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CRETACEOUS STRATIGRAPHY OF THE BELVIDERE AREA, KIOWA COUNTY, KANSAS

By Bruce F. Latta

Prepared by the State Geological Survey of Kansas and the United States Geological Survey with the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

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ABSTRACT

The Belvidere area comprises about 100 square miles in southeastern Kiowa County, Kansas, located at the eastern edge of the High Plains. This is the type area for the Comanchean series of Early Cretaceous age as developed in Kansas and includes the type localities for 17 group, formation, and member names. Only two of these names—Cheyenne sandstone and Kiowa shale—have come into general use, however. The development of present classification of the Cretaceous rocks in southern Kansas is reviewed and a detailed description of the Cretaceous formations exposed in the Belvidere area is given.

Sandstone, sandy shale, and conglomerate belonging to the Cheyenne sandstone are the oldest Cretaceous rocks known in Kansas. They are of continental origin and were deposited on the eroded surface of various Permian rocks. The thickness of the Cheyenne sandstone in the Belvidere area ranges from 32 to 94 feet. Conformably overlying the Cheyenne is the Kiowa shale, which comprises nearly 300 feet of marine shale, thin sandstone, and fossiliferous limestone. Beds of iron-cemented sandstone, light-colored clay, and shale containing fossil plants that overlie the Kiowa shale in the upper part of the Medicine Lodge Valley are assigned to the Dakota (?) formation.

The contact between Kiowa and Dakota (?) beds, which is presumed to divide the Comanchean from the succeeding Gulfian series, is difficult to determine in most places for the two formations are conformable and gradational. In places the contact is represented by a transition zone in which rocks having predominantly marine characteristics are interbedded with rocks having predominantly continental characteristics. The line between the two formations in Kansas is arbitrarily placed at the top of the highest bed of marine origin.

INTRODUCTION

The Belvidere area described in this report comprises about 100 square miles in southeastern Kiowa County, Kansas (Fig. 1). It is named the Belvidere area for a small unincorporated town that serves as headquarters and cattle-shipping point for the surrounding ranches.

The Belvidere area is in the Plains Border section of the Great Plains physiographic province. At one time the surface of this area was continuous with that of the upland plains on the west and north, but Medicine Lodge River and its tributaries have since cut below the Quaternary and Tertiary deposits that underlie the uplands and exposed a large area of Cretaceous and Permian rocks. Rocks belonging to the Comanchean series are especially well developed in this area and many excellent outcrops are found. Overlying the Comanchean rocks in the upper part of Medicine Lodge Valley are younger Cretaceous sediments belonging to the Dakota

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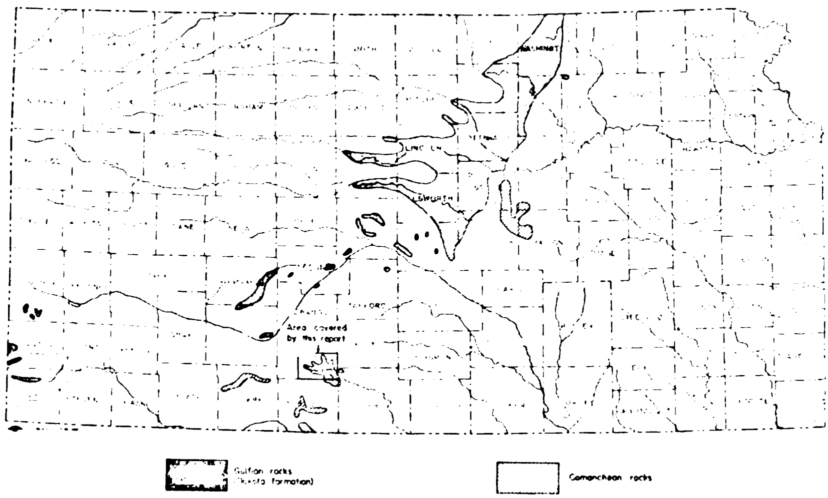

FIG. 1. Area covered by this report and the outcrop areas of the Comanchean series (Cheyenne sandstone and Kiowa shale) and lowermost Gulfian series (Dakota formation) in Kansas.

formation—the lowermost formation of the Gulfian series in Kansas.

The stratigraphy of the Comanchean and lowermost Gulfian rocks in Kansas and adjacent areas has been studied by numerous geologists for many years. Although the character of these sediments is fairly well known, their relationship to one another and hence their proper classification have been a matter of controversy. The Belvidere area is the type area for the lower part (Comanchean series) of these Cretaceous rocks as developed in Kansas, inasmuch as the type localities for 17 group, formation, and member names are located within this area. Only two of the 17 names have come into general use, however. These are the Cheyenne sandstone and the Kiowa shale, which together comprise all of the Comanchean series of Kansas.

The chief purpose of this report is to describe the classification, lithology, distribution, and thickness of the Comanchean and lowermost Gulfian beds as they are developed in the southern Kansas area. The field work on which the report is based was done during the summer of 1941 as part of an investigation of the geology and ground-water resources of Kiowa County made by the State and Federal Geological Surveys in cooperation with the Division of Water Resources of the Kansas State Board of Agriculture and the

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Division of Sanitation of the Kansas State Board of Health. The results of this county investigation are reported in a separate bulletin of the State Geological Survey of Kansas (Latta, 1947). As part of the county investigation numerous geologic sections were measured, and 18 test holes were drilled in Kiowa County. The log of one of the test holes and nine of the measured sections are given in this report.

Acknowledgments.—John C. Frye of the State Geological Survey of Kansas and Claude W. Hibbard, curator of vertebrate paleontology of the Dyche Museum of Natural History, University of Kansas, spent several days in the field with me studying the Cretaceous rocks of Kiowa County and adjacent areas. Their aid in locating and measuring geologic sections was invaluable. Test hole 1 was drilled by Ellis D. Gordon, Perry McNally, and Lawrence Buck, using a portable hydraulic-rotary drilling rig owned by the State Geological Survey.

The manuscript for this report has been critically reviewed by O. E. Meinzer, S. W. Lohman, and J. B. Reeside, Jr. of the Federal Geological Survey, and R. C. Moore of the State Geological Survey. The manuscript was edited by Betty Hagerman and the illustrations were drafted by Woodrow Wilson and Murl Rush.

HISTORICAL SUMMARY OF CRETACEOUS NOMENCLATURE

The following review of the development of the present classification of the Cretaceous rocks of southern Kansas includes only papers dealing with the classification and nomenclature of these rocks. Papers describing the lithology, paleontology, or paleobotany of the various rock units are cited in the descriptions of the various formations. Figure 2 shows in chart form a generalized geologic section of the Cretaceous rocks of southeastern Kiowa County, the classifications that have been applied to these rocks by various authors in the past, and the classification used in this paper.

The first reference to the geology of the southern Kansas area was made by Mudge in 1878 (p. 55). On a geologic map of the State (p. 47) he shows Upper Carboniferous and Cretaceous rocks in Kiowa County, the dividing line passing diagonally from the northeastern corner to the southwestern corner of the county. Mudge (p. 55) states that the area south of Arkansas River and west of Harper County had received little work but seemed to be

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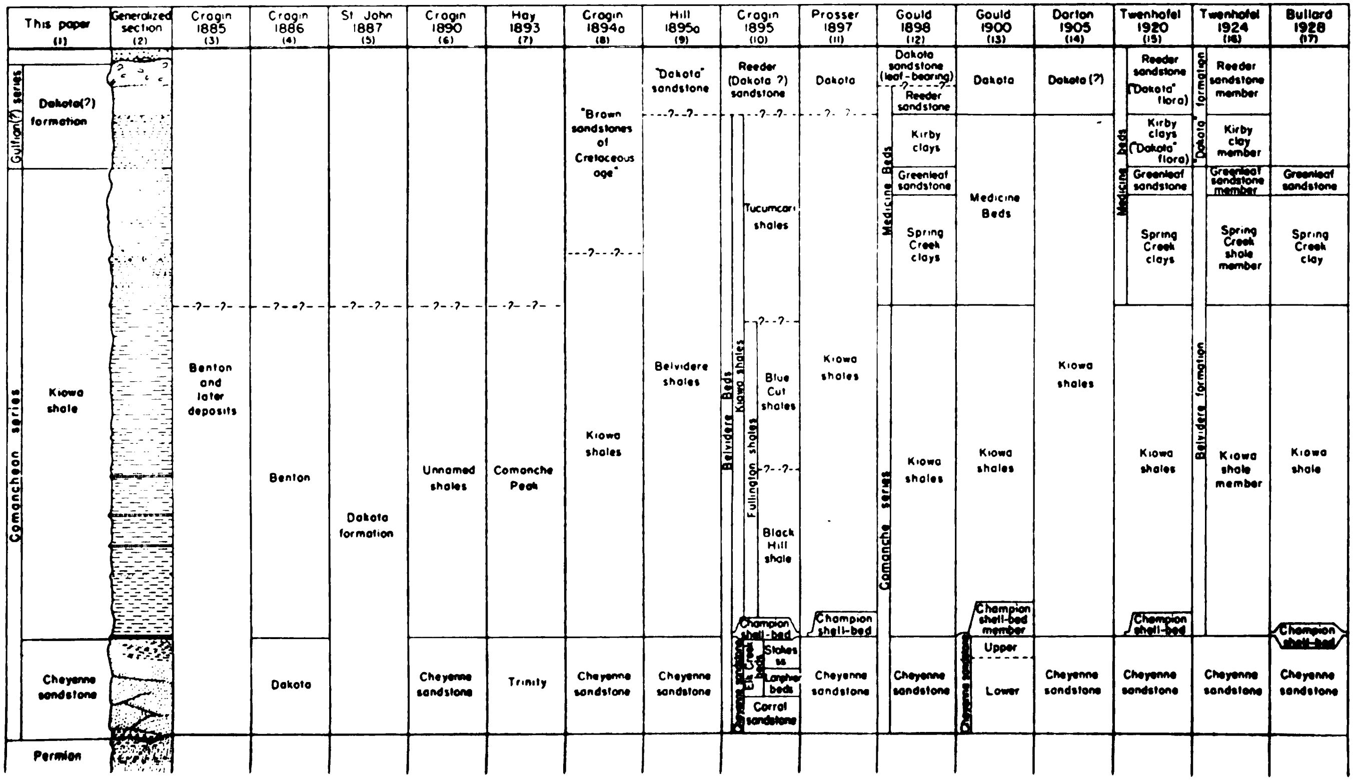

Fig. 2. Generalized geologic section of the Cretaceous rocks of the Belvidere area showing the classifications that have been applied to these rocks by various authors in the past and the class ificatoion used in this paper.

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represented by the "Fort Benton and Dakota groups." St. John published a geologic map of the state in 1883 on which he shows Cretaceous rocks covering all of Kiowa County.

The first description of the rocks in southeastern Kiowa County was given by Cragin in 1885 (p. 90):

They belong to the Benton and later deposits . . . . The deposit (at the Black Hill) is a bed of carbonaceous and rapidly decomposing shale. In connection with the shale are found fragmentary seams of poor lignite. Immediately above and below this is a layer of shell conglomerate made up largely of *Ostrea* and *Gryphaea*.

Below these is a formation quite unlike any other I have seen or heard of in Kansas . . . . It is a variegated sandstone . . . . displaying a most beautiful variety of colors. . . . I have no positive evidence of the Niobrara here as yet, but I am inclined to think it here, and that it would be found to begin shortly above the horizon of the Black Hill shale.

Black Hill, to which Cragin refers, is in the southeastern corner of Kiowa County in sec. 36, T. 30 S., R. 16 W.

The following year Cragin (1886, p. 166) changed his earlier correlation of the Black Hill section by concluding that the variegated sandstone marked the upper limit of the Dakota and the overlying dark shale marked the base of the Benton. A year later, St. John (1887, pp. 143-144) wrote:

. . . . only the Dakota and Niobrara members [of the Cretaceous] have been with certainty identified in this southwest region. . . . The lowermost deposits [of the Dakota formation] consist of soft white-and-yellow-stained sandstone, in places obliquely laminated, with hard, indurated layers, the weathering of which produces monumental forms . . . . This sandstone . . . . is succeeded by dark blue, drab and buff shales, 50 to 70 feet, including above a soft yellow, sometimes reddish, obliquely laminated sandrock, five feet, more or less, and below a stratum of drab, sometimes sandy, shales two to five feet, containing streaks of lignite and fragments of bituminized wood. . . .

Succeeding the shale horizon occur successive beds of shaly limestone, alternating with drab and buff, more or less arenaceous shales, which are charged with fossils, mostly belonging to a species of *Gryphaea* resembling *G. Pitcheri*, an *Exogyra*, *Trigonia*, *Turritella*, etc. . . . . The association of species and abundance of individuals strongly recall occurrences in Texas. . . it would appear that the present region marks the limits of the northern extension of this peculiar southern fauna of the Cretaceous. . . .

Hay (1887, p. 22) said that the variegated sandstone referred to by Cragin was undoubtedly Dakota and that where he had observed the base it seemed to rest on the eroded surface of the "Red Rock".

Cragin (1889, pp. 35-37) published the first detailed description of a section of Cretaceous rocks southwest of Belvidere on Med-

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icine Lodge River and listed the fossils collected from them. He notes that in an earlier paper he (pp. 33, 37)

. . . . wrongly assigned all the formations between the great gypsum horizon and the base of the Tertiary southwest of Sun City to the Benton epoch. . . .

The . . . . study of the Medicine River Cretaceous suffices to show something very like the fauna of the recently discovered Comanche series of Texas, which is said to be lower than the Dakota, or lowest hitherto known American Cretaceous.

Hill (1889, p. 115), in referring to Cragin's paper, said that the rocks in Kiowa County represent the Comanchean series, and he correlated the variegated sandstone with the Trinity division of the Texas coastal plain region and the overlying shell bed with the Fredericksburg division. Cragin (1889a, p. 65) tentatively accepted Hill's correlation for the sandstone and named it the Cheyenne sandstone, from Cheyenne Rock opposite Belvidere, Kiowa County, Kansas. The following year Cragin (1890, 1890a) described more fully the lithology, paleontology, thickness, and distribution of the Cheyenne sandstone and overlying shale, the latter of which he placed in the Fredericksburg division.

Hay made a reconnaissance of the geology of southwestern Kansas in 1885 and in his report (Hay, 1890, pp. 27-30) correlated the lower sandstone (Cheyenne) with the Dakota and the shell bed and black shale with the Fort Benton, but stated that he realized that the beds above the "Jura Trias" (Permian) might possibly belong to the Comanchean series of Texas.

In 1891 Cragin visited the Comanche rocks in northern Texas with Hill and agreed with him in correlating the Cheyenne sandstone of Kiowa County with the Trinity sandstone of Texas and the shales overlying the Cheyenne with the Fredericksburg shale (Cragin 1891a, pp. 179-181). The first geologic map to show Comanchean rocks in Kansas was published the following year by Williston (1892); on this map "Comanche Cretaceous" rocks are shown in the southeastern and southwestern corners of Kiowa County.

Hay outlined the geology and mineral resources of Kansas and described the different geological formations of the state. In describing the strata above the redbeds along the Medicine Lodge Valley, he said (Hay, 1893, pp. 108-109):

. . . . there seems no doubt but that they belong to lower horizons than the Kansas Dakota. There is no reason why the Texan names given to the beds—

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Trinity for the lower, fine-grained sandstones, and Comanche Peak for the upper strata—should not be permanent, but some of the paleontologists still differ as to whether certain of the shells are Lower Cretaceous or of the Jurassic type. . . . I have placed them as Lower Cretaceous.

In 1894 three reports dealing wholly or in part with the Comanchean rocks of southern Kansas were published by Cragin (1894, 1894a, 1894b). In the second paper Cragin (1894a, p. 49) named the black shale above the Cheyenne sandstone the Kiowa shale, stating:

The designation, *Kiowa shales,* is proposed for the inferiorly dark-colored and superiorily light-colored shales that outcrop in several of the counties of southwestern Kansas, resting upon the Cheyenne sandstone in their eastern, and upon the "Red-beds" in their middle and western exposures, and being overlaid by brown sandstones of middle Cretaceous age, or Tertiary or Pleistocene deposits, according to locality.

The Kiowa shales are a locally modified northern extension of part of Hill's Comanche series, cut off from the main part by erosion. They are named from the place of their typical occurrence, Kiowa County, Kansas . . . .

In 1895, Hill (p. 273) announced the discovery of a typical dicotyledonous flora in the Cheyenne sandstone and stated:

This sandstone has heretofore been referred to the Trinity Division of Texas by Prof. F. W. Cragin, but the flora . . . . consists entirely of species hitherto supposed to be peculiar to the Dakota Group, while the flora of the Trinity Division of Texas . . . . is all of the non-dicotyledonous Potomac type. The Cheyenne sandstones are separated from the true Dakota sands of Kansas by nearly 200 feet of shale, containing a molluscan fauna . . . . characteristic of the Washita Division of the Comanche Series of Texas . . . .

Later in the same year Hill (1895a) described the flora of the Cheyenne sandstone and the fossils of the overlying shale, gave measured sections of Stokes Hill (Cragin's Black Hill) and Blue Cut (a railroad cut southwest of Belvidere), and correlated the Cretaceous rocks of southern Kansas, Oklahoma, and New Mexico. In introducing the term "Belvidere shales" for shale that lies above the Cheyenne sandstone, Hill says (1895a, p. 211):

Since writing this paper Prof. Cragin has proposed the name Kiowa for the shale beds. The name would no doubt have priority over the one herein used by me, but owing to doubt as to which sub-division Prof. Cragin would have included the beds 2, 3, and 4 (Cheyenne sandstone), I prefer to retain for the present the term Belvidere shales.

In his Blue Cut section, Hill (1895a, p. 210) lists the Cheyenne sandstone, "Belvidere shale", " 'Dakota' sandstone", and "Plains

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Tertiary." He says (1895a, p. 211) that these formations may be grouped into a generalized section which is characteristic of the bordering breaks of the plains in southern Kansas, western Oklahoma, and northeastern New Mexico. He calls this the Plains section (column 9, Fig. 2). Hill (1895a, pp. 223, 226-227) disagreed with Cragin's correlation of the Cheyenne sandstone and Kiowa shale, stating:

> . . . . these fossils from the Kiowa shale are largely of the age of the Washita division of my Texas section, and not solely the Fredericksburg and Trinity divisions as maintained by Cragin. . . . The Belvidere beds represent in general the Washita division and probably the attenuated Fredericksburg as seen in the north Texas sections. . . . The Cheyenne sandstones are of far later age than the Trinity, and occupy a stratigraphic position at the base of the Washita midway between the Trinity and Dakota.

Cragin (1895) discussed Hill's conclusions and introduced two new formation names and several member names. He said (1895, p. 357) that he had formerly used the name "Belvidere" in a manuscript to designate the Comanchean shales of southern Kansas but withheld it from publication because of its similarity to the term "Belvedere"—a name already given to certain Tertiary sand and gravel beds of Austria. He also proposed that, if the term "Belvidere" were retained, it should be used as a group name to include the Cheyenne sandstone and Kiowa shales, and not as a synonym for the name "Kiowa". This is the usage given "Belvidere beds" in Hill's (1895a, p. 211) Plains section. Cragin (1895, p. 368) gave formation rank to the thin shell bed at the base of the Kiowa shale and called it the "Champion shell bed," from Champion Draw—a small tributary of Medicine Lodge River south of Belvidere, and described the "Champion shell bed" as a "thin stratum of gray shell-conglomerate." He adds:

> In the Belvidere district proper the Champion shell-bed is remarkably persistent, though commonly less than a foot and rarely more than a foot and a half in thickness. Sometimes the bed consists almost wholly of shells cemented into rock by means of arenaceous limestone and calcite, again of a matrix of sand and clay mingled in varying proportion, containing few or many fossils and more or less impregnated with iron oxide and carbonate and sulphate of lime . . . . the forms of Invertebrata known from it already number thirty-six, or more than half of the entire number known from the lower Cretaceous sediments of Kansas south of the Arkansas River.

The Cheyenne sandstone was subdivided by Cragin (1895, p. 366) into the "Corral sandstone" below and the "Elk Creek beds"

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above. The "Corral sandstone"—named for Natural Corral, a short box canyon in the southeastern corner of Kiowa County—consists of 30 to 50 feet of sandstone. Cragin (1895, p. 366) says that the lower part of it is white, but the upper part is often beautifully variegated with the various bright reds mingled with yellow, purple, and brown. The upper part of the Cheyenne sandstone was named the "Elk Creek beds" because of exposures at the head of Elk Creek in southeastern Kiowa County (Cragin, 1895, p. 366), and Cragin subdivided the "Elk Creek beds" into the "Lanphier Beds" below and "Stokes sandstone" above. The "Laniphier beds" were named from exposures in a draw that runs through the Lanphier claim. Cragin (1895, p. 367) describes them as comprising

.... some ten or fifteen feet of incoherent, more or less shaly sands, sometimes passing into shales, often heavily charged with carbonaceous matter, pyrites of iron and selenite crystals, and including numerous fragments of lignite.

According to Cragin (1895, p. 367) the "Lanphier beds" grade upward into the "Stokes sandstone," which is

.... a few feet in thickness .... and .... consists of more constantly arenaceous and consolidated sediments. It is named from one of the localities of its outcrop, the head of what may be called Stokes draw, which proceeds from the foot of Stokes Hill near and south of Lanphier draw. At one of the .... localities on South Elk Creek .... the sandstone of the Stokes horizon, like that part of the Corral horizon at the same locality, is brilliantly colored, scarlet and other shades of red.

The Kiowa shale was subdivided by Cragin (1895, pp. 379-381) into two divisions, the lower of which was called "Fullington shales," from the Fullington ranch near Belvidere, and the upper the "Tucumcari shales," for Mount Tucumcari, New Mexico. A zone of *Gryphaea tucumcarii,* which characterizes part of the "Tucumcari shales," was originally discovered at Mount Tucumcari. The "Fullington shales," according to Cragin (1895, p. 379)

.... include the lower and major part of the Kiowa shales. They are not sharply separated from the overlying Tucumcari shales either lithologically or paleontologically. They include that portion of the Kiowa shales in which the *Gryphaea* is Marcou's *G. roemeri.*

Cragin further subdivided the "Fullington shales" into the "Black Hill shale" and the "Blue Cut shale". In describing the "Black Hill shale," Cragin (1895, p. 379) wrote:

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.... the name was derived from the Black Hill adjoining Hell's Half acre on Elk Creek in Comanche County. The terrane consists of a bed of black carbonaceous clay-shale fifteen or twenty feet thick, resting upon the Champion shell-bed and characterized by a peculiar method of disintegration, breaking down under the weather into small, flat and thin, sharp-edged spalls resembling wafers, a peculiarity that has suggested for this shale the name of *Wafer-shale*.

The "Blue Cut shale" was named from a railroad cut a few miles south-southwest of Belvidere which was known by that name. This division was reported (Cragin, 1895, p. 380) to consist of

alterations of blue-black and gray argillaceous shales with minor beds of sandy shale, ferruginous sandstone and shell limestone.

Concerning the "Tucumcari shale," Cragin (1895, p. 381) stated:

The shells of the genus *Gryphaea* increase in size as found in successively higher horizons of the Belvidere beds from the appearance of the genus in the Champion shell-bed to its disappearance just below the base of the leaf-bearing *Reeder* (Dakota?) sandstone which surmounts the Kiowa shales in the upper valley of the Medicine Lodge River near the post office at Reeder. . . . To the zone characterized in part by .... *G. tucumcarii*, the name *Tucumcari shales* is here given ....

They are chiefly clay-shales, and lighter hued, as a whole, than the Blue Cut shales, which graduate insensibly into them. At their summit, they frequently contain bands and concretions of clay-ironstone ....

This is the first mention of the term "Reeder sandstone" in published literature. Cragin's complete classification of the Cretaceous rocks of southern Kansas is given in column 10, Figure 2.

A comprehensive report by Prosser (1897) on the Comanchean series of Kansas, including several measured sections and a thorough review of all previous work, recognizes this series as comprised of two formations—the Cheyenne sandstone and Kiowa shale—that are readily distinguished by both lithologic and paleontologic characters (column 11, Fig. 2). Prosser (1897, p. 114) considered the "Champion shell bed" as the basal part of the Kiowa shale. Concerning ferruginous sandstone occurring above the Kiowa shale in the upper part of Medicine Lodge Valley Prosser (1897, p. 118) says:

.... the writer .... in correlating this sandstone doubtfully with the Dakota simply follows the general custom. The writer, however, understands that Professor Cragin in his last paper has proposed for this ledge the name *Reeder* (Dakota?) sandstone ....

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Gould (1898), after spending parts of four summers in the southern Kansas area, described a series of "transition beds" from the "Comanche to the Dakota Cretaceous," introducing several new names and giving the classification of the Cretaceous rocks shown in column 12, Figure 2. He used the term Cheyenne sandstone and Kiowa shales in the same sense as Prosser (1897), and wrote in regard to strata above the Kiowa shales (Gould, 1898, pp. 174-175):

. . . . The Spring Creek clays are named for Spring Creek, a southern tributary to the Medicine River 12 miles west of Belvidere, on which the clays are well exposed. The Greenleaf sandstone is named from the Greenleaf ranch on which the sandstone was first studied, and the Kirby clays from the Kirby (also known as the C. W. or Fullington) ranch on which the clays have a typical exposure. Professor Cragin's term, Reeder sandstone, is used to include all the sandstone between the Kirby clays and the true leaf-bearing Dakota. The entire series of transition beds is included under the term Medicine beds, named from the river near the head of which the beds are best studied.

The term "Dakota sandstone" refers to the true leaf-bearing sandstone. Spring Creek, to which Gould refers, is now known as Spring Draw, the name Spring Creek being applied to a northern tributary of Medicine Lodge River just east of Belvidere. Gould (1898, pp. 171-173) lists three sections of rocks that he measured on the Greenleaf and Kirby ranches. The Greenleaf and Kirby (now Parkin) ranches are about 10 miles west of Belvidere and 10 miles south of Greensburg.

In 1900 Gould described the Cretaceous rocks of southern Kansas more fully and classified them as shown in column 13, Figure 2. The names "Corral sandstone," "Lanphier beds," and "Stokes sandstone" apply only in the limited area where they were described (Gould, 1900, p. 18), and concerning the "Medicine beds" he stated (p. 25):

As used in my paper [Gould, 1898] the term included the dark brown sandstone, usually concretionary, below the true leaf-bearing Dakota. Leaves have since been found in the Reeder and the term [Reeder] becomes synonymous with Dakota.

In his conclusions Gould (1900, p. 40) stated:

. . . . Comanche fossils are known to extend many feet into the sandstones which were once considered Dakota, and even above horizons yielding typical Dakota leaves. . . . The opinion of the writer is that by the law of priority the

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base of the Dakota will eventually be recognized at the lowest stratum above the Cheyenne yielding typical Dakota leaves.

Gould later (1901, p. 133) discarded the term "Medicine beds" and said that the transition beds above the Kiowa shale should be classed either in the Comanchean or Dakota, although he was unable to draw a line between the two.

A report on the geology and underground water of the central Great Plains by Darton (1905) includes brief statements on the Cretaceous rocks of Kiowa County. The Comanchean series or Lower Cretaceous in central-southwest Kansas is considered to be represented by two formations: the Cheyenne sandstone and Kiowa shale (column 14, Fig. 2). In describing the Dakota formation of Kansas Darton stated (1905, p. 152):

> Some outcrops of sandstone in the head of Medicine Lodge River, in the southeast corner of Kiowa County, are doubtfully referred to the Dakota; they lie directly upon upper members of the Comanche series.

The sandstone to which he refers probably is that described as the "Reeder sandstone" by Cragin and Gould.

In a report on the Comanchean and Dakota strata of Kansas, Twenhofel (1920, pp. 282-286) briefly describes the Cheyenne sandstone, Kiowa shales, and "Medicine beds" and discusses their origin. He uses the names "Spring Creek," "Greenleaf," "Kirby," and "Reeder" for the divisions of the "Medicine beds" (column 15, Fig. 2), as Gould (1898) had, and gives evidence for placing the Dakota of Kansas in the Comanchean series instead of at the base of the Upper Cretaceous.

Stanton (1922, p. 261) discusses some problems connected with the Dakota sandstone, as follows:

> In the southern Kansas section .... the upper part of the Dakota and all of the later Cretaceous formations have been removed by erosion; there is a greater thickness of marine beds, with a well developed and distinctive Comanche fauna, represented in the sandstones which seem to form a transition to the Dakota; and at the base is the Cheyenne sandstone .... The flora of the Cheyenne sandstone resembles the Dakota flora, but may be specifically distinct.

The flora and origin of the Cheyenne sandstone were described by Berry (1922, pp. 202-203) who lists 23 fossil plants from the Cheyenne sandstone in the immediate vicinity of Belvidere. The "Spring Creek clay," "Greenleaf sandstone," "Kirby clay," and "Reeder sandstone," according to Berry (p. 199),

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. . . . are chiefly local phases or lentils in the Kiowa, of little significance except as indicative of local and more or less contemporaneous variations in conditions of deposition, with perhaps a basal member of the Dakota sandstone represented in the "Reeder".

Twenhofel (1924) described in detail the geology and invertebrate paleontology of the Comanchean and "Dakota" formations of Kansas, and divided the rocks of southern Kansas into three formations: the Cheyenne sandstone, Belvidere formation, and "Dakota" formation (column 16, Fig. 2). The Cheyenne was used without modification of previous usage, but in regard to Cragin's divisions of the Cheyenne, Twenhofel (1924, pp. 14-15) says:

The writer does not consider it possible definitely to recognize any member beyond the limits of one locality, and the divisions of Cragin . . . . are considered to have no validity for more than local application . . . .

Concerning the upper two members of the Belvidere formation, Twenhofel (1924, pp. 27, 28) says:

The writer is not certain to what extent the differentiation of the Spring Creek and Greenleaf members as distinct from the Kiowa is justified, but since it has been done, and there are differences in the character of the sediments, it is considered best to continue the usage of these terms.

In describing the subsurface distribution of the Comanchean rocks in western Kansas, Twenhofel and Stryker (1925, p. 1105) held that in south-central Kansas the Comanchean strata consist of the Cheyenne sandstone at the base and the "Belvidere formation" above. They add:

Above the Belvidere formation are red sandstones of scattered and limited distribution which have been named the "Reeder formation". These belong to the "Dakota".

Bass (1926, pp. 59, 73-76) used the name "Dakota sandstone" to describe the strata between the Graneros shale and the Permian in Hamilton County, but stated that possibly it included representatives of the Purgatoire formation of eastern Colorado.

A lengthy report by Bullard (1928) on the Lower Cretaceous of western Oklahoma includes a discussion of the stratigraphy of the Lower Cretaceous rocks in the Belvidere area, Kiowa County. He discarded the term "Belvidere formation," elevated the members to formations, and for convenience of description, separated the "Champion shell bed" from the Kiowa shale, but says (1928, p. 50): ". . . . considered from the standpoint of the Kansas area alone, the

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Champion may well be included with the Kiowa." Bullard's (1928, pp. 50-63) classification of the Lower Cretaceous rocks of the Belvidere area is shown in column 17, Figure 2. He apparently considered the top of the "Greenleaf sandstone" to be the top of the Lower Cretaceous of this area, for he does not mention any of the beds above the "Greenleaf".

Elias (1931, p. 28; 1937, p. 10) and Landes and Keroher (1939, p. 24) grouped all of the Cretaceous rocks below the Graneros shale in western Kansas into the Dakota group. Tester (1931, pp. 234-283) assigned the name "Dakota stage" to the succession of sandstone and shale that lies beneath the Graneros shale and above the Pennsylvanian rocks at the type locality in eastern Nebraska, and stated that the Washita-Kiowa-Mentor series of Kansas belonged to the same general sequence as the Dakota stage.

In 1937, the Kansas Geological Survey (Moore and Landes, 1937) used the term Dakota group to include all Cretaceous strata below the Graneros. At a conference of Survey geologists in Lawrence in January 1941, a decision was reached by the state geologists to continue the use of the term "Dakota group" as interpreted by Tester (1931), which was to include all the strata from the base of the Cheyenne sandstone to the base of the Graneros shale. Local names were to be used for the subdivisions of the group in those areas where it was possible to subdivide it. Accordingly, all Cretaceous strata of Stanton County, Kansas, were placed in the Dakota group and subdivided into three formations: the Cheyenne sandstone at the base, the Kiowa shale, and the Cockrum sandstone (Latta, 1941, p. 70). This same classification was used in Morton County by McLaughlin (1941, p. 74).

In February 1942, several conferences were held by Survey geologists in Lawrence on the nomenclature and classification of the pre-Greenhorn Cretaceous deposits of Kansas. As a result, the term "Dakota group," which formerly included the Cheyenne sandstone, the Kiowa shale, and the overlying beds to the base of the Graneros shale, was abandoned by the Kansas Geological Survey. In explanation Waite (1942, p. 137) wrote:

The group as previously defined, transgressed the Upper Cretaceous-Lower Cretaceous boundary line; a multiplicity of names has existed for the various units involved, many of them having been applied to such nonpersistent units as channel sandstone that cannot be correlated with certainty beyond the confines of their type localities; many of the stratigraphic units were never ad-

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equately described. Moreover, the Dakota group, as used previously in Kansas, could not be correlated with the Dakota sandstone at the type locality; it was not acceptable to the Committee on Geologic Names of the U.S. Geological Survey; it did not constitute a satisfactory genetic grouping of strata; and the term Dakota group was confused with other usages of Dakota and almost universally implied a sandstone.

It was proposed, therefore, to use the term "Dakota formation" for the nonmarine beds above the Kiowa shale and below the Graneros shale. This term was formally adopted for use in the main area of outcrop in central Kansas.

In a recent paper by Plummer and Romary (1942), the pre-Greenhorn Cretaceous beds of central Kansas are described and classified according to the revised usage of the State Geological Survey of Kansas. Their classification includes three Cretaceous formations below the Graneros shale: Dakota formation, Kiowa shale, and Cheyenne sandstone. The term "Cheyenne sandstone" is used in the same sense as originally defined by Cragin (1890) and includes (Plummer and Romary, 1942, p. 319)

"sandstone strata of continental origin that lie unconformably on Permian rocks and that conformably underlie the Kiowa shale."

Plummer and Romary (p. 319) retained the name Kiowa shale "to designate the dark-colored marine shale, sandstone, and fossiliferous limestone, which occur above the Cheyenne sandstone and below the beds here included within the Dakota formation." The Dakota formation (p. 319):

. . . . is restricted to include only the continental and littoral beds that occur above the Kiowa shale and below the Graneros shale. . . . .

The Dakota formation is divided into parts, the lower of which is named the "Terra Cotta clay member" and the upper, the "Janssen clay member." The Terra Cotta member is defined to include massive clay, silt. and sandstone comprising approximately the lower two-thirds of the Dakota formation. The most conspicuous lithological feature of the Terra Cotta member is the widespread distribution of gray-and-red-mottled massive clay. The Janssen member includes beds of lignite, gray to dark-gray massive clay, silt, and some shale above the Terra Cotta member and below the Graneros shale.

The term "Dakota" has since been used as a formation name in Ford County (Waite, 1942, p. 141), Hamilton and Kearny Counties (McLaughlin, 1943, p. 120), Ellis and Russell Counties (Frye and Brazil, 1943, p. 21), and Finney and Gray Counties (Latta, 1944, p. 145).

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COMANCHEAN SERIES

General Statements

The main outcrop area, and type locality, of the Comanchean rocks of the southwestern United States is in Texas, where the thickest and most complete section is found. Other outcrop areas of Comanchean rocks occur in eastern New Mexico, southern and western Oklahoma, southeastern Colorado, and central and south-central Kansas. These have been called "outlying areas" by some writers because they are not connected with the main area of outcrop in Texas. The surface distribution of Comanchean rocks in Kansas is shown in Figure 1. Only a small part of the area shown has been mapped in detail; therefore the boundaries are generalized.

The base of the Comanchean in Kansas is marked by a pronounced unconformity. Where the base is exposed it lies on a mature erosional surface developed on various Permian rocks. A thin zone of well-rounded pebbles and cobbles occurs locally at the Permian-Cretaceous contact. In the Belvidere area this zone of pebbles and cobbles was found at the Permian-Cheyenne sandstone contact in Champion Draw, about one-half mile south of Belvidere. The pebbles here are 1 to 3 inches in diameter, are composed of gray and pink quartzite, quartz, and chert, and are embedded in a matrix of gray to yellow-tan medium sand. Some of the chert pebbles have weathered into soft gray to white granular masses that may be easily broken by hand. Charles C. Williams (personal communication) has observed a similar zone of pebbles and cobbles in western McPherson County where it occurs at the contact between the Permian and Kiowa shale, and Plummer and Romary (1942, p. 320) report its occurrence at the contact beween the Permian and the Dakota formation in northern Clay County. The relationship between these pebbles and cobbles and the overlying Cretaceous rocks has not been determined. They may represent the earliest continental deposits of Cretaceous age as suggested by Plummer and Romary (1942, p. 320) or they may be the remnants of a formerly more continuous deposit laid down during earlier Mesozoic time.

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Cheyenne Sandstone

Character.—The Cheyenne sandstone was named by Cragin (1889, p. 65) in 1889 from Cheyenne Rock—an indurated mass of this sandstone that forms a prominent ledge on the north side of the Medicine Lodge Valley about three-fourths of a mile west of Belvidere (Pl. 1A). It unconformably overlies the eroded surface of the Permian Whitehorse sandstone in the Belvidere area and is conformably overlain by the Kiowa shale. The upper contact in most places is sharply defined and abrupt, although Moore (in Twenhofel, 1924, fn., p. 21) believes there is evidence, at least locally, of an unconformity.

The Cheyenne consists chiefly of light- -colored fine- to medium-grained friable cross-bedded sandstone and lenses of sandy shale and conglomerate. Minor amounts of clay, selenite crystals, iron nodules, and pyrite occur in different parts of the formation. The bedding is extremely irregular and discontinuous so that it is impossible to trace any one bed for more than a short distance (Pls. 1A, 1C, and 2A). Most of the beds are merely lenses of limited extent.

Sandstone is by far the most dominant type of rock in the Cheyenne. The most common colors of the sandstone are white, light gray, and tan, but in some places iron staining has produced beautiful shades of yellow, red, purple, and brown along bedding and lamination planes or in irregular splotches. The brightly colored zones are most common in the upper half of the formation. The texture of the sandstone ranges from flourlike material of silt and clay size to fine gravel, but fine- to medium-grained sandstone is most common. The material in general is well sorted although the degree of assortment varies from one part of the formation to another and from one locality to another.

Quartz grains comprise the greater part of the sandstone although minor amounts of other minerals are also present. Pyrite and small pellets or concretions of limonite are locally present in the sandstone. Where present, pyrite is generally found near the top of the formation, and limonite concretions, which are small and of irregular shapes, are more common in the lower part. The insoluble residues of 25 samples of Cheyenne sandstone from the Belvidere area were studied by Swineford and Williams in conjunction with an investigation of the subsurface characteristics of the Cheyenne sandstone of a part of Russell County, Kansas (Swineford

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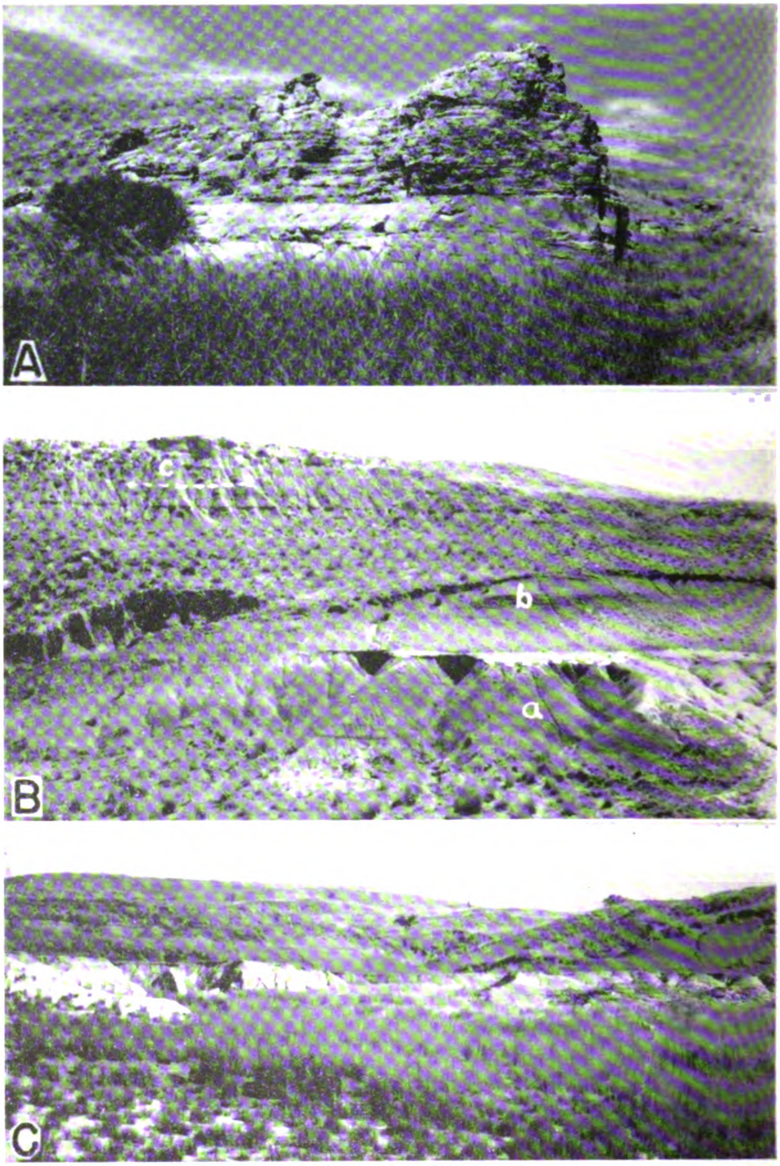

PLATE 1. *A*, Prominent ledge of Cheyenne sandstone known as Cheyenne Rock, from which the Cheyenne received its name. Cheyenne-Permian contact is concealed by weeds in foreground. Kiowa shale forms rounded hill in background. North bluff of Medicine Lodge Valley about three-quarters of a mile west of Belvidere. *B*, Exposure of (a) Cheyenne sandstone, (b) Kiowa shale, and (c) Pleistocene deposits in the NE¼ sec. 5, T. 30 S., R. 16 W., about

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and Williams, 1945). The predominant heavy minerals in the samples were zircon, tourmaline, staurolite, ilmenite, and leucoxene, but also present were small amounts of rutile, hornblende, titanite, cassiterite, and muscovite. In addition to quartz, the prominent light minerals in the samples were feldspar and chert.

The sandstone as a whole is loosely cemented and is therefore easily eroded, but there are hard zones or layers that resist erosion. Differential erosion of the hard and soft layers by rain wash, running water, and wind has produced many fantastic and oddly-shaped forms in the sandstone. Buttes, badland areas, steep-walled canyons, box canyons, high steep-sided ledges, overhanging cliffs, "chimney-rocks", "pulpit rocks", and many other forms may be seen in the outcrop area of the Cheyenne sandstone (Pls. 1A, 2A, and 3C), many of which have received names. The name "Natural Corral" has been applied to a box canyon in the middle of sec. 36, T. 30 S., R. 16 W. Another well-developed but unnamed box canyon occurs in the SE¼ sec. 9, T. 30 S., R. 16 W. Both of these box canyons have been used in the past as corrals by putting a fence across the open end. Two prominent ledges of sandstone west of Belvidere are known as Cheyenne Rock and Osage Rock.

Lenses of pebble conglomerate were found at or near the base of the Cheyenne sandstone at nearly every exposure examined in Kiowa County (see measured sections 4, 5, 6, 7, 8, and 10). The conglomerate is poorly cemented and consists of pebbles of red, gray, and clear quartz and weathered white to gray chert in a matrix of fine to coarse quartz sand. Most of the chert pebbles are subangular to subrounded, and the quartz pebbles are subrounded to well rounded. The pebbles range in size from about 2 mm to about 10 mm in diameter. Most of the lenses of conglomerate range from only a few inches to 1 foot in thickness. The thickest section was found in the SW¼ sec. 26, T. 30 S., R. 16 W., where 45.5 feet of conglomerate was measured at the base of the Cheyenne (Pl. 2B and measured section 7).

Thick lenses of gray to black sandy and silty carbonaceous shale are common in the upper part of the Cheyenne sandstone and thin-

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1¼ miles north of Belvidere. *C*, Cheyenne sandstone and Kiowa shale in Champion Draw. The thin bed in the middle of the picture is the shell-limestone ("Champion shell bed") at the base of the Kiowa. Note how the top of the Cheyenne grades laterally from light-colored sandstone (at left) into dark-colored sandy shale (at right).

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ner lenses of shale are found near the base. In some places the upper 5 to 16 feet consists almost entirely of shale, which laterally grades into sandstone (Pl. 1C). Remains of fossil plants, lignite, and selenite crystals are common in the shales in the upper part of the formation.

Cragin (1895, pp. 366, 367) divided the Cheyenne sandstone into two members. He named the upper member "Elk Creek beds" and the lower member "Corral sandstone" (column 10, Fig. 2). The "Elk Creek beds" were subdivided into the "Stokes sandstone" above and the "Lanphier beds" below. These units can be recognized at their type localities, but because of the lensing nature of the beds it is impossible to trace them from one exposure to another with certainty. Moreover, in many localities the shaly "Lanphier beds" are missing and the upper part of the Cheyenne consists almost entirely of sandstone. In other areas shale lenses extend to the top of the formation. Therefore, as Twenhofel (1924, p. 14) has pointed out, these divisions have no stratigraphic value beyond their type localities.

Distribution and thickness.—South-central Kansas is the only place in the state where the Cheyenne sandstone is exposed. Here it crops out as an irregular narrow band around the headwaters of Medicine Lodge River, Mule Creek, Bluff Creek, and other streams in Barber, Kiowa, and Comanche Counties. Exposures of sandstone in Clark County are of undetermined age but may belong to the Cheyenne sandstone. The best exposures are found in the Belvidere area where the Cheyenne crops out in irregular bands on both sides of the Medicine Lodge Valley (Fig. 3).

There is considerable variation in the thickness of the Cheyenne sandstone, chiefly because of the uneven erosion surface on which the sediments were deposited (Fig. 4). The measured thicknesses of the sandstone in the Belvidere area ranged from 32.5 feet in Champion Draw (measured section 4) south of Belvidere to more than 94 feet in the SW¼ sec. 26, T. 30 S., R. 16 W. (measured section 7). The top of the formation was not present at the latter section. The average thickness of the Cheyenne sandstone in this area as based on measured sections is about 45 feet.

Fossils.—Fossil leaves, logs, and branches are found in the Cheyenne sandstone in some places and seem to be most common in the upper part of the formation. No fossil remains of animals are known to have been collected from the Cheyenne sandstone.

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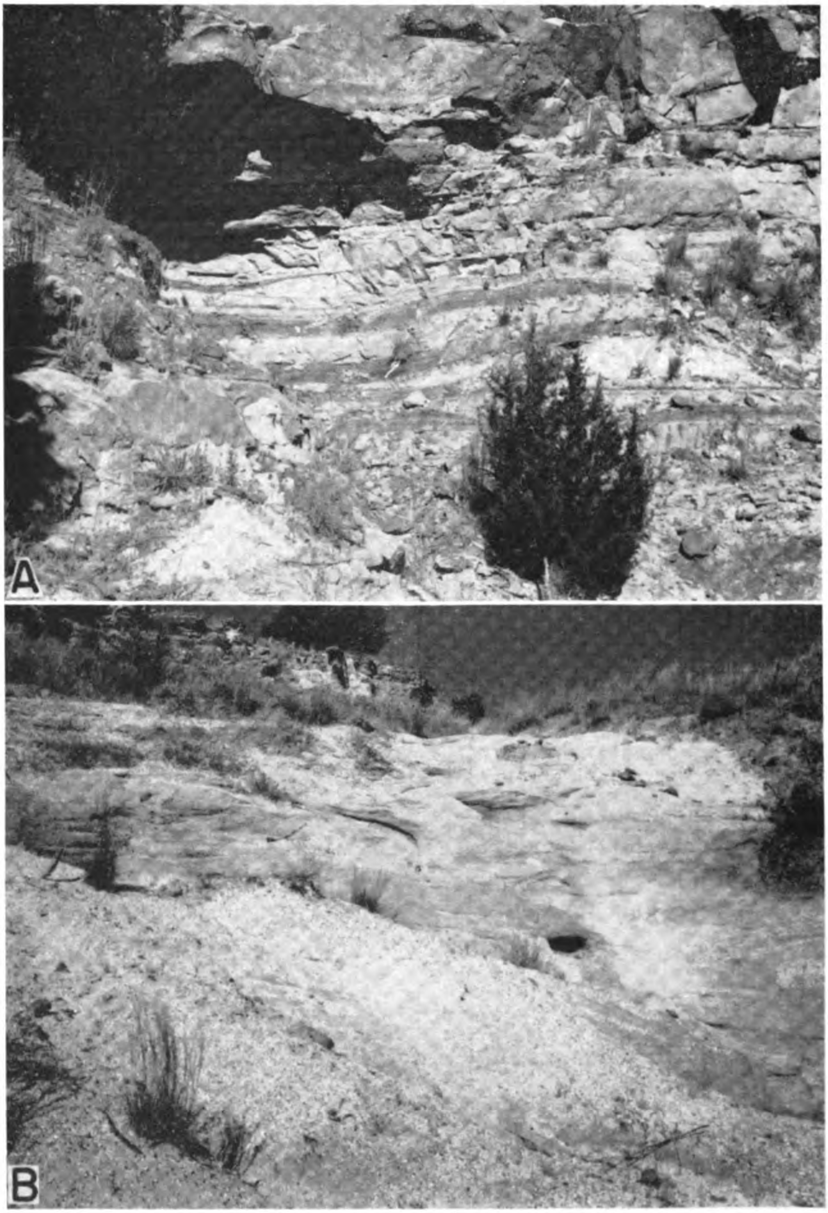

PLATE 2. Exposures of the Cheyenne sandstone in the SW¼ sec. 26, T. 30 S., R. 16 W. *A*, Massive sandstone containing thin lenses of sandy shale (see measured section 6). *B*, Part of thick lens of conglomerate overlain by massive fine- to medium-grained sandstone (see measured section 7).

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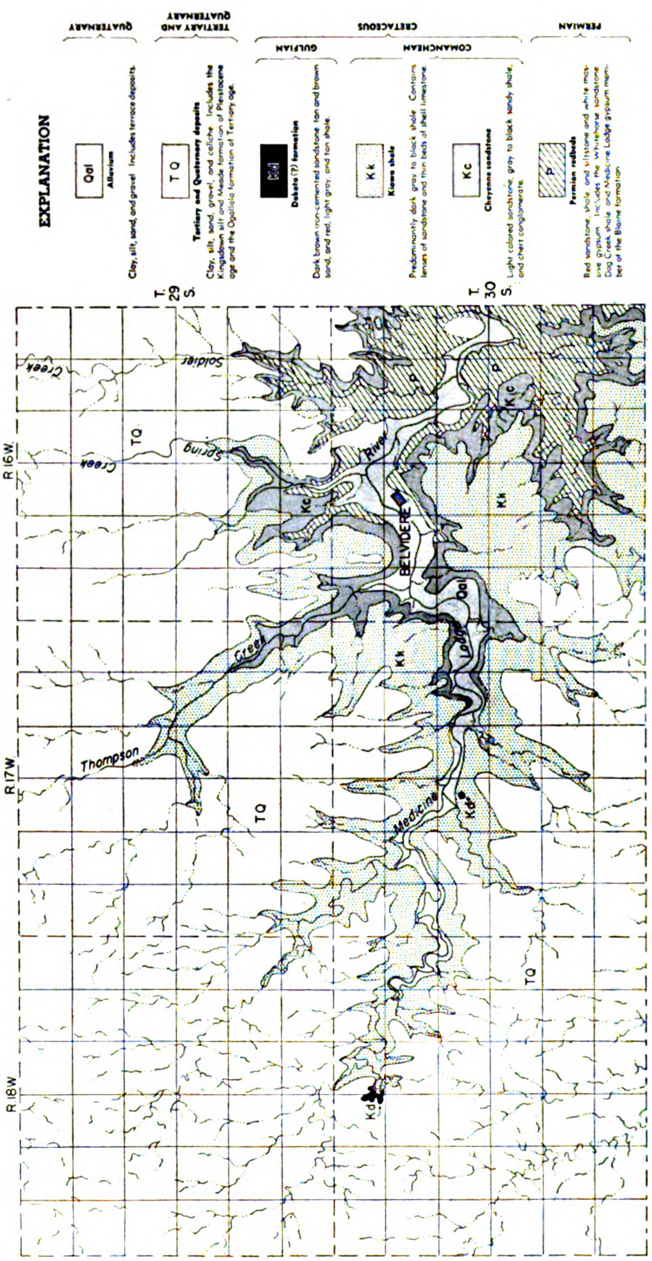

FIG. 3. Geologic map of the Belvidere area, Kansas.

The flora of the Cheyenne sandstone has been summarized and described by Berry (1922, pp. 202-203). It contains 23 species, including 4 ferns, a supposed cycadophyte seed of doubtful relationship, the fragment of a trunk of the genus *Cycadeoidea*, 4 coniferophytes, and 11 angiosperms of which 1 is a supposed monocotyledon and 10 are dicotyledons.

Age and correlation.—The proper position of the Cheyenne sandstone within the Comanchean series has been a matter of dispute for many years. Twenhofel (1924, p. 45) placed the Kiowa shale in the Washita division of the Texas Comanchean series and stated that because the Cheyenne lies beneath the Kiowa shale it is older than the Washita. Bullard (1928, p. 53) made the following statement concerning the age of the Cheyenne:

> The fact that the Cheyenne is overlain by a formation containing a very characteristic basal Washita fauna would indicate that the Cheyenne is of pre-Washita age, perhaps Fredericksburg. . . . The question of the exact correlation of the overlying formation, the Kiowa, will be discussed later and it will be shown that there are many elements of Fredericksburg aspects in it, so that until a more accurate correlation of the Kiowa is accomplished the best statement that can be made in regard to the age of the Cheyenne is that it is pre-Washita, or may represent a portion of the most basal Washita.

On the basis of the flora, Berry (1922, p. 226) concluded that the Cheyenne is younger than the Trinity and older than the Woodbine, which would place the Cheyenne in the Fredericksburg or Washita division in approximate accordance with the conclusions reached by Twenhofel and Bullard.

Origin.—The Cheyenne sandstone of Kansas is generally considered to be of continental origin and to have been deposited on or near the strand line of a northward advancing Comanchean sea (Plummer and Romary, 1942, p. 340). Probably the most comprehensive discussion of the origin of the Cheyenne sandstone is that given by Twenofel (1924, pp. 18-20), who believes that the Cheyenne was deposited on a dry coastal plain, partly by aggrading streams that spread sediments over their flood plains and built deltas, and partly by wind action. Goldman (quoted by Berry, 1922, p. 204) suggested a delta origin for these sediments. Berry (1922, p. 203) believes that most of the sand was deposited by wind and that the clay was waterlaid and represents flood-plain or playa deposits.

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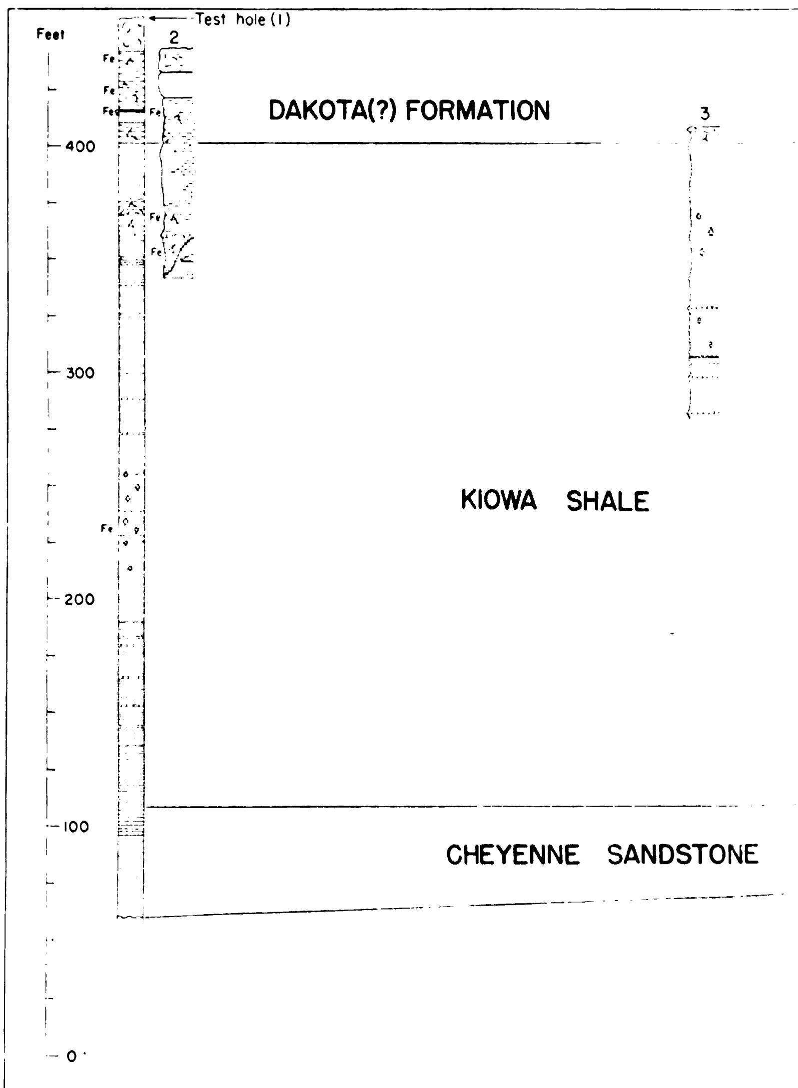

FIG. 4. Correlated outcrop sections of the Cretaceous

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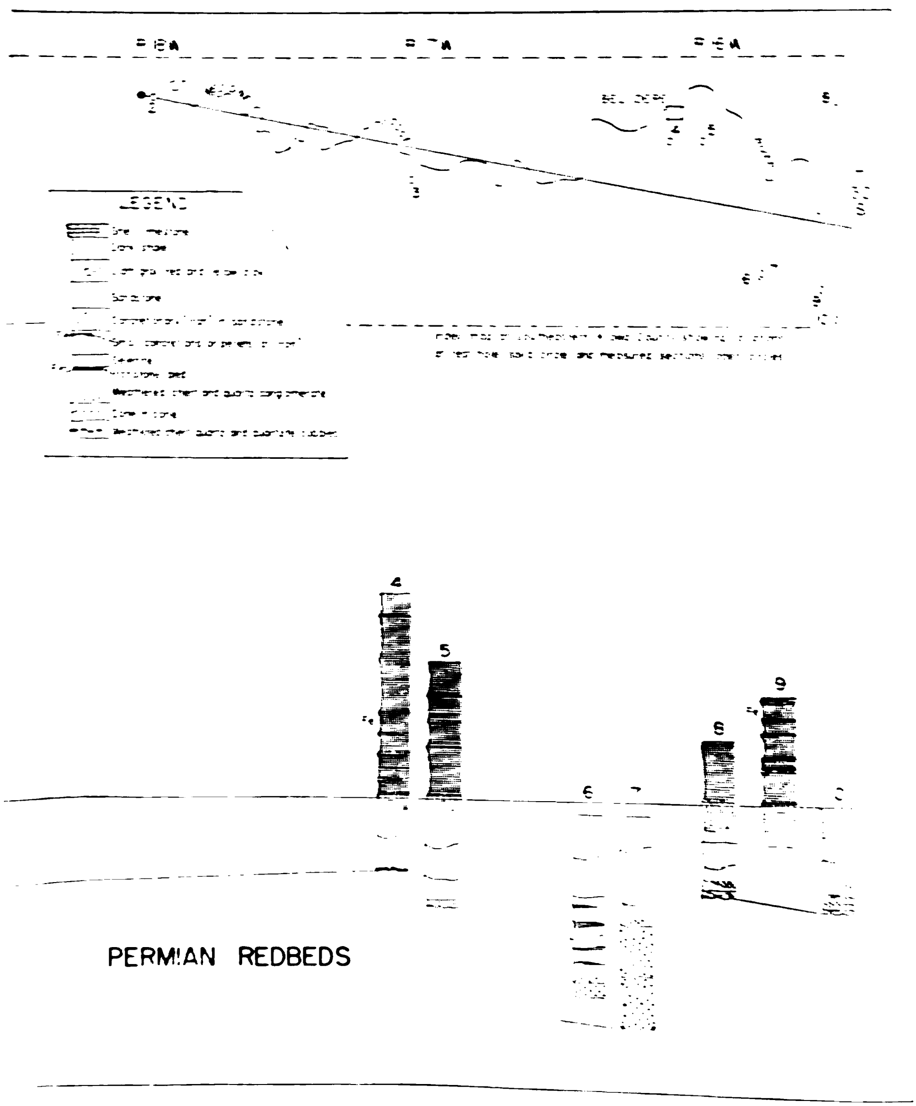

rocks of the Belvidere area, Kansas.

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The above explanations of the origin of the Cheyenne sandstone of Kansas have two points in common: (1) the Cheyenne is dominantly a continental deposit, and (2) sedimentation took place on or near a shore line. Whether the sediments represent eolian deposits, deposits of aggrading streams, delta deposits, or a combination of these still remains to be determined.

Kiowa Shale

The Kiowa shale, as the term is used in this paper, includes the thick series of marine shale, sandstone lenses, and fossiliferous limestones that occurs above the Cheyenne sandstone and below the Dakota formation. No member of the formation is recognized, but it includes units formerly called Champion shell bed, Spring Creek clay, Greenleaf sandstone and the lower part of Gould's (1900) Medicine Beds. It is equivalent to Twenhofel's (1924) Belvidere formation (Fig. 2). The Kiowa shale was named by Cragin (1894a, p. 49) from exposures in Kiowa County, Kansas.

Character.—The contact between the Kiowa shale and the underlying Cheyenne sandstone is conformable in most places, but locally it may be unconformable (p. 235). The Kiowa shale is overlain conformably by the Dakota formation or unconformably by the Meade (Pleistocene) and Ogallala (Tertiary) formations. Although many good exposures of the Kiowa are found in this area, the top and bottom of the formation are nowhere found in the same exposure. The lower part of the formation and its contact with the Cheyenne sandstone is well exposed in the vicinity of Belvidere (measured sections 4, 5, 8, and 9) and the upper part and contact with the Dakota (?) formation is exposed in Medicine Lodge Valley and its tributary valleys several miles upstream from Belvidere (measured sections 2 and 3).

The Kiowa shale consists dominantly of thinly laminated dark-gray to black shale in the lower part grading upward into gray, tan, mottled tan, red, and brown clay and clay shale. The shale in the lower part generally is black and has been called a paper-shale because it is so thinly laminated. A conspicuous feature of the formation, especially of the lower part, is the presence of thin beds of shell limestone—a name that has been given to these beds because they consist almost wholly of fossil shells. These limestone beds are 3 to 18 inches thick, generally are light gray, and locally contain

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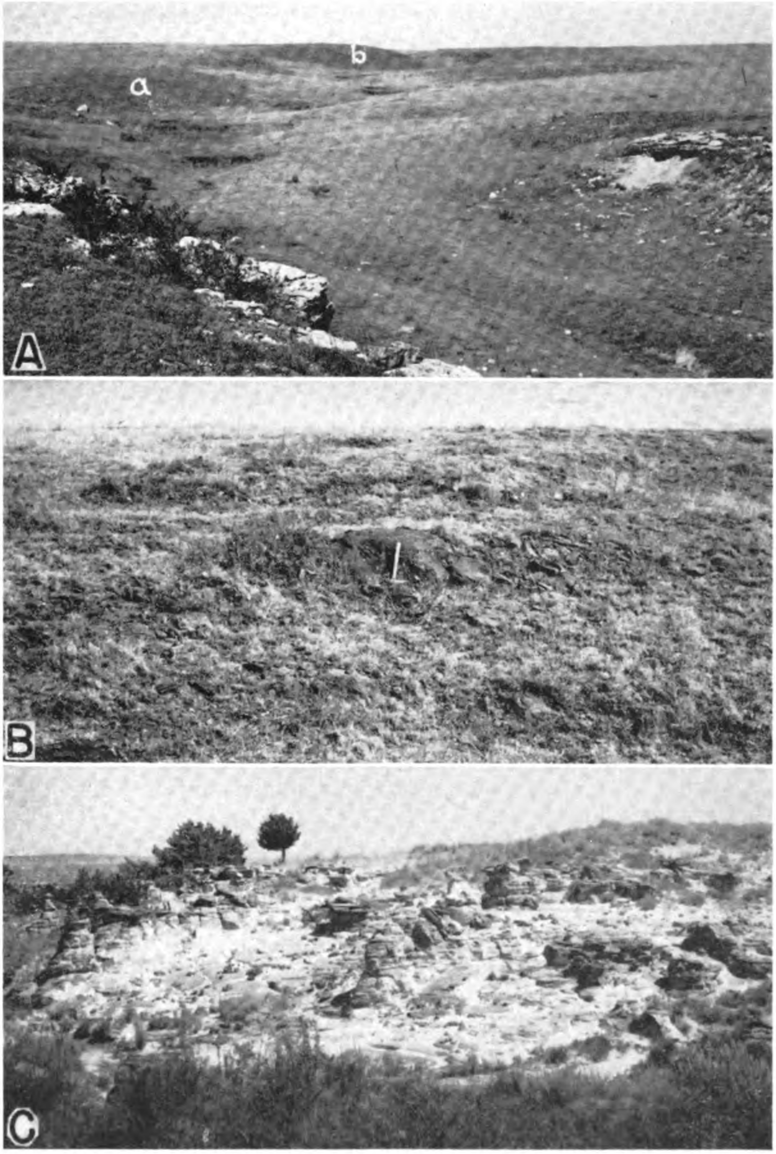

PLATE 3. *A*, The Dakota (?) formation (a, Gould's "Kirby clays"; b, Cragin's "Reeder sandstone") at the head of Spring Draw in the SE¼ sec. 4, T. 30 S., R. 18 W. In the foreground are "mortar beds" of the Tertiary Ogallala formation. *B*. Hard iron-cemented sandstone of the Dakota (?) formation. Type locality of Cragin's "Reeder sandstone." Exposure is at the head of Spring Draw opposite "b" in the above photograph. *C*, Small badland area in the SW¼ sec. 22, T. 30 S., R. 16 W., produced by differential erosion of the Cheyenne sandstone.

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gypsum or pyrite. The matrix consists of shell fragments and sand or of sand and clay. In some places oxidation of the pyrite has caused the rock to disintegrate and the fossils have been largely decomposed. Where this has happened, the shell bed is stained with iron, which gives it a red-brown or rusty color. A shell bed at the base of the Kiowa shale was named the "Champion shell bed" by Cragin (1895, p. 368), who gave it a rank equivalent in stratigraphic value to the Cheyenne sandstone and Kiowa shale. The term "Champion shell bed," however, has only local value in designating this basal layer. The bed is persistent in parts of the Belvidere area, where it forms a prominent bench above the Cheyenne sandstone (Pl. 1B and 1C), but was not recognized in any of the test holes drilled in other parts of Kiowa County. There seems to be no essential difference between the "Champion shell bed" and other shell beds in the Kiowa, although Cragin believed the fauna of the "Champion shell bed" was different from that of the rest of the Kiowa shale.

A large lens of cross-bedded yellow-tan to buff fine-grained sandstone occurs in some places at the top of the Kiowa shale on the Greenleaf and Parkin ranches about 10 miles west of Belvidere. The thickness of the sandstone lens in Spring Draw in the SE¼ sec. 4, T. 30 S., R. 18 W., is 29 feet (measured section 2). Smaller lenses of yellow-tan angular clay pebbles occur in the sandstone, and a thin bed of iron-cemented sandstone that contains small clay pellets and shark teeth caps the sandstone in the SE¼ sec. 2, T. 30 S., R. 18 W. Gould (1898, p. 174) named this the "Greenleaf sandstone" from exposures on the Greenleaf ranch. Inasmuch as the sandstone is merely a lens of limited extent, differentiation of it as a stratigraphic unit is not justified. The same applies to the "Spring Creek clay"—the term Gould (1898, p. 174) used to describe the clay underlying the "Greenleaf sandstone." These units have not been recognized with certainty outside their type areas. Near the top of a high hill on the south side of the Medicine Lodge River in the E½ of sec. 16, T. 30 S., R. 17 W., about 5 feet of cross-bedded tan to buff fine-grained sandstone is exposed (measured section 3) at the top of the Kiowa shale that may be the thinned extension of the sandstone lens exposed on the Greenleaf and Parkin ranches or it may be a part of another lens. Thinner beds or lenses of sandstone occur throughout the Kiowa shale. They range from less than 1 inch to about 18 inches in thickness and consist of white

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or light- to dark-gray fine-grained sandstone. The "Champion shell bed" in many places is capped by a thin bed of sandstone.

Gypsum, generally in the form of selenite, is common throughout the formation and occurs both in the beds of shell limestone and at many different places in the shale. A layer of fibrous aragonite having a cone-in-cone structure was found capping beds of shell limestone in two (4 and 9) of the sections measured and was found interbedded between gray to tan shale and black shale in one section (3). Small red-brown iron concretions are found in various parts of the Kiowa shale, but are more abundant in the clay and clay-shale near the top of the formation (measured section 2). Ironstone, occurring in beds from less than 1 inch to about 20 inches in thickness, is also common in the upper part of the formation.

Distribution and thickness.—The Kiowa shale is exposed extensively on both sides of the Medicine Lodge Valley in the southeastern part of Kiowa County (Fig. 3). There is no complete section of the Kiowa exposed anywhere in this area, but the thickness of the Kiowa in test hole 1 (log 1) in the SE¼ sec. 4, T. 30 S., R. 18 W., was 293 feet.

The Kiowa shale is exposed over a wide area in central Kansas where the maximum thickness is reported to be 100 to 125 feet (Plummer and Romary, 1942, p. 323).

Fossils.—More than 50 species and varieties of invertebrate fossils have been identified from the Kiowa shale (Twenhofel, 1924, pp. 22, 23). In addition to the above invertebrates, fragments of fossil insects have been found in the black shale immediately above the "Champion shell bed" (Gould, 1899, p. 284).

Numerous vertebrate fossils have also been collected from the Kiowa shale in this area. A list of the vertebrate fossils found in the Kiowa shale is given by Twenhofel (1924, p. 23). Most of the forms described were found in the vicinity of Belvidere.

The beds formerly referred to as the "Spring Creek clay" and "Greenleaf sandstone" do not contain as many fossils as lower beds of the Kiowa. According to Gould (1900, p. 26), 12 invertebrate forms, shark teeth, and fish scales have been collected from thin sandstone beds and iron concretions of the "Spring Creek clay," which is represented by beds 1 to 3 of measured section 2. Fossils from the "Greenleaf sandstone" (bed 4 of measured section 2) are poorly preserved. They include four invertebrate forms and shark teeth (Gould, 1900, p. 26).

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Age and correlation.—That the Kiowa shale is of Comanchean age has not been questioned since Cragin (1889, p. 37) and Hill (1889, p. 115) first correlated the fauna of the Kiowa with the fauna of the Comanchean series of Texas. The proper position of the Kiowa shale in the Comanchean series of Texas, however, has been a matter of dispute for many years. The first attempt at correlating the Kiowa shale with a specific part of the Texas section was made by Hill (1889, p. 115), who correlated the basal shell bed ("Champion") with the Fredericksburg division. Cragin (1890, p. 75) correlated all of the marine beds that overlie the Cheyenne sandstone with the Fredericksburg division. In 1895 Hill (p. 273) changed his earlier correlation and stated that the fauna of the Kiowa shale was characteristic of the Washita division. In a letter quoted by Prosser (1897, pp. 114-115), Cragin maintained that the fossils from the "Champion shell bed" and those from the overlying shales comprised two distinct faunas and stated that the "Champion shell bed" should be referred to the Fredericksburg and the overlying shales to the basal Washita. Twenhofel (1924, pp. 23-45) said that there are no essential differences between the faunas of the "Champion shell bed" and the overlying shales. He placed the Kiowa shale in the Washita division but recognized that there are some things in the fauna of Fredericksburg aspect. Bullard (1928, p. 61) correlated the Kiowa shale (except the Champion shell bed) with the Kiamichi clay (basal Washita) of the southern Oklahoma and northern Texas section and the "Champion shell bed" with the Goodland limestone (Fredericksburg), but stated that the line between the Fredericksburg and the Washita was difficult to establish on the basis of paleontologic evidence.

The available evidence indicates, therefore, that the Kiowa shale is equivalent in age to the Washita division and possibly in part to the Fredericksburg division of the Texas section.

The upper part of the Purgatoire formation of western Oklahoma (Stovall, in Schoff, 1943, p. 79) and southeastern Colorado (Sanders, 1934, p. 865) has been correlated with the Kiowa shale of southern Kansas.

Origin.—The Kiowa shale is marine in origin and probably represents shallow-water deposition of a transgressing sea. Detailed descriptions of the mode of deposition of the Kiowa have been given by Twenhofel (1924, pp. 26, 27) and Plummer and Romary (1942, pp. 340, 341).

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GULFIAN (?) SERIES

Dakota (?) Formation

General statements.—Tester (1931, p. 283), after a critical study of the basal Cretaceous rocks in Kansas, Nebraska, and western Iowa, concluded that it was impractical to separate the "Dakota" rocks of Kansas and the "Kiowa-Mentor series" of Kansas because of their close relationship and similar physical histories. Later workers (Plummer and Romary, 1942, pp. 318-319; Frye and Brazil, 1943, pp. 20-24; Swineford and Williams, 1945, pp. 111-121), however, have separated the Kiowa shale and Dakota formation on the basis of lithology and origin, the contact generally being placed arbitrarily at the top of the highest bed of marine origin.

At most places in Kansas where the Kiowa shale and Dakota formation occur together, it is difficult to determine the contact between the two formations with certainty. The contact is not abrupt as might be expected between marine and continental beds, and the boundary can not be drawn consistently above or below any one bed having a distinctive lithology, for no such bed occurs at the contact. The two formations seem to be entirely conformable and gradational. In places the contact is represented by a transition zone in which rocks having predominantly marine characteristics are interbedded with rocks having predominantly continental characteristics. This feature is well shown in a section at Natural Corral, a box canyon about 5 miles southwest of Marquette in western McPherson County, where a bed of sandstone containing terrestrial plant material occurs below the so-called "Mentor beds," which contain marine fossils and are included in the Kiowa shale (Twenhofel, 1924, p. 32; Moore, Frye, and Jewett, 1944, p. 154).

In the upper part of the Medicine Lodge Valley in the Belvidere area, the Kiowa shale grades with apparent conformity into beds of sandstone, shale, and clay which contain fossil plants and are lithologically similar to certain beds in the Dakota formation of central Kansas. These plant-bearing rocks cannot be traced into beds of known Dakota age, but on the basis of their fossils and similar lithology they are here classed as Dakota (?) formation. It is recognized, however, that the presence of fossil plants is not a diagnostic criterion and that marine rocks of the Kiowa shale may occur above these plant-bearing beds elsewhere in the subsurface. A query is used to indicate the tentative nature of the correlation.

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Character.—The Dakota (?) formation as herein described includes all the beds formerly classed as "Kirby clay" and "Reeder sandstone" and in addition higher beds found only in the subsurface. The line of division between the Dakota (?) formation and the Kiowa shale is arbitrarily placed at the top of the highest known bed of predominantly marine origin. The Dakota (?) formation in Kiowa County is overlain unconformably by silt, sand, and gravel of Tertiary and Quaternary age.

The best exposures are found at the head of Spring Draw (Pl. 3A, measured section 2), where about 10 feet of hard dark-brown iron-cemented sandstone containing large nodular concretions (Pl. 3B) is underlain by about 12 feet of tan and brown fine to medium loose sand. Below the sand is red and light-gray silty shale that grades downward into tan clay shale containing small red iron concretions, mottled red and gray clay shale, and light-gray silty shale containing thin beds of yellow-buff fine-grained sandstone. The clay and clay shale is about 20 feet thick and is underlain by sandstone of the Kiowa shale. This is the type section for Cragin's (1895, p. 381) "Reeder sandstone" (the upper sandy unit) and for Gould's (1898, p. 175) "Kirby clays" (the lower clay unit).

In an exposure in the E½ sec. 16, T. 30 S., R. 17 W., at the top of a high hill on the south side of Medicine Lodge Valley, the Dakota (?) consists of 2 feet of hard dark-brown sandstone underlain by 5 feet of tan to gray clay (measured section 3). No plant remains have been found at this locality.

Distribution and thickness.—The Dakota (?) formation is exposed in only two places in the Belvidere area (Fig. 3) in the SE¼ sec. 4 and SW¼ sec. 3, T. 30 S., R. 18 W., and in the E½ sec. 16, T. 30 S., R. 17 W. Most of the formation was removed from this area by post-Dakota erosion. The maximum exposed thickness of the formation in the Belvidere area is 42 feet.

The Dakota formation is exposed over a wide area in central and north-central Kansas where it attains a thickness of about 275 feet (Plummer and Romary, 1942, p. 330). Smaller areas of outcrop occur north of Arkansas River in Ford, Hodgeman, Pawnee, and Barton Counties, and in the extreme southwestern part of the State (Fig. 1).

Fossils.—The series of beds exposed in Spring Draw (measured section 2) is correlated with the Dakota formation on the basis of their similar lithology and fossil plants. Gould (1900, p. 30) col-

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lected the following fossil plants from the Reeder sandstone (beds 6 and 7 of measured section 2):

Proterides daphnogenoides Heer
Embrothrites daphneoides Lesquereux
Laurus plutonia Heer
Eucalyptus geinitzi Heer
Eucalyptus gouldi Ward
Eucalyptus sp.

Fragments of dicotyledonous plants have also been collected from the Kirby clay, bed 5 of measured section 2 (Twenhofel, 1924, p. 29).

No plant remains have been found in beds 15 and 16 of measured section 12, in the E½ sec. 16, T. 30 S., R. 17 W., but because of their similar lithology they are tentatively assigned to the Dakota (?) formation.

MEASURED STRATIGRAPHIC SECTIONS AND LOG OF TEST HOLE

The log of test hole 1 shown in Figure 4 and referred to in the text is given below. The stratigraphic sections that follow the log were measured by me unless otherwise noted. Stratigraphic names that are no longer in use have been placed in parentheses.

Locations of the test hole and measured sections are shown in Figure 4.

1. *Sample log of test hole 1 in SW¼ NE¼ SE¼ sec. 4, T. 30 S., R. 18 W., drilled by the State Geological Survey, 1941. Surface altitude, 2,201.0 feet.* (Samples studied by Perry McNally and Bruce F. Latta.)

	Thickness, feet	*Depth, feet*
Soil, sandy, dark gray	1	1
TERTIARY—Pliocene		
Ogallala formation (?)		
Sand and gravel, limy; contains pebbles of caliche	1	2
Silt, sandy, tan; contains pebbles of granite, caliche, and ironstone	1	3
CRETACEOUS		
Dakota (?) formation (Gulfian)		
Sandstone, fine- to medium-grained, iron cemented, hard, dark brown; contains small nodules of weathered yellow to light-gray clay. Thin beds of light-gray clay in lower part	15	18
Shale, silty, light gray	2	20
Clay, mottled red and gray	6	26
Clay, gray; contains small concretions of red iron	6	32

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Clay, mottled red and gray	4	36
Clay, silty, bright red; contains some mottled red and gray clay	4	40
Clay, mottled red, gray, purple, and yellow	4	44
Ironstone, clayey, hard, red brown to dark brown	.3	44.3
Siltstone, sandy, light gray and yellow gray	5.7	50
Clay, silty, light gray and some yellow	9	59
Kiowa shale (Comanchean)		
Sandstone, fine-grained, yellow brown	24.5	83.5
Clay, sandy, silty, light gray; contains some mottled gray, red, and yellow silty clay in lower part	5.5	89
Ironstone, clayey, hard, dark red brown and yellow	2	91
Clay, silty, light gray and yellow gray; contains a little fine sand	6	97
Clay shale, silty, light gray	3	100
Shale, silty, blue gray	10	110
Shale, silty, blue gray; contains thin beds of brown hard very fine-grained sandstone at 111, 114, 122, and 136 feet	30	140
Shale, sticky, blue gray; contains beds of hard sandstone or shell-limestone at 162, 173, 182, and 188 feet	60	200
Shale, sticky, blue gray, and shale, blue gray, sandy; contains gypsum	20	220
Shale, blue gray; contains gypsum, pyrite, and zones of hard sandy shale	20	240
Shale, blue gray; contains thin beds of shell-limestone and hard sandy shale, and a little gypsum and pyrite	14	254
Shale, dark blue gray	16	270
Shale, dark blue gray; contains thin beds of brown fine-grained sandstone	10	280
Shale, dark blue gray; contains thin beds of shell-limestone at 282, 296, 308, and 317 feet, and a thin bed of gray fine-grained sandstone at 324.5 feet	60	340
Shale, dark blue gray and black	12	352
Cheyenne sandstone (Comanchean)		
Shale, sandy, blue gray to black	12	364
Sandstone, fine- to medium-grained, light gray	36	400
Permian redbeds		
Shale, silty and fine sandy, red	8	408

2. *Section of the Dakota formation and Kiowa shale in Spring Draw in the SE¼ sec. 4 and E½ sec. 3, T. 30 S., R. 18 W.* (Measured by Bruce F. Latta, John C. Frye, and Claude W. Hibbard.)

	Thickness, feet
CRETACEOUS	
Dakota (?) formation (Gulfian)	
("Reeder sandstone")	
7. Sandstone, iron-cemented, hard, massive, dark brown	10.0
6. Sand, loose, fine to medium, tan and brown	12.0
("Kirby clay")	
5. Clay, mottled red and gray, and shale, silty, red and light gray; contains thin seams of yellow fine-grained sandstone in lower part. Mottled clay contains small red concretions of iron that have weathered out and cover the slope	20.0
Thickness of Dakota formation exposed	42.0

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Kiowa shale (Comanchean)	
("Greenleaf sandstone")	
4. Sandstone, fine-grained, cross-bedded and lensing, yellow tan and buff	29.0
("Spring Creek clay")	
3. Clay shale, silty, mottled gray tan, red, and red brown; contains small concretions and thin beds of ironstone. Weathered slope is strewn with red-brown ironstone rubble	11.0
2. Sandstone, iron-cemented, silty, irregularly bedded, red brown to gray tan; contains concretions, nodules, and wavy bands of ironstone; weathers to brownish black	1.7
1. Clay shale, silty, massive to thin-bedded, mottled gray, red, and red brown; contains concretions of iron. Grades laterally into blue-gray siltstone and shale that contain beds and lenses of light-gray fine-grained sandstone	17.8
Thickness of Kiowa shale exposed	59.5

3. *Section of Kiowa shale along the south bluff of Medicine Lodge River in the E½ sec. 16, T. 30 S., R. 17 W.* (Measured by Bruce F. Latta, Claude W. Hibbard, and John C. Frye.)

	Thickness, feet
CRETACEOUS	
Dakota (?) formation (Gulfian)	
16. Sandstone, hard, dark brown	2.0
15. Clay shale, tan to gray	5.0
Kiowa shale (Comanchean)	
14. Sandstone, fine-grained, cross-bedded, tan to buff	5.2
13. Shale (covered)	20.8
12. Shale, fissile, black; contains crystals of selenite	31.2
11. Shale, gray to black; contains thin bed of tan and buff sandstone near top. Mostly covered	15.6
10. Shell-limestone, gray	.2
9. Shale, blue black and tan; contains beds of thinly laminated sandstone and crystals of selenite	21.2
8. Aragonite (?), fibrous; cone-in-cone structure	.2
7. Shale, thinly bedded, gray to tan	2.5
6. Shell-limestone, gray	.8
5. Shale, fissile, black to dark gray	5.2
4. Shell-limestone, gray	.4
3. Shale, fissile, black; contains thin beds of gray to tan shale	15.6
2. Shell-limestone, gray	.9
1. Shale, fissile, black	2.5
Thickness of Kiowa shale exposed	122.3

4. *Section of Kiowa shale and Cheyenne sandstone in east branch of Champion Draw about one-half mile south of Belvidere, Kansas* (Measured by Bruce F. Latta, John C. Frye, and Claude W. Hibbard).

	Thickness, feet
CRETACEOUS—Comanchean	
Kiowa shale	
12. Shale, black; contains few thin beds of sandstone (mostly covered)	43.0

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11. Shale, thinly laminated, black	10.0
10. Shell bed, capped by 1-inch layer of aragonite	.3
9. Shale, thinly laminated, black; contains small red to brown concretions of iron (limonite)	9.9
8. Shell bed, capped by thin bed of tan fine-grained sandstone	.3
7. Shale, thinly laminated, black	8.4
6. Sandstone, fine-grained, light gray	.5
5. Shale, thinly laminated, black	1.8
4. Shale, fissile, thinly laminated, black; contains few thin lenses of fine-grained sandstone	16.7
3. Shell bed (Champion), capped by thin layer of white fine-grained sandstone	.8
Thickness of Kiowa shale exposed	91.7
Cheyenne sandstone	
2. Sandstone, fine to medium-grained, tan, buff, and brown. Grades laterally into blue-gray lensing shale that contains crystals of selenite and fossil plant material	6.0
1. Sandstone, fine- to medium-grained, cross-bedded, white, gray, tan, buff, and brown; streaked locally with brighter colors such as red, yellow, and purple. Contains small lenses of weathered chert conglomerate and lenses and partings of blue-gray shale. A 3- to 4-inch zone of pebbles and cobbles of quartzite, quartz, and chert is at the base	26.5
Thickness of Cheyenne sandstone exposed	32.5
Unconformity	
PERMIAN—Guadalupian	
Whitehorse sandstone	

5. *Section of Kiowa shale and Cheyenne sandstone in draw in the SE¼ sec. 9, T. 30 S., R. 16 W.*

	Thickness, feet
CRETACEOUS—Comanchean	
Kiowa shale	
12. Shale (covered)	15.0
11. Shell-limestone, hard, gray and brown	.3
10. Clay shale, blocky, black; contains thin beds of buff to tan fine-grained sandstone	10.8
9. Shell-limestone, hard, gray to brown	.2
8. Shale, thinly laminated, black: contains irregular yellow and brown streaks	11.0
7. Sandstone, fine-grained, buff to tan	.1
6. Shale, thinly laminated, black	23.0
5. Sandstone, fine-grained, white	.2
4. Shell-limestone, weathered, red brown; contains crystals of selenite. Fossils are poorly preserved. ("Champion shell bed")	.8
Thickness of Kiowa shale exposed	61.4
Cheyenne sandstone	
3. Clay shale, lensing, dark gray; contains crystals of selenite	6.0
2. Sandstone, fine- to medium-grained, cross-bedded, massive, gray, white, tan, buff, red, and purple; contains white conglomeratic zones of pebbles of quartz and chert in lower part	39.0

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1. Shale, fissile, light gray	3.3
Unconformity	
Thickness of Cheyenne sandstone exposed	48.3
PERMIAN—Guadalupian	
Whitehorse sandstone	

6. *Section of Cheyenne sandstone in the SW¼ sec. 26, T. 30 S., R. 16 W., about 50 yards north of measured section 7.* (Measured by Bruce F. Latta and Claude W. Hibbard.)

	Thickness, feet
CRETACEOUS—Comanchean	
Cheyenne sandstone	
4. Sandstone, fine- to medium-grained, cross-bedded, white, gray, buff, tan, and brown	36.5
3. Sandstone, fine- to medium-grained, yellow, buff, tan, and gray, and shale, fissile, black; interlensing. The maximum thickness of the shale lenses is about 2 feet and of the sandstone lenses about 4 feet	30.0
2. Sandstone (same as bed 2 in section 7)	8.5
1. Conglomerate (same as bed 1 in section 7)	6.0
Thickness of Cheyenne sandstone exposed	81.0

7. *Section of Cheyenne sandstone in the SW¼ sec. 26, T. 30 S., R. 16 W.* (Measured by Bruce F. Latta and Claude W. Hibbard.)

	Thickness, feet
CRETACEOUS—Comanchean	
Cheyenne sandstone	
2. Sandstone, fine- to medium-grained, cross-bedded, white, tan, buff, and brown; contains few lenses of weathered chert gravel in lower part	48.5
1. Conglomerate, cross-bedded, white to gray. Consists of loosely cemented fine to coarse sand that contains pebbles of white to gray weathered chert and quartz. Coarser in upper part	45.5
Thickness of Cheyenne sandstone exposed	94.0
Unconformity	
PERMIAN—Guadalupian	
Whitehorse sandstone	

8. *Section exposed on side of hill and in draw in the NE¼ sec. 12, T. 30 S., R. 16 W.* (Measured by Bruce F. Latta and Perry M. McNally.)

	Thickness, feet
CRETACEOUS—Comanchean	
Kiowa shale	
7. Shale, thinly laminated, black; grade upward into soft blue-gray shale containing yellow streaks and splotches	26.3
6. Sandstone, fine-grained, shaly in places, light- to dark-gray	.5
5. Shell-limestone, brown. Composed almost entirely of fossil shells ("Champion shell bed")	1.6
Thickness of Kiowa shale exposed	28.4

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Cheyenne sandstone	
4. Shale, silty, blue gray to black; grades upward into light- to medium-gray silty shale; contains large crystals of selenite	11.2
3. Sandstone, very fine-grained, shaly, light- to medium-gray; contains veins and lenses of dark-red sandy and silty clay	5.2
2. Sandstone, massive, cross-bedded, fine- to coarse-grained, gray, yellow, tan, white, and purple; contains lenses of coarse weathered chert and quartz. Small nodules of iron weather out on surface. White to gray fine-grained sandstone is most prominent	21.6
1. Sandstone, soft, shaly, very fine-grained, light gray to yellow brown; contains yellow streaks and splotches	2.8
Thickness of Cheyenne sandstone exposed	40.8
Unconformity	
PERMIAN—Guadalupian	
Whitehorse sandstone	

9 *Section of Kiowa shale and Cheyenne sandstone in draw in the N½ sec. 36, T. 30 S., R. 16 W.* (Measured by Bruce F. Latta and Claude W. Hibbard.)

	Thickness, feet
CRETACEOUS—Comanchean	
Kiowa shale	
14. Shale (covered)	
13. Shell-limestone, gray. Fossils are larger than those found in lower shell-beds. Thin layer of fibrous aragonite occurs above shell bed	1.1
12. Shale, thinly laminated, black; contains concretions of iron near top of interval	7.8
11. Shell-limestone, brown	.3
10. Shale, thinly laminated, black	6.2
9. Shell-limestone, hard	.2
8. Shale, thinly laminated, black	11.2
7. Shell-limestone, weathered. Breaks apart easily	.2
6. Shale, thinly laminated, black	4.3
5. Sandstone, fine-grained, white, and shale, thinly laminated, black. Forms ledge	1.5
4. Shale, thinly laminated, black	14.6
3. Shell-limestone, gray (Champion shell bed)	.5
Thickness of Kiowa shale exposed	47.9
Cheyenne sandstone	
2. Clay shale, sandy, gray (Stokes sandstone)	1.5
1. Clay shale, blue gray; contains crystals of selenite. A thin bed of white to gray fine-grained sandstone occurs about 2 feet below top of interval (Lanphier beds)	15.0
Thickness of Cheyenne sandstone exposed	16.5

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10. *Section of Cheyenne sandstone in box canyon in the cen. sec. 36, T. 30 S., R. 16 W.* (Measured by Bruce F. Latta and Claude W. Hibbard.)

	Thickness, feet
CRETACEOUS—Comanchean	
Cheyenne sandstone	
4. Sandstone, fine- to medium-grained, gray to white; contains fossil plants and pyrite. Weathered surface is brown owing to iron staining (Stokes sandstone)	1.5
3. Clay shale, blue gray, sandy at top; contains yellow streaks and splotches (Lanphier beds)	9.5
2. Sandstone, fine-grained, gray to white; contains zones of pebbles of weathered chert in lower part and lenses of gray to black shale. (Corral sandstone)	34.0
1. Clay shale, blue gray to yellow	1.5
Thickness of Cheyenne sandstone exposed	46.5
PERMIAN—Guadalupian	
Whitehorse sandstone	

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