000 tons. Total accessible anhydrite reserves in the Carter area thus are 1,140,000,000 tons.

The outcropping anhydrite beds are low in impurities and generally are partly hydrated to gypsum. Chemical analysis of the 26-inch bed from the Cedartop (laboratory number 10191, Table I) shows approximately 66 percent anhydrite and 33 percent gypsum; and an analysis of a 7-foot bed from Blaine County showed nearly 81 percent anhydrite and 18.5 percent gypsum. Underground the anydrite probably is lacking in gypsum and would be suitable for the uses outlined in the next section.

Uses of gypsum and anhydrite. Gypsum is one of the most widely used nonmetallic mineral commodities, and in 1956 slightly more than 14.6 million short tons was produced domestically and imported for consumption or processing in the United States (Larson and Jensen, 1957). This was a one percent net increase in tonnage over 1955, a 27.5 percent increase over 1953, and 113 percent more than the 1944-1948 average. Average value of crude gypsum at the mine in the United States in 1953 was $2.79 per short ton (Minerals Yearbook, 1953, p. 529).

The calcining of gypsum to make industrial and building plasters, lath and wallboard, and special cements accounted for most of the tonnage, about 77 percent in 1956. Approximately three-fourths of the remaining 23 percent was used as a retarder in the manufacture of portland cement, and the rest was used as a soil conditioner or for fillers. A summary of the principal uses, together with the amount sold or used in the United States in 1956, is given in Table II.

Chemical quality of commercial gypsum deposits ranges widely throughout the world, and no strict specifications are available. Gypsum with a purity of 99 percent or more is most desirable but is virtually unobtainable, as all deposits contain other mineral constitutents. For a soil conditioner, earthy gypsite containing no more than 70 percent gypsum is acceptable locallv; gypsum board products may be made from deposits

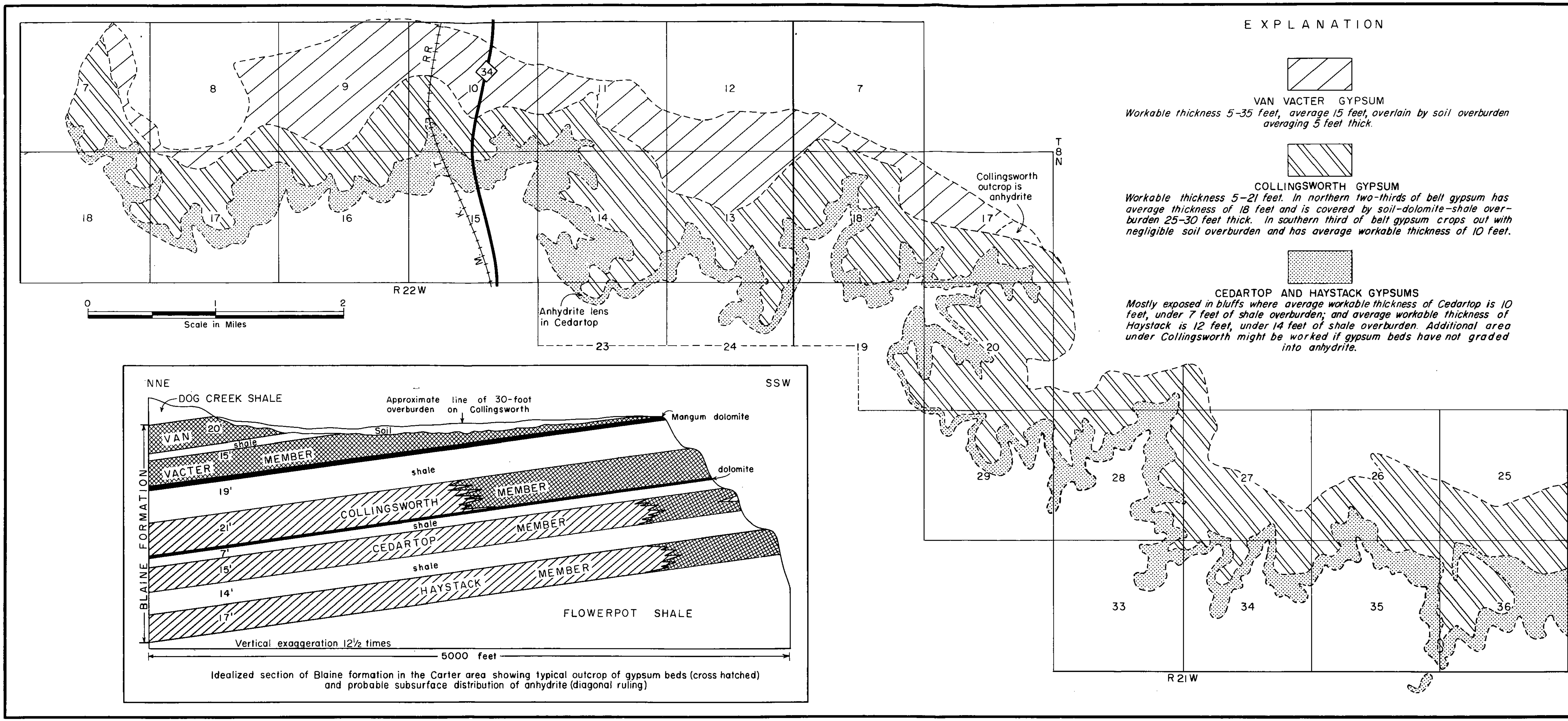


Figure 5. AREAL MAP AND SECTION SHOWING PROBABLE GYPSUM RESERVES IN THE CARTER AREA

containing only 80 percent gypsum; and portland cement retarder has been used from deposits of 90 percent purity. In general, however, deposits containing 90 percent or more gypsum are most sought after, and deposits are considered to be high purity if they contain 95 percent or more gypsum.

TABLE II

GYPSUM AND GYPSUM PRODUCTS IN THE UNITED STATES, 1956
(*U. S. Bureau of Mines, Quarterly Gypsum Report* 108, *March*, 1957)

Crude Gypsum:		
Mined	10,312,784	
Imported	4,346,854	
Apparent supply	14,659,638	
Calcined gypsum produced	8,545,641	
Gypsum products sold or used:		
Uncalcined uses:		
Portland-cement retarder	2,485,491	
Agricultural gypsum	836,305	
Fillers and unclassified	35,481	
Industrial uses:		
Plate-glass and terra-cotta plasters	68,031	
Pottery plasters	51,295	short tons
Dental and orthopedic plasters	10,111	
Industrial molding, art, and casting plasters	91,111	
Other industrial uses	113,561	
Plasters:		
Base-coat	1,566,587	
Sanded and premixed perlite	656,601	
To mixing plants	4,830	
Gauging and molding	153,199	
Prepared finishes	12,863	
Roof-deck plasters	432,139	
Other building plasters	22,248	
Keene's cement	46,918	
Lath	2,647,197	
Wallboard	4,588,906	
Sheathing	139,049	1000 square feet
Laminated board in component board footage	1,249	
Formboard for poured-in-place gypsum roof-deck	53,428	
Tile—partition and other	32,286	

The four gypsum beds in the Blaine formation of the Carter area have an average purity of 96.86 percent and range in purity up to 97.83 percent. As they also are white and not pink or otherwise discolored, it is clear that the deposits would make high-quality plasters and would be suitable for all uses listed in Table II, with the possible exception of certain specialty products that are manufactured in small volume.

POTENTIAL USES

Anhydrite is associated with gypsum in many deposits, because the two minerals are genetically interrelated. It is well known that massive gypsum may be formed in large deposits through hydration of anhydrite, and it is also believed by some that gypsum may be converted through geologic processes into anhydrite. Either mineral can be precipitated directly from sea water. In Oklahoma, California, Nevada, and Nova Scotia, many large commercially worked deposits of gypsum overlie or grade into anhydrite, resulting in the generally accepted belief that anhydrite is the original rock from which the gypsum has been derived. In the working of these deposits, anhydrite is either avoided or sorted and rejected, as there is no large established market for this commodity in the United States.

Two small-tonnage uses of anhydrite have been developed in the United States, for agricultural soil conditioner and for retarder in portland cement. The largest user of agricultural gypsum is California, and where used in California for soil conditioner no distinction between gypsum and anhydrite is recognized by regulatory state agencies (Ver Planck, 1952, p. 97). Anhydrite is used in California also as a retarder for portland cement. Its use as a retarder has been investigated, and from laboratory experiments it is known that 25 to 70 percent anhydrite may be substituted for gypsum in making certain cements (Roller and Halwer, 1937; Hansen and Hunt, 1949).

A possible new use for crude anhydrite is as crushed stone for road construction. The Oklahoma Highway Commission has made field and laboratory tests on a 3-mile section of road in which anhydrite was used, and first results indicated that the road was giving satisfactory service.

Probably the greatest potential use of anhydrite is for chemical raw material. In England it is heated with coke, clay, and siliceous material to make sulfuric acid and portland cement clinker (Anon., 1951; Anon., 1955). This process is not used at present in the United States, apparently because sulfuric acid here is available from native sulfur produced from salt domes in the Gulf Coast region of Texas and Louisiana.

Under favorable economic conditions an integrated sulfuric acid-portland cement industry would appear feasible for the Carter area. Shale for the alumina-silica additive to make portland cement is available in beds 19, 7, and 14 feet thick that are interstratified with the evaporite beds. As these shales would have to be stripped as overburden if the evaporites were worked by open-cut methods, they could be produced at slight cost. Chemical analyses of channel samples of the three shale beds are given in Table I.

Another chemical for which anhydrite is used as raw material is ammonium sulfate, a common fertilizer. In both England and Germany ammonium sulfate is made by reacting ammonia and carbon dioxide with an aqueous suspension of anhydrite. New methods of using anhydrite or gypsum for producing (a) quicklime and hydrogen sulfide by reduction with natural gas, and (b) for producing a fertilizer consisting of ammonium sulfate and calcium carbonate, have been described by Burwell (1955). His experiments were performed on gypsum from Oklahoma deposits.

Other Mineral Resources

Petroleum and natural gas. Petroleum is produced in the Southeast Carter pool, on the north side of the Northeast Moravia dome, and in the vicinity of Lake Creek. Production is obtained from Lower Permian granite wash at depths ranging from 800 to 1,500 feet. Oil accumulation is associated with stratigraphic traps modified by local structure and by the configuration of the granite surface beneath the granite wash.

Southeast Carter was discovered in January, 1954, by Ward No. 1 Van Vacter, SW¼ NW¼ NW¼ sec. 19, T. 8 N., R. 21 W. Three wells produced 2,396 barrels of 39 degree gravity oil in 1955, and cumulative production was 12,314 barrels.

Ground-water. Ground-water is available from several aquifers in the Carter area. Wells in the terrace sands south of North Fork (Plate I) locally yield water for irrigation and, although the water is hard, it is suitable for domestic, stock, and irrigation use. No adequate supply for groundwater is to be expected from the gypsiferous shales of the area, but some water probably can be produced from underground caverns in gypsum members of the Blaine formation. Water is difficult to find in the gypsum because there is no systematic pattern in the development of caverns, and furthermore the water itself is likely to be too highly mineralized for human consumption.

The Whitehorse sandstone crops out along the northern part of the map area and doubtless is an aquifer of gypsiferous water. This sandstone is approximately 385 feet thick, and the upper part of it in particular probably will yield water for domestic use and possibly for irrigation.

Sand and gravel. Sand and gravel for construction have not been produced in the mapped area, but south of North Fork about 35 square miles is covered by terrace sands with which are associated local lenses of gravel. Similar materials have been worked for road sand and gravel elsewhere in the region and probably could be worked in the Carter area.

Shale. The predominant bedrock of the area is red gypsiferous shale, available in large quantity from the Hennessey, Flowerpot, Blaine, and Dog Creek formations. All appear to be approximately the same in composition. From the chemical analyses of the three shale beds in the Blaine formation (Table I) it is inferred that the gypsum content averaging 7.16 percent is too high for shale used in making brick or tile, and the only probable use for such shale is as admixture with gypsum or anhydrite to make portland cement.

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Appendix

MEASURED STRATIGRAPHIC SECTIONS

I. Measured from exposures along unnamed creek about two miles southwest of Plainview, Oklahoma, in the NE¼ sec. 29, T. 7 N., R. 24 W.

	feet
DOG CREEK SHALE (only basal part exposed)	
Red shale, partly covered, and scattered float of gray, fine-crystalline dolomite	3.0
BLAINE FORMATION (125.5 feet thick)	
Van Vacter gypsum member (50.5 feet thick)	
Gypsum, gray, massive, fine-to-coarse crystalline. Interval partly covered; thin shale and dolomite beds may be present. A dolomite 3 inches thick, underlain by 3 feet of partly covered green and red shale, occurs near middle of unit. A gray to light brown, dense to fine-crystalline, gypsiferous dolomite 3 inches thick is at base of unit	33.0
Shale, lower 4 feet red, blocky; upper 6 inches blocky, grayish-green. A 4-inch pink and gray shaly gypsum bed occurs 1 foot below top of unit	4.5
Gypsum, gray to white, massive	13.0
Mangum dolomite member:	
Dolomite, gray to brown, fine- to medium-crystalline, slightly oolitic, hard to soft, honeycombed to massive, calcareous in part	2.0
Unnamed shale:	
Shale, gray-green	2.0
Shale, red, blocky	19.0
Collingsworth gypsum member:	
Gypsum, gray to white, massive, fine- to coarse-crystalline. A thin yellowish to rusty, fine- to medium-crystalline dolomite 3 inches thick occurs at base, and a similar dolomite is 1½ feet above base. A gray coarse-crystalline anhydrite bed occurs near middle of member	9.0
Unnamed shale:	
Shale, red, a few inches of green shale at top	5.0
Cedartop gypsum member:	
Gypsum, white, massive, fine- to coarse-crystalline One foot of red shale is about 1 foot below top of member. A 1- to 3-inch yellowish, rusty, platy, fine- to medium-crystalline dolomitic limestone is at base	12.0
Unnamed shale:	
Shale, red, gypsiferous, greenish at top	7.0
Haystack gypsum member:	
Gypsum, gray to white, massive, hard, most prominent ledge, typically fine-grained. A gray, fine- to medium-crystalline, argillaceous dolomite ½ to 1 inch thick occurs about 8 feet above base	19.0
FLOWERPOT SHALE (upper 35.3 feet exposed)	
Unnamed beds:	
Shale, red, blocky, and gypsiferous. One foot of green shale at top	9.5
Dolomite, yellow, fine- to medium-crystalline	0.3
Shale, red, blocky, gypsiferous	18.0
Kiser member:	
Gypsum, greenish to gray, well-bedded, dense to fine-crystalline	4.5
Unnamed beds:	
Shale, lower 2 feet red, gypsiferous; upper 1 foot green, gypsiferous	3.0
Covered on grassy pasture	

II. Composite section measured in the vicinity of Haystack Butte, sec. 23, T. 7 N., R. 23 W. by McLaughlin (1955).

BLAINE FORMATION (basal 15 feet only)	
Haystack gypsum member:	
Gypsum, white, massive, top possibly eroded on crest of butte	15.0
FLOWERPOT SHALE (161.9 feet thick)	
Unnamed beds:	
Shale, reddish-brown	3.6
Gypsum, white to pink	0.3
Shale, reddish brown	4.0
Gypsum, white	0.3
Shale, reddish-brown	4.0
Gypsum, gray	0.3
Shale, brown	0.7
Dolomite, light buff to yellow	0.4
Shale, green	4.6
Kiser gypsum member:	
Gypsum, green, shaly	2.0
Unnamed beds:	
Shale, reddish-brown	3.5
Gypsum, gray	0.3
Shale, reddish-brown	4.2
Gypsum, gray	0.3
Shale, brown	5.8
Gypsum, gray	0.5
Shale, brown	4.2
Chaney gypsum member:	
Gypsum, well-bedded	1.8
Unnamed beds:	
Shale, brown	1.0
Shale, green	1.0
Shale, brown	1.3
Gypsum, green, shaly	0.3
Shale, green	1.3
Shale, brown	3.0
Dolomite, green, shaly	0.8
Shale, brown	2.2
Shale, brown, gypsiferous	1.4
Gypsum, brown, shaly	0.6
Shale, brown	2.0
Shale, brown, with hard, thin gypsum beds	3.0
Shale, brown	4.3
Gypsum, greenish	0.6
Shale, brown	2.0
Shale, green	3.0
Shale, brown	2.0
Shale, green, gypsiferous	3.0
Shale, reddish	2.0
Gypsum, gray	1.0
Shale, brown	2.0
Dolomite, coarse-crystalline	0.1
Gypsum and green shale	2.0
Shale, green	4.0
Shale, brown	2.0
Shale, green	1.0
Shale, brown	3.0
Shale, green	2.0
Shale, green, gypsiferous	1.0
Shale, brown	3.0

Shale, green	1.0
Shale, brown	3.0
Dolomite, shaly, poor bench former	0.1
Shale, green	2.0
Gypsum, bench former	0.5
Dolomite, brown, thin, hard	0.1
Shale, brown	0.6
Shale, green	0.4
Shale, brown	1.8
Gypsum, brown	0.3
Shale, brown	2.0
Gypsum, thin-bedded	0.5
Shale, green	0.8
Shale, brown	1.0
Gypsum	0.6
Shale, brown	0.2
Shale, green	1.8
Dolomite, brown, with green shale layer	1.0
Shale, green	2.0
Shale, brown	3.5
Shale, green, gypsiferous	1.0
Shale, red, with thin green streaks	12.0
Shale, green, gypsiferous	2.0
Shale, brown	3.0
Gypsum	1.0
Shale, brown	1.0
Shale, green	1.0
Shale, brown	2.0
Shale, green	2.0
Shale, brown, gypsiferous	4.0
Shale, green	1.0
Shale, brown, gpysiferous	4.0
Shale, green, gypsiferous	2.0
Shale, brown	2.0
Shale, green	3.0
Shale, green, highly gypsiferous	1.0
DUNCAN SANDSTONE (2.8 feet thick)	
Sandstone, brown, fine-grained	1.0
Shale, brown	1.0
Sandstone, brown, fine-grained	0.8
HENNESSEY SHALE (only upper 6 feet exposed)	
Shale, brown, impregnated with weathered gypsum and caliche	4.0
Shale, green	2.0

III. Section measured along east side of prominent butte in the SE¼ sec. 36, T. 8 N., R. 23 W.

	feet
FLOWERPOT SHALE (about 9 feet of uppermost beds eroded from top of butte)	
Shale, reddish-brown, capped with 1 inch of red satin spar gypsum	1.0
Shale, green, with thin platy dolomite 1 inch thick at base	0.8
Shale, red	2.0
Shale, green, gypsiferous near top	1.5
Dolomite, buff to brown, rusty, yellowish, platy, laminated	0.5
Shale, green	2.3
Gypsum	0.3
Shale, greenish	0.8
Gypsum	0.3
Shale, reddish-brown	1.0

Kiser gypsum member:	
Gypsum, green-gray, shaly bedded, ledge forming	0.7
Unnamed beds:	
Shale, green	1.7
Shale, reddish-brown	3.0
Shale, green in upper 6 inches; red in lower part, highly gypsiferous, forms small bench	2.0
Shale, red and brown, blocky, impregnated with satin spar gypsum	12.5
Shale, green	1.0
Dolomite; several thin, platy, gray dolomites interbedded with red shale	1.0
Chaney gypsum member:	
Gypsum, white-gray-mottled, massive ledge former	2.0
Unnamed beds:	
Shale, red, with thin green stringers	1.5
Gypsum, white to gray, massive, ledge former	1.0
Shale, red and brown, blocky	8.0
Gypsum, green, white, and mottled. Shaly, poor ledge former	0.5
Shale, red, largely covered	27.5
Gypsum, green, slightly shaly	2.0
Shale, red , with several green shale and thin gypsum streaks	27.2
Dolomite, gray, buff, and light brown; gypsiferous, shaly, with small green malachite nodules along bedding plane	0.3
Shale, green, blocky	3.8
Shale, reddish-brown, blocky	5.5
Dolomite, gray to dark brown, highly contorted, nodular, finely crystalline to dense. Bench former	0.3
Shale, green	3.0
Shale, red	2.0
Gypsum, white, gray, light green, and buff-yellow concretions in red shale; concretions are as much as 1 foot in diameter, and have flattened, ellipsoidal shape	0.8
Shale, reddish-brown, blocky, and gypsiferous	9.0
Lower beds covered	

IV. Section of bluff on north side of North Fork of Red River, three miles south of Carter, Oklahoma, sec. 15, T. 8 N., R. 22 W. (Modified after Gould, 1905).

BLAINE FORMATION (Partial section)

	feet
Mangum dolomite member:	
Dolomite, rough. weathered, sandy, caps the high hills	3.0
Unnamed beds:	
Shale, red and green, gypsiferous	24.0
Collingsworth gypsum member:	
Gypsum, white, massive	22.6
Dolomite, gray, slabby, fine- to medium-crystalline	0.4
Unnamed beds:	
Shale, red and green	6.0
Cedartop gypsum member:	
Gypsum, white, massive; contains a 2-foot bed of gray, coarse-crystalline anhydrite	17.8
Unnamed beds:	
Shale, red and green	15.0
Haystack gypsum member:	
Gypsum, white, massive, with a gray argillaceous gypsiferous dolomite 2 inches thick about 7 feet above base	25.0

FLOWERPOT SHALE	
Unnamed beds:	
Shale, red and green	24.0
Kiser gypsum member:	
Gypsum and gypsiferous shale, greenish, becoming compact locally	5.0
Unnamed beds:	
Shale, red and green, gypsiferous, not measured	

V. Section measured up escarpment on west side of Boggy Creek in the SW¼ sec. 11, T. 8 N., R. 22 W.

BLAINE FORMATION (Partial section)	Feet
Van Vacter gypsum member: (36.5 feet thick)	
Gypsum, gray and white, massive, poorly exposed, partly covered. Erosion has removed the overlying Dog Creek shale and probably part of this gypsum bed	18.0
Dolomite, gray to light, fine- to medium-crystalline, honeycombed and compact in part	0.5
Covered, probably shale	4.0
Gypsum, white, slightly pink in part, compact and fine-crystalline in part	14.0
Mangum dolomite member:	
Dolomite, gray; soft portions are fine-crystalline and oolitic in part, and have poorly preserved pelecypods. Harder portions are medium- to coarse-crystalline and honeycombed	2.0

VI. Section measured at escarpment north of North Fork of Red River in NE¼ sec. 24, T. 8 N., R. 22 W.

BLAINE FORMATION (Partial section)	Feet
Mangum dolomite member:	
Dolomite, gray-blue to brown, honeycombed, fine- to medium-crystalline, oolitic in part, forms ledge and caps escarpment	2.0
Unnamed beds:	
Shale, red, covered in part	11.5
Shale, red, gypsiferous	3.0
Shale, red and green, with several highly gypsiferous beds	3.0
Collingsworth gypsum member:	
Gypsum, white, massive, selentic in upper part, ledge forming. Gray-blue to rusty brown, honeycombed, crystalline dolomite 4 to 6 inches thick is at base, and a similar dolomite occurs about 2½ feet higher	19.5
Unnamed beds:	
Shale, green	0.8
Shale, alternating maroon and blue-green streaks about 1 foot thick	6.2
Cedartop gypsum member:	
Gypsum, white, massive, medium-crystalline in part, ledge forming. A yellowish-brown dolomite 2 inches thick occurs at base	17.5
Unnamed beds:	
Shale, green, with small nodules of white to brown gypsum	1.5
Shale, brick-red	12.0

Haystack gypsum member:

Gypsum, white, massive, compact, fine-crystalline. Has 1-inch dolomite 7 feet above base. Lower 1 foot of member is dark gray	22.0

FLOWERPOT SHALE (Partial section)

Unnamed beds:	
Shale, green, gypsiferous	0.5
Shale, predominantly red, with thin green shale streaks and thin satin spar gypsum veins	20.5
Kiser gypsum member:	
Gypsum, white to light green to dark gray, finely laminated and shaly. Contains green shale streaks at base and near top	3.8
Unnamed beds:	
Shale, green	0.5
Shale, maroon and orange	16.0
Chaney gypsum member:	
Gypsum, green to white, laminated to massive gypsum with green shale streaks	4.0
Unnamed beds:	
Shale, green	0.8
Shale, maroon, with thin green streaks	35.0
Shale, alternating red and green, in beds about 1 foot thick	6.0
Shale, green, with satin spar gypsum	2.0
Shale, red, with thin blue-green streaks and satin spar	3.5
Shale, blue-green	0.5
Shale, reddish-brown	11.0
Lower beds covered	

VII. Section measured approximately north-south across the western half of sec. 17, T. 8 N., R. 21 W.

	Feet
WHITEHORSE GROUP (UNDIFFERENTIATED)	
Sandstone, gray, loose, very fine- to fine-grained. This is the basal sandstone of the Whitehorse group	1.0
DOG CREEK SHALE (80.3 feet thick)	
Covered	27.5
Dolomite, blue-gray, platy, castellated, dense to fine-crystalline, slightly silty. Forms slight ledge	0.3
Shale, green	0.3
Covered, probably red shale	5.0
Dolomite, blue-gray, platy, dense	0.1
Shale, green	1.0
Covered, probably red shale	5.5
Dolomite, gray, platy, dense, forms slight ledge	0.1
Covered, probably red shale	8.0
Dolomite, gray, dense	0.1
Covered, probably red shale	5.5
Shale, green, with two 1-inch slabby, dense, shaly dolomites near middle	2.0
Shale, red, blocky	0.5
Dolomite, light brown to bluish-gray, laminated, dense, slightly vuggy; has many rhomboidal holes and contains thin shale layers. Good ledge former	0.7
Shale, green	1.5
Shale, red	3.0
Shale, green, with ½-inch platy dolomite near base and ½-inch of similar dolomite near top	1.0

Shale, red	2.0
Shale, green	0.5
Shale, red	2.0
Shale, green	0.5
Shale, red	1.0
Shale, green	0.5
Shale, red	1.5
Dolomite, blue-gray, platy, fractured, dense	0.1
Shale, red to brown, blocky	1.5
Siltstone, red, shaly, interstratified with gray-green, fine-grained, unindurated sandstone. Slight ledge former	0.5
Shale, red, blocky	1.5
Siltstone, greenish, shaly	1.0
Shale, green	1.0
Dolomite, green to gray, fractured, dense	0.1
Shale, red, upper 2 inches green	1.0
Shale, red, with satin spar gypsum in the top	1.5
Gypsum, orange, coarse-crystalline, shaly	1.0
Dolomite, gray to gray-green, platy to massive and dense, with irregular thin green shale layers	1.0
BLAINE FORMATION (128.7 feet thick)	
Van Vacter gypsum member: 35.8 feet thick	
Gypsum, gray to white, massive, and fine- to coarse-crystalline. Partly covered and somewhat slumped	20.0
Dolomite, gray to light brown; gritty, sandy texture on weathered surfaces; contains red, dense calcite veins, large vugs; sugary to medium-crystalline in fresh sample; calcitic	0.8
Covered, probably shale	3.0
Gypsum, white, massive, fine-crystalline	12.0
Mangum dolomite member:	
Dolomite, gray to light brown on weathered surfaces, hard, massive to bedded, slightly cross-bedded in part, gray on fresh surfaces, fine-crystalline, vuggy, calcareous. Slumps on talus slopes as honeycombed blocks 5 feet across	2.0
Unnamed beds:	
Shale, red, blocky, with scattered green streaks	16.5
Collingsworth gypsum member:	
Gypsum, white, coarse-crystalline, selenitic at outcrop	18.5
Dolomite, gray to brown to gray-black, gritty on weathered surfaces, fine- to medium-crystalline, selenitic, 2 thin gray shale streaks	0.7
Gypsum, white, with red splotches, massive	2.2
Dolomite, gray, granular appearing, gritty on weathered surfaces, fine-crystalline, calcitic	0.3
Unnamed beds:	
Shale, green	2.0
Shale, red	3.0
Gypsum, green, shaly	0.1
Shale, red	3.0
Cedartop gypsum member:	
Gypsum, white, massive	11.0
Dolomite, brown to rusty yellow, fine-crystalline, calcitic	0.1
Gypsum, white, massive	2.6
Dolomite, brown to rusty yellow, fine-crystalline, calcitic	0.1
Unnamed beds:	
Shale, yellowish green, laminated	3.0
Shale, red	10.0
Haystack gypsum member:	
Gypsum, white, massive, hard, fine-crystalline, with thin gray banding	9.0
Dolomite, gray, soft, granular, medium-crystalline	0.1
Shale, green, laminated	0.1
Gypsum, same as above	8.0
Gypsum, dark gray, fine-crystalline, shaly	0.6
FLOWERPOT SHALE	
Shale, gray-green, laminated, contains satin spar gypsum veins	1.0
Lower beds not measured	

VIII. Section measured across sec. 2, T. 7 N., R. 21 W. in a north by slightly east direction. Exposures were measured along ravines and up the side of Cedartop Butte.

FLOWERPOT SHALE (165 feet thick)

	Feet
Unnamed beds:	
Mostly red shale, poorly exposed beneath Haystack gypsum	24.0
Kiser gypsum member:	
Gypsum, green, hard, ledge forming, massive to well-bedded, gypsiferous	1.5
Unnamed beds:	
Shale, green, with satin spar gypsum	1.0
Shale, red, blocky	8.5
Gypsum, grayish-green, massive, shaly, slight ledge former	1.0
Shale, red, with satin spar gypsum streaks	11.0
Chaney gypsum member:	
Gypsum, white, massive, with thin green streaks. Bottom 3 inches has green shaly gypsum and thin green shale streaks	1.0
Unnamed beds:	
Shale, red, blocky	4.0
Shale, green, thin-bedded	0.5
Shale, predominantly red, soft, blocky, with a few thin green shale streaks and satin spar gypsum veins	21.5
Shale, green and red, thin-bedded. Very gypsiferous	1.0
Shale, red, thin-bedded, with satin spar and selenite	5.5
Shale, red	0.5
Gypsum, white to yellow, brown, flattened, nodular, ellipsoidal concretions like small boulders, 1 to 4 inches in diameter, in red shale	0.5
Shale, red, soft, blocky	5.0
Shale, blue-green, thin- bedded. Shale highly impregnated with thin satin spar gypsum. Slight ledge former	2.0
Shale, blue-green, blocky	2.0
Shale, reddish-brown	5.0
Shale, yellowish-gray to green; thin yellowish selenitic gypsiferous shale zone two inches thick 2 inches below top. Marble-sized rusty concretions	5.5
Shale, grayish-buff to gray-green, with scattered, thin, cross-bedded, very fine-grained dolomitic sandstone containing asymmetrical, small ripple marks and fucoids	5.5
Sandstone, light to dark gray, brown, thinly bedded to massive, highly-cross-bedded, silty, very fine-grained and calcareous. Forms ledges. Contains poorly preserved dark brown, shiny, probably phosphatic, fossil fragments 1/5 inch long, which appear to be fragments of pelecypod valves	1.0
Shale, yellowish gray, containing small yellow, rusty, red, and brown irregular-shaped limonitic concretions	9.0
Shale, blue-green	1.0
Shale, blue-green, blocky	2.0
Shale, gray to gray-green, gypsiferous, slightly calcareous, thin-bedded, slightly cross-bedded, very silty	0.5
Shale, blue-green, blocky	1.5
Shale, red, blocky	2.0
Gypsum, occurs in white, rounded or flattened ellipsoidal concretions 2 to 4 inches in maximum diameter. Concretions are oriented with the bedding of the enclosing red shale	0.5
Shale, red, with satin spar gypsum. A white salty crust covers this shale	7.0
Shale, blue-green, blocky, with thin satin spar veins	3.0
Covered, in cultivation, appears to be predominantly reddish-brown shale	26.0

DUNCAN SANDSTONE

Sandstone, gray, very fine-grained, calcareous. Very poor exposures, outcrop largely covered	4.0
Lower beds of Duncan not exposed	

IX. Section measured about one-half mile northeast of Cedartop Butte, in the SW¼ sec. 36, T. 8 N., R. 21 W.

BLAINE FORMATION (Partial section)	
Mangum dolomite member:	
Dolomite, gray, brown, compact, honeycombed, medium-crystalline, calcitic. Only a few slumped scattered outliers present	2.0
Unnamed beds:	
Shale, red, partly covered. Most of this interval eroded away	2.0
Collingsworth gypsum member:	
Gypsum, white, massive, sugary to fine-crystalline	19.0
Dolomite, brownish, rusty, slabby, with thin interbedded gray shale streaks, coarse-crystalline, calcitic	1.5
Unnamed beds:	
Shale, red, partly covered	13.0
Cedartop gypsum member:	
Gypsum, gray, massive, selenitic in uppper 3 feet	10.0
Limestone, brown, rusty, yellow, platy, medium- to coarse-crystalline, dolomitic	0.2
Unnamed beds:	
Shale, red	11.0
Gypsum, gray to gray-green, coarse-crystalline, vuggy, calcareous	0.2
Shale, gray	1.0
Haystack gypsum member:	
Gypsum, white, gray, massive	2.5
Shale, grayish-green	1.5
Dolomite, gray to gray-brown, slabby, oolitic in part, coarse-crystalline, contains thin lenses of gypsum near the base	2.5
Shale, grayish-green, bedded, gypsiferous	1.5
Gypsum, white, massive, fine-crystalline	12.5
FLOWERPOT SHALE (Partial section)	
Unnamed beds:	
Shale, green, well-bedded	1.0
Shale, reddish-brown, with satin spar gypsum	11.0
Shale, green	2.5
Shale, red	4.5
Shale, green	5.0
Gypsum, light brown to light green, shaly	0.5
Shale, green	4.0
Kiser gypsum member:	
Gypsum, gray-green with brown irregular mottling, slightly silty, very shaly	2.5
Unnamed beds:	
Shale, chocolate to reddish, with satin spar and thin green shale streaks	7.5
Shale, gray-green, gypsiferous, slight ledge former	1.0
Shale, reddish-brown	4.5
Shale, green	2.0
Shale, red	4.5
Chaney gypsum member:	
Gypsum, white and gray, massive, green, calcareous, and shaly near base. Ledge former	1.0
Lower beds poorly exposed and not measured	

X. Section measured along Crooked Creek in the western half of sec. 32, T. 8 N., R. 20 W.

BLAINE FORMATION (Partial section)	
Mangum dolomite member:	
Dolomite, gray, brown, honeycombed, hard, medium-crystalline, red calcite veins, slumped	2.0
Unnamed beds:	
Shale, red	15.5
Collingsworth gypsum member:	
Gypsum, white, massive, shaly, slumped, largely covered with shale and dolomite talus. Slumping may make this gypsum appear to be thicker than it actually is	21.0
Shale, red and green, gypsiferous	2.0
Dolomite, gray to light brown, gritty, slightly sandy, fine- to medium-crystalline and oolitic in part. Contains very poorly preserved molds of pelecypods, and red, shaly, dense calcite deposited along vertical and horizontal fractures and in irregular "veins"	1.5
Unnamed beds:	
Shale, green, thin-bedded	3.3
Shale, red, blocky	3.0
Shale, green, blocky, nodular, gypsiferous in top 2 inches	1.0
Shale, red, blocky	0.2
Shale, green, blocky to thin-bedded	1.0
Shale, red, nodular, blocky, contains satin spar gypsum	1.6
Shale, green	0.2
Shale, brown, blocky, nodular, contains satin spar veins	1.0
Shale, brown, covered in part	2.0
Cedartop gypsum member:	
Gypsum, white to gray, massive; lower part has many thin, dark gray to black bands, some of which show penecontemporaneous slumping. Southeast of here 100 yards, this member appears to be largely dissolved away. A yellowish-brown, brittle, coarse-crystalline limestone 1 inch thick occurs at the base of the gypsum at several outcrops	7.0
Unnamed beds:	
Shale, green, blocky	2.0
Shale, red	3.6
Shale, green	0.5
Shale, red	4.0
Gypsum, red and green, shaly	0.2
Shale, red, gypsiferous	0.2
Haystack gypsum member:	
Gypsum, white, massive	2.0
Shale, red, thin-bedded, with satin spar gypsum veins	0.5
Shale, green, thin-bedded, contains satin spar	3.0
Gypsum, white, massive, with thin green laminations and splotches	2.0
At creek bottom, lower beds not exposed	

XI. Section measured across a pasture in the NW¼ NW¼ sec. 10, T. 7 N., R. 20 W.

	Feet
BLAINE FORMATION (Partial section)	
Dolomite at base of Collingsworth gypsum member:	
Dolomite, gray, brown, slabby, slightly honeycombed, fine- to medium-crystalline, calcareous; softer parts are more dolomitic and are oolitic. Forms ledge	1.5
Covered interval, completely masked by grass cover	45.0
Dolomite in upper part of Haystack member:	
Dolomite, gray, massive to slabby, fine- to medium-crystalline. Highly calcitic in part	1.5

XII. Section measured in the NW¼ NW¼ sec. 11, T. 7 N., R. 20 W. Exposures are poor; most of the section was measured across cultivated soil.

BLAINE FORMATION (Partial section)	Feet
Van Vacter member:	
Limestone, dark-brown to buff, hard, honeycombed, hackly, layered, coarse-crystalline, silty, dolomitic limestone	0.6
Covered with brown soil	13.0
Mangum dolomite member:	
Dolomite, gray to brown, slabby to massive, hard, fine- to medium-crystalline, dolomitic limestone in part; softer, gray and white parts are composed of dolomitic oolites in dense matrix, and clear, coarse crystals of calcite inside vugs. This member exhibits much slumping at this locality	2.0

XIII. Section measured in road cut along the east side of the NE¼ sec. 12, T. 7 N., R. 20 W.

BLAINE FORMATION (Partial section)	Feet
Mangum dolomite member:	
Dolomite, gray-blue to dark gray, rusty brown in part. The softer, gray parts have poorly preserved pelecypods and contain oolites, many of which are partly dissolved. The matrix is compact and calcitic. The oolites are fine- to medium-grained, rounded, elongate to spheroidal and appear to be mostly dolomite. The hard, dark gray parts are typically honeycombed, coarse-crystalline limestone. Pink veins of dense, fine-grained, shaly calcite are associated with the hard, honeycombed limestone	2.0
Unnamed beds (The lower part is the stratigraphic equivalent of the Collingsworth gypsum):	
Predominantly red, poorly bedded shale, appearing somewhat slumped. Scattered green bands and splotches appear. A 1-foot green streak occurs 3 feet below top	50.0
Dolomite at base of the Collingsworth gypsum member:	
Dolomite, brown, buff, dark gray, hard, slabby, fine- to medium-crystalline, commonly granular. Small vugs, tiny black and brown stains, and small red, calcite veins are present	1.5
Unnamed beds:	
Shale, green	1.0
Shale, red	13.0
Lower beds covered	

XIV. Section measured up steep bluffs along east bank of North Fork of Red River in the NE¼ of sec. 13, T. 7 N., R. 21 W.

	Feet
QUATERNARY TERRACE SAND:	
Thickness not measured. Has erosional contact with the Duncan sandstone.	
DUNCAN SANDSTONE (Partial section, top eroded)	
Sandstone, grayish-green, finely cross-bedded, silty, fine-grained, contains many thin layers of thin-bedded grayish-green shale	2.5
Shale, gray, with yellow, limonitic concretion zones 1 inch thick, and thin irregular sandstone beds	6.5
Sandstone, grayish-green, finely cross-bedded, silty, fine-grained, with thin shale laminations	4.0
Conglomerate, gray to yellowish-brown, cross-bedded, sandy, very silty, shaly, and dolomitic. Contains well-rounded granules and pebbles of green shale and angular quartz. Cross-bedding dips are in various directions	1.0
Sandstone, gray, very fine-grained, silty, finely cross-bedded	2.0
HENNESSEY SHALE (Partial section)	
Shale, buff to grayish-yellow, with 10 streaks of yellow-orange shale containing limonitic gypsiferous concretions. Blocky in part, thin-bedded in part	14.5
Shale, bright blue-green	2.0
Shale, bright brick red	2.0
Lower beds covered	

XV. Section measured up the escarpment on a prominent spur capped by the Duncan sandstone in the NW¼ SE¼ NE¼ sec. 24, T. 7 N., R. 21 W.

	Feet
DUNCAN SANDSTONE (28 feet thick)	
Sandstone and silty shale. Gray, laminated, finely cross-bedded, very fine- to fine-grained sandstone interbedded with drab, yellowish-gray, silty shale. Poor ledge former. Probable top of Duncan	13.0
Shale, drab, yellowish-gray	2.0
Sandstone, gray, buff, gray-blue, current rippled, minutely cross-bedded, silty, fine-grained. It is hard, resistant, and ledge forming. Large blocks break along joints and slide down escarpment	8.5
Shale, interbedded bluish-gray, yellowish-gray, and buff layers, with thin (about 1 inch thick) bright maroon and yellow bands containing yellow, rusty concretions and small selenite crystals. Generally well bedded	4.0
Siltstone, gray-blue, shaly, dolomitic, massive	0.5
HENNESSEY SHALE (Partial section)	
Shale. Same as lower shale of Duncan	7.5
Sandstone, white to light pink, hard, dolomitic, fine-grained	0.1
Covered, probably gray shale	8.5

XVI. Section measured in badlands in SW¼ sec. 12, T. 8 N., R. 22 W.

	Feet
WHITEHORSE GROUP, UNDIFFERENTIATED	
Sandstone, gray, loose, well sorted, fine-grained	1.0
DOG CREEK SHALE (82.4 feet measured, practicaly a complete section)	
Shale, red	4.0
Siltstone, gray argillaceous	0.5

Shale, red, blocky	12.5
Sandstone, gray, shaly, fine-grained, slight ledge former	1.0
Shale, red, blocky	2.0
Dolomite, gray, green, soft, argillaceous, slight ledge former	0.2
Shale, red and gray, mottled, silty	1.5
Sandstone, red and gray, shaly, loose, slightly ledge-forming, irregularly bedded	1.0
Shale, pink, with scattered thin gray sandstone bands	2.5
Shale, green	1.0
Shale, red	1.0
Shale, gray, sandy, forms slight ledge; top 3 inches are red sandy shale	0.5
Shale, red, silty, with thin green bands	7.0
Shale, green	1.0
Dolomite, gray and light green, argillaceous, platy and dense	0.2
Shale, green	0.5
Shale, red	3.5
Shale, red and gray, with thin argillaceous dolomite near the top	0.5
Sandstone, gray, fine-grained, well-sorted, forms slight escarpment	0.3
Shale, red	1.0
Siltstone, red and gray, argillaceous	1.5
Shale, red, blocky	1.0
Dolomite, gray, lumpy, soft, argillaceous	0.1
Shale, green	0.1
Shale, red, blocky	6.5
Shale, blue-green, thin-bedded, dolomitic at base	3.5
Shale, red, fine-bedded	1.0
Dolomite, gray to light brown, highly fractured, dense, lithographic	0.3
Shale, green, laminated	0.5
Shale, red, blocky	2.5
Shale, green	1.0
Shale, red, blocky	3.5
Shale, green, blocky	1.5
Shale, red	3.0
Sandstone, gray, fine-grained, lenticular	0.2
Shale, red, blocky	1.0
Sandstone, gray, fine-grained, shaly	0.2
Shale, red, blocky	0.5
Sandstone, gray, with red splotches, fine-grained, friable	0.5
Shale, covered	11.0
Shale, gray to green	0.3
Shale, pink, red	1.0
Covered, probably only a few feet to top of Van Vacter gypsum	

XVII. Section measured along the east side of a gully in the NW¼ sec. 11, T. 8 N., R. 22 W.

	Feet
WHITEHORSE GROUP, UNDIFFERENTIATED	
Sandstone, gray, loose, fine-grained	1.0
DOG CREEK SHALE (Partial section)	
Shale, mostly covered, intermittent exposures are red	33.0
Dolomite, gray, platy, brittle, slabby, highly fractured, dense to fine-crystalline	2.5
Shale, reddish-brown, blocky	4.5
Dolomite, brown, argillaceous; contains ellipsoidal flattened concretions 2 to 10 inches across long diameter and 2 to 3 inches across short diameter. Concretions are oriented parallel to bedding	0.5
Shale, red, blocky	2.5
Shale, green	4.0
Shale, red, brown, covered in part	11.0
Dolomite, gray, platy, compact, brittle, highly fractured	0.1

Sandstone, gray on weathered surface, massive, compact, dolomitic, well-sorted, fine-grained, with small black specks. Fresh surface is white	0.5
Shale, red, green in top 2 inches	1.0
Shale, blue-green	0.5
Shale, reddish-brown	3.0
Shale, green	1.0
Shale, red to pinkish	1.0
Lower beds covered	

XVIII. Section measured along the creek in the NE¼ sec. 12, T. 8 N., R. 22 W. to the NW¼ NW¼ NW¼ sec. 6, T. 8 N., R. 21 W.

	Feet
CLOUD CHIEF FORMATION	
Gypsum, white, granular, medium-crystalline	4.5
WHITEHORSE GROUP, UNDIFFERENTIATED (386.7 feet thick)	
Sandstone, orange, soft, loose, with fine, frosted quartz grains	1.0
Covered, cultivated, brown loamy soil	38.5
Sandstone, orange to red, massive, gypsiferous, fine-grained. Slight ledge former	5.5
Covered. Brown, sandy, cultivated soil	11.0
Sandstone, orange to pinkish-red, fine-grained, slight ledge former	1.0
Covered. Brown, shaly, sandy soil with bunch grass and some sagebrush	33.5
Covered. Red and orange, shaly, silty soil	73.7
Covered. Brown, sandy, shaly top soil	16.0
Covered. Brown to red, sandy soil with sagebrush and buffalo grass	17.0
Sandstone, pink to red, massive, loose to friable, silty, very fine- to fine-grained	71.5
Covered. Red, sandy, shaly top soil, supports bunch grass and sagebrush	11.0
Sandstone, pink to red, penecontemporaneous contortion and slumping is well displayed; composed of subangular to subrounded, fine to medium, frosted quartz grains. Cemented in part with glistening transparent gypsum	5.5
Sandstone, orange-red, loose, current-rippled, fine- to medium-grained, frosted quartz grains	5.0
Sandstone, pink to red, gypsiferous, with fine- to medium-grained frosted quartz grains; irregular, contorted bedding	5.5
Covered by red sandy soil with sagebrush and bunch grass	8.0
Sandstone, red, fine-grained, gypsiferous	1.0
Shale, red, slabby, irregularly bedded, silty, contains gypsum nodules	2.0
Sandstone, red, slabby, with contorted bedding and fine, frosted, quartz grains	3.0
Covered. Red soil	13.5
Gypsum, white, massive, fractured, coarse-crystalline, with thin red bands	0.2
Shale, red	0.3
Sandstone, orange-red, slabby, very fine- to fine-grained, shaly, and cross-bedded. Contains satin spar and gypsum nodules	4.5
Sandstone, red, friable, containing frosted fine quartz grains	12.0
Covered. Red to pink, sandy soil with sagebrush and bunch grass	13.0
Siltstone, red, shaly	3.0
Covered by red, sandy soil	11.0
Sandstone, red, very fine- to fine-grained, contains thin gray streaks	3.0
Covered by red, loose, sandy soil which supports sagebrush and bunch grass	15.5
Sandstone, gray, soft, composed of fine quartz grains, frosted in part	1.0
DOG CREEK FORMATION:	
Shale, red	5.0
Lower beds covered	

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