

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 40-13**

**THE ROCK FORMATIONS OF KANSAS**

by

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Knowledge of the characters of rock formations occurring in Kansas has greatest practical importance in exploration for oil and gas in this part of the mid-continent region and in development of the oil and gas supplies after fields have been discovered. Work of the geologist in studying surface outcrops is commonly a first step in the location of acreage that may be deemed worthy of leasing and drilling. In some cases these studies have direct bearing on the interpretation of observed local geologic structures, and in all cases they furnish guides for correlation of <sup>the</sup> formation penetrated in wells. As matter of fact, there are innumerable ways in which the investigations of characters of rock formations have direct or indirect bearing on oil and gas development. This article has been prepared in response to a request for a summary of the rock characters observed in Kansas. The classification, nomenclature, and correlation of rock strata from place to place comprise <sup>the</sup> a division of geologic science termed stratigraphy. It is interesting to note that nowhere in the United States are conditions better suited for a variety of strati-

graphic studies, many of which help in establishing principles, than such work in Kansas.

### Six Major Rock Divisions of Kansas

Consideration of Kansas rocks in broadest view calls attention to a natural division of them into six major parts. This division is not based on kinds of materials, such as sandstone, shale, limestone and other rocks, and it does not refer to the condition of the rocks, whether consolidated or unconsolidated, whether exposed at the surface or known to exist only in certain parts of the subsurface. The major divisions here considered are based on relationships in the age of their formation, on general distinguishing features of composition, and on significant dissimilarities in their regional structure. In order of age from oldest to youngest, the six major rock divisions of Kansas are as follows: 1, the Pre-Cambrian rocks; 2, the Pre-Carboniferous Paleozoic sedimentary rocks; 3, the Lower Carboniferous or Mississippian rocks; 4, the Upper Carboniferous or Pennsylvanian and Permian formations; 5, the Mesozoic rocks, chiefly belonging to the Cretaceous system; and 6, the Tertiary and Quaternary sedimentary deposits. The distribution and general character of each

of these divisions will be described briefly.

### The Pre-Cambrian Rocks

This division underlies all of Kansas, but is exposed nowhere within the borders of the state. It forms the so-called basement, or floor, on which all of the succeeding rocks are laid, and a well located in any county, if drilled sufficiently deep, would encounter it. About 300 wells have actually been drilled into the pre-Cambrian rocks of Kansas. About two-fifths of these "granite wells" are located in the eastern one-third of the state, east of the prime meridian. Many are distributed along the Nemaha granite ridge, trending in a south-southwesterly direction from Nemaha County to eastern Sumner County. Three-fifths of the number of wells penetrating pre-Cambrian rocks are located in western ranges of the state. Many occur along the general Kansas uplift, extending northward from Barton County.

The pre-Cambrian rocks consist chiefly of granite and schist, but there are various other sorts of igneous and metamorphic rocks, including some dark basic types. Among metamorphosed sedi-

mentary formations that are recognized in Kansas are rocks such as quartzite and slate. Locally there is much arkose, a type of grit or sandstone that contains detrital feldspar.

Because of their dense texture, extreme geologic antiquity, and the conditions of their formation, pre-Cambrian rocks are well known to be lacking in value as potential containers of oil or gas. In view of this, it is especially interesting to report commercial quantities of oil in pre-Cambrian arkose on flanks of the central Kansas uplift. This is one of the exceptions that prove a rule, however, for there is no question but that the oil is derived from geologically younger formations, and that it has found its way into the arkose because of the structural conditions and the pore space available in the arkose.

The surface of the pre-Cambrian rocks is decidedly uneven from the standpoint of its elevation in different parts of Kansas. From its highest elevation, a little over 500 feet above sea level in Nemaha County, this surface descends to below sea level in most of eastern Kansas and is considerably below sea level in the western part of the state. In any one district the surface is probably fairly smooth, although gently sloping, and it lies approximately

parallel to the bedding planes of the stratified rocks that rest upon it.

### Pre-Carboniferous Rocks

Formations belonging to the Cambrian, Ordovician, Silurian and Devonian systems form a natural major group of rocks in Kansas, because the strata belonging to them lie essentially parallel to one another throughout their thickness, and because they exhibit general similarities in composition and structure. In upward order, stratigraphic divisions belonging to these systems include (1) the Lamotte sandstone (Upper Cambrian); (2) the Arbuckle group (Upper Cambrian and Lower Ordovician), consisting mostly of cherty dolomite and commonly known as the "siliceous lime"; (3) the Simpson group (Lower Ordovician), consisting largely of sandstone and green shale and comprising the so-called "Wilcox" sand of many oil fields, and the St. Peter sandstone of areas in eastern Kansas; (4) the Viola "lime" (Middle and Upper Ordovician); (5) the Maquoketa shale, (Upper Ordovician); and (6) the Hunton "lime" (Silurian and Devonian). There is much variation in the thickness and character of these divisions from place to place in Kansas. The lowermost rocks (Lamotte and lower

Arbuckle) are much the most widespread, and they tend to retain lithologic characters with little variation between districts. The uppermost, youngest part of the pre-Carboniferous rocks is restricted in distribution to basins such as the Forest City Basin, the Salina Basin, and the Dodge City Basin. The maximum combined thickness of the pre-Carboniferous rocks is a little over 2,000 feet, but in most places the total thickness is much less than this figure. There are several unconformities within the succession, but because there was absence of any significant deformation in the Kansas region until after the time of making these rocks, the beds lie essentially parallel one on another.

#### Lower Carboniferous (Mississippian) Rocks

The Lower Carboniferous, or Mississippian, rocks of Kansas consist mostly of limestone, but they include some shale and sandstone. One of the most widespread formations is the Chattanooga shale, mainly a black slaty deposit containing much carbonaceous matter and considered by many geologists importantly related to the occurrence of oil and gas in associated strata. It is not certain whether the Chattanooga shale is actually of late Devonian or earliest Mississippian age, but there is no question as to its sharp distinction, both structurally and stratigraphically, from the Hunton and underlying pre-Carboniferous rocks on

the one hand, and its close similarity in structure to succeeding Mississippian formations on the other. The pre-Chattanooga formations of the Kansas region were gently folded and leveled by erosion before deposition of the Chattanooga shale and the succeeding Mississippian rocks.

The thickness of the Chattanooga and overlying Mississippian rocks ranges from a feather edge to a known maximum in Kansas of 1138 feet. Detailed studies of the Mississippian rocks of Kansas by Wallace Lee, in a cooperative project of the Federal and State Geological Surveys, have led to recognition in the subsurface of Kansas of most of the Mississippian formations occurring in western Missouri and in Iowa. The report by Lee is now in press and is to appear as Bulletin 32 of the Kansas Geological Survey. Among the units recognized by Lee are the following, arranged in order of age from oldest to youngest: (1) Chattanooga shale, unconformity, (2) Chouteau limestone (including Northview shale and Compton limestone), (3) Sedalia limestone, unconformity, (4) Gilmore City limestone, unconformity, (5) St. Joe limestone, (6) Reeds Spring limestone, (7) Burlington limestone, unconformity (8) Keokuk limestone, unconformity, (9) Cowley formation, (10) Warsaw limestone, (11) Spargen limestone, (12) St. Louis limestone, (13) Ste. Genevieve limestone, unconformity, and (14) rocks of Chester age. The Chouteau beds are of Kinderhook age, the Sedalia and Gilmore City are considered by Lee as undetermined Osage or Kinderhook.

the St. Joe to Keokuk rocks are of Osage age, and the Cowley to Ste. Genevieve beds are of Meramec age. The Osage and Meramec deposits are the most widespread Mississippian rocks in Kansas. Beds of Chester age are only very locally and in part somewhat doubtfully determined.

The Chattanooga shale is thin and black in southeastern Kansas. Northwestward it thickens and changes to dark gray or somewhat greenish. The thin Compton and Northview beds of southeastern Kansas grade into cherty Chouteau limestone in the northeastern part of the state, where this division is locally more than 125 feet thick. The Sedalia limestone consists mostly of buff dolomite containing a little chert. This formation is recognized by Lee in northeastern Kansas, and he reports that it overlaps the Chouteau and rests on the weathered surface of the Chattanooga shale. The Gilmore City limestone is non-cherty, gray and buff, and contains some colitic zones. This formation is tentatively identified in the studies by Lee as present in the northeastern part of Kansas, and as comprising the oldest Mississippian rocks west of the Nemaha ridge.

Rocks of Osage age include non-cherty semi-granular limestone (St. Joe) containing some red and green shale, these beds occurring mainly in southeastern Kansas; dolomitic limestone containing much dark chert (Reeds Spring), spread far to the northwest but not reaching the northeastern part of Kansas; <sup>and</sup> gray limestones and dolomites with opaque white cherty (Burlington and Keokuk), widely distributed.

The Cowley formation is a subsurface division proposed by Lee for dark silty limestones and dolomites that reach a maximum thickness of about 550 feet in Cowley and Chautauqua counties, Kansas. The formation rests unconformably on lower Mississippian formations and the Chattanooga shale and is regarded as filling a broad basin carved in the south-central Kansas and northern Oklahoma region after Keokuk time. The formation is conformably overlain by the Warsaw limestone, which consists mostly of gray cherty limestone. Rocks of later Meramec age include the Spergen, St. Louis and Ste. Genevieve strata, consisting mainly of white oolite and somewhat granular non-cherty limestone. The upper Meramec beds (Warsaw to Ste. Genevieve)

are reported by Lee to have an aggregate thickness of 690 feet in Clark County.

Limestone and shale of Chester age occur locally in southeastern Kansas resting unconformably on the Warsaw limestone, and it has been reported by G. S. Dille from wells in southwestern Kansas and northwestern Oklahoma.

#### Upper Carboniferous (Pennsylvanian) and Permian rocks

The uppermost Paleozoic formations of Kansas, which are classified as Upper Carboniferous (Pennsylvanian) and Permian in age, are grouped together because of their entirely similar parallel structure, their general resemblance in lithologic features, and because they are set apart from underlying and overlying beds by differences in regional structure and occurrence of very important bounding unconformities. The Mississippian and older rocks have been deformed rather considerably. (although not folded), especially along the line of the Nemaha granite ridge and the axis of the central Kansas uplift, and the date of this deformation clearly belongs before the time of early Pennsylvanian sedimentation in the Kansas region. Upper-

most Mississippian (Chester) rocks and lowermost Pennsylvanian (Pushmataha, Morrow, and Lampasaq--stages defined in the Texas, Oklahoma and Arkansas regions) are almost entirely lacking in Kansas. Erosion that occurred in late Mississippian and early Pennsylvanian times resulted in truncation of uplifted portions of the older rocks, developing a fairly smooth plane surface. The lowermost Pennsylvanian sediments deposited on this surface consist of sand, clay, and locally, residual chert and other pebbles that are included in the <sup>Cherokee</sup> shaly shale or, in parts of the subsurface, the Socy formation ("Pennsylvanian basal conglomerate").

The chief subdivisions of the Pennsylvanian and Permian rocks are made on the basis of widespread but obscure unconformities that separate rocks having generally distinct type of fossils and lithologic features. These large divisions have generally been designated as series in Survey reports and other papers of recent years. Present study indicates that they may more appropriately be designated as stages,--a time-rock classificatory term that is next ~~in rank~~ below that of series. <sup>in rank</sup> Thus, the Carboniferous system in Kansas comprises

the Mississippian and Pennsylvanian series, and the latter contains the Des Moines, Missouri and Virgil stages.

The successive stages are divided into groups and these in turn are divided into formations. Most of the Pennsylvanian and Permian formations have been traced entirely across the state along their lines of outcrop, and many of them have been traced in the subsurface to the northern, western, and southern state boundaries. Also, many of the formations have been subdivided into members, which are likewise very widely traceable in careful stratigraphic study. These formations and members, much too numerous for individual mention here, are treated in several reports of the Kansas Geological Survey and the state geologic map.

The Permian rocks, which have long been considered as a geologic system in publications on the geology of Kansas, have generally been divided into two main parts, the Big Blue series, below, and the Cimarron series, above. The Big Blue strata consist mostly of alternating limestone and shale of marine origin, resembling the Pennsylvanian beds. The Cimarron rocks, on the other hand, consist mostly of red sandstone and shale, but they include two or three widely persistent dolomite and anhydrite deposits. The Permian rocks of Kansas are now being divided stratigraphically into

"series" corresponding to those established recently on the basis of western Texas type sections. These major divisions that are applicable to Kansas stratigraphy are, in upward order, Wolfcamp, Leonard, and Guadalupe. Beds tentatively assigned to the Wolfcamp include the Kansas Permian rocks to the top of the Herington limestone; the Leonard is considered to include strata from the Herington to the base of the Whitehorse sandstone; the Guadalupe comprises the higher Permian rocks of Kansas. Inconsistency in classing these Permian divisions as series appears in that they correspond in rank to such parts of the Pennsylvanian series as the Virgil, Missouri and Des Moines "stages". The problem in classification that is presented here calls for further study. Probably the Permian units mentioned should be classed as stages, rather than series.

Consideration of the late Paleozoic rocks of Kansas would be very incomplete without mention of the remarkable nature of cyclic sedimentation that is here observed. This refers to a regular order of succession of individual rock layers in a manner that follows certain very definite lines and that is very frequently repeated with striking fidelity. It is established that the reason for these cycles is the regular oscillatory movements of advancing and retreating shallow seas that invaded the Kansas region. Recognition of various cyclic elements in the rock formations has furnished

basis for a precision of stratigraphic treatment, both in surface and sub-surface work, that would not otherwise have been possible. It is a factor that, combined with other features, makes stratigraphic studies in Kansas of unusual scientific interest, and at the same time of great practical importance.

### Mesozoic Formations

Rocks of Cretaceous age are distributed throughout most of western Kansas, and with possible exception of a very small exposure in Morton County, in southwesternmost Kansas, no Mesozoic strata older than Cretaceous are known to crop out in this region. Jurassic formations have been identified in the subsurface of western Kansas, and it is probable that Triassic beds also occur. Collectively, the Mesozoic rocks form a major structural and stratigraphic unit, for they rest unconformably on an erosion surface that cuts across various Paleozoic rocks, and in places north of Kansas they lie directly on pre-Cambrian rocks. Maximum thickness of the Mesozoic strata in Kansas occurs in the northwestern counties. The regional dip of the Cretaceous rocks is generally northwestward and northward toward the area of

greatest thickness.

The Cretaceous rocks are divided in three main groups, -- the Dakota, Colorado, and Montana. Subdivision of the Dakota group is difficult because of the irregular lenticular nature of the sandstones and other variations. Investigation of Dakota clays of Kansas, now in progress, indicates that the Terra Cotta shale, in the upper part of the Dakota group, is widely persistent in central and northern counties of the state.

Formations and members of the Colorado and Montana groups have been established on the basis of lithologic and faunal characters, which are mostly very regular and clearly defined. A feature of importance in the stratigraphic study of the thick shale and chalk formations has been identification and correlation of very numerous thin bentonite deposits that are distributed through this part of the rock column. The bentonites represent altered volcanic ash falls that apparently affected all of the Kansas region during the time of Cretaceous sedimentation. Each bed was formed in a very short space of time, geologically speaking, and identification of it from place to place serves reliably as a marker in determining

associated deposits that correspond in age. Correlation of bentonite beds observed in different sections has been made very successfully by careful measurements to determine the intervals between the beds. Thus, the Cretaceous, like parts of the Pennsylvanian and Permian beds in Kansas, has furnished opportunity for some very careful detailed stratigraphic subdivisions.

#### Tertiary and Quaternary Rocks

Formations in Kansas that are younger than the Cretaceous consist mostly of unconsolidated sands, clays, and gravels that are spread as a relatively thin veneer over large parts of the High Plains country and distributed along stream courses as valley filling. On first thought, there appears to be little of stratigraphic importance in the geologically young, unconsolidated deposits of the Kansas region. Actually, the study of them reveals much that is of interest. The Tertiary deposits, most of which are included in the Ogallala formation, have been shown by M. K. Elias to be divisible into zones on the basis of different types of fossil grass seeds, and at some places there are rich deposits of fossil bones representing assemblages of extinct mammals. These fossils, and characters of the rocks themselves, give basis for division of the Tertiary strata into definable parts. The rocks