SUBSURFACE GEOLOGIC CROSS SECTION FROM BACA COUNTY TO YUMA COUNTY, COLORADO

By
JOHN C. MAHER

Prepared by Geological Survey, United States Department of the Interior, with cooperation of State Geological Survey of Kansas.

UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS, OIL AND GAS INVESTIGATIONS
PRELIMINARY CROSS SECTION NO. 6
LAWRENCE, KANSAS
1948

SUBSURFACE GEOLOGIC CROSS SECTION FROM BACA COUNTY TO YUMA COUNTY, COLORADO

By

JOHN C. MAHER

INTRODUCTION

Stratigraphic investigations designed to assist in the search for oil and gas in southwestern Kansas, southeastern Colorado, the panhandle of Oklahoma, and a part of the panhandle of Texas were begun in the fall of 1943 by the Geological Survey, U. S. Department of the Interior. The chief purpose of the investigations is to correlate the subsurface Paleozoic beds in this area with the formations in the oil fields of central Kansas. The results of these studies are being presented as a series of regional cross sections published by the State Geological Survey of Kansas. The cross sections previously published as a part of this series, as well as the section presented herewith, are indicated on the index map of this chart. This cross section, the sixth in the series, extends from the Marland Production Company No. 1 Mesa well in the NW¼ SE¼ NE¼ sec. 8, T. 30 S., R. 50 W., Baca County, Colorado, northward to the Indian Territory Illuminating Oil Company No. 1 Strangways well in the Cen. NW¼ SW¼ sec. 21, T. 2 S., R. 43 W., Yuma County, Colorado[1]. It includes nine wells, numbered from south to north.

This investigation has been aided by the cooperation of many geologists and oil companies. The well cuttings on which the work is based were generously loaned by the oil companies and the Colorado School of Mines. The microfossils in the cuttings were identified by L. G. Henbest, who gave considerable assistance with correlations of the Pennsylvanian rocks. The writer is indebted to E. C. Reed of the Nebraska Geological Survey for several discussions of the correlations in the I.T.I.O. Strangways well in Yuma County and the subsurface geology of northeastern Colorado. The cross section was drafted by Catheleen Saint and both the cross section and text were carefully reviewed by H. D. Miser and N. W. Bass.

[1] At the time that this section was submitted for publication (January 22, 1947), no information or samples were available from the Sharples, J. M. Huber, and Frontier Refining Company No. 1 Murray well, SW¼ SW¼ SE¼ sec. 26, T. 29 S., R. 50 W., the Sharples, J. M. Huber, and Frontier Refining Company No. 1 Jacobson well, SE¼ SE¼ SE¼ sec. 28, T. 29 S., R. 50 W., or the J. M. Huber and Frontier Refining Company No. 1 Ingle well, SW¼ SW¼ SE¼ sec. 27, T. 29 S., R. 50 W.

METHODS OF INVESTIGATION

The subsurface stratigraphy of the central Kansas oil fields has been well established through years of work by petroleum geologists who have examined samples from thousands of wells and outcrops. Many of the smaller units of the Permian and Pennsylvanian Systems described on the surface in central and eastern Kansas, and most of the major subdivisions of the Mississippian, Silurian, Devonian, Ordovician, and Cambrian Systems recognized in Missouri, Iowa, and Oklahoma have been identified in the wells and their terminology is generally agreed upon by the Kansas petroleum geologists. These subsurface lithologic units as thus identified and accepted were traced into eastern Colorado by Maher and Collins.[2] This cross section in eastern Colorado extends these correlations northward into Yuma County and southward into Baca County.

[2] Maher, J. C., 1946, Subsurface geologic cross section from Ness County, Kansas, to Lincoln County, Colorado: Kansas Geol. Survey, Oil and Gas Invest., Prelim. Cross Sec. No. 2.
Maher, J. C., 1947, Subsurface geologic cross section from Scott County, Kansas, to Otero County, Colorado: Kansas Geol. Survey, Oil and Gas Invest., Prelim. Cross Sec. No. 4.
Collins, J. B., 1947, Subsurface geologic cross section from Trego County, Kansas, to Cheyenne County, Colorado: Kansas Geol. Survey, Oil and Gas Invest., Prelim. Cross Sec. No. 5.

All logs used on this section are based on detailed microscopic examination of samples by the writer in 1945 and 1946. The microscopic examination of the samples consisted of describing the kind and character of the rocks by their color, hardness, texture, mineral composition, bond or cementing material, and the type and characteristics of chert, oölites, casts, microfossils, glauconite, pyrite, calcite, siderite, and sphalerite. The characteristics of some of the rocks are so distinctive that thin key beds can be traced over great distances. These key beds assisted in the recognition of large sequences of less distinctive or less persistent strata.

Most of the deep wells in eastern Colorado have been drilled by rotary methods which do not permit accurate sampling of the formations penetrated execpt where cores are procured. Each sample of rotary cuttings contains fragments of many different kinds of rock, most of which have been cut at shallower depth than that at which the sample was collected. Usually only a small part of the sample represents the rock actually drilled at the depth marked on the sample container. Therefore the logging of such samples consists of describing for a given interval only that type of rock that has not appeared in the samples at shallower depth and which the geologist believes belongs in that interval. Because this involves interpretation, the logs prepared from rotary cuttings are subject to the personal equation of the geologist, and complete agreement by different geologists regarding details cannot be expected.

In the preparation of this cross section the sample logs were drawn on a vertical scale of one inch equals 100 feet and were reduced to one inch equals 200 feet on the published chart. The logs are alined on sea-level datum and the horizontal scale between wells is 1 inch equals 6 miles. The vertical exaggeration of the section is 158.4 times. This exaggeration permitted the representation of most stratigraphic units, but not all the finer details serving to differentiate those units could be shown.

Electric logs of wells 3, 7, and 9 were plotted on the section to illustrate the close correspondence between the electric logs and the sample logs and to show the relation of the distinctive markers on the electric logs to the geological formations identified in the samples. The sample logs were prepared without reference to the electric logs and no adjustments have been made. Comparison of the two types of logs reveals that generally the recorded depth of a given bed is a few feet less on the electric log than on the sample log. This difference is explained by the fact that the sampling at the surface lags behind the actual cutting of the given bed at depth. Depth corrections or adjustments can be made on the sample log if the electric log is at hand while the samples are being examined.

STRATIGRAPHY

Rocks of Tertiary and Upper Cretaceous age are present at the surface along the line of this section except in the narrow valleys near well 1 in Baca County where Freezeout and Two Butte Creeks have cut through the Upper Cretaceous beds to expose small areas of Lower Cretaceous and Jurassic rocks. Beneath the Jurassic rocks are Triassic (?), Permian, Pennsylvanian, Mississippian, Ordovician, and Cambrian sedimentary rocks lying on Pre-Cambrian igneous and metamorphic rocks. The thickness of the sedimentary rocks penetrated by wells on this section ranges from 1,932 feet in well 1 to 6,346 feet in well 8. The Cenozoic and Mesozoic rocks range in thickness from 640 feet in well 1 to 3,160 feet in well 9, and the Paleozoic rocks from 1,295 feet in well 1 to 4,638 feet in well 4. Only the Paleozoic rocks were studied in this investigation, and they are described herein beginning with the youngest.

PERMIAN SYSTEM

The Permian rocks along the line of this section are about 1,100 feet thick in southeastern Yuma County, nearly 2,000 feet thick in northwestern Prowers County, and about 1,200 feet thick in northwestern Baca County. The thinning toward the north from northwestern Prowers County has been caused by post-Permian and intra-system erosion as well as by depositional conditions; the thinning toward the south from northwestern Prowers County is primarily a result of overlap of lower Pennsylvanian beds on uplifted older Paleozoic and Pre-Cambrian rocks. The Permian rocks are predominantly continental in character and consist mainly of red shale, sandstone, dolomite, anhydrite, and salt. The marine limestones and shales that compose the lower Permian of Kansas are greatly reduced in prominence in eastern Colorado as a result of westward facies changes.

GUADALUPIAN SERIES

The Taloga formation, the Day Creek dolomite, and the Whitehorse sandstone constitute the Guadalupian Series which ranges in thickness from a few feet in wells 8 and 9 to 455 feet in well 4. The Taloga formation, 82 to 220 feet thick in wells 1 to 5, is composed of red shale and thin beds of silty sandstone and stringers of buff dolomite. The Day Creek dolomite, 10 to 78 feet thick in wells 1 to 6, differs in character from well to well. In well 6, it is represented by a 10-foot bed of white finely crystalline anhydrite; in well 2, it consists of white to pink granular anhydrite and dolomitic anhydrite beds, 78 feet thick; and in well 1, it is represented by a bed of cream-colored to pink finely granular dolomite, 15 feet thick. The Whitehorse sandstone, the lowest formation of the Guadalupian Series, ranges in thickness from 10 feet in well 9, where it has been mostly removed by post-Permian erosion, to 218 feet in well 4, where a complete section is present. It consists principally of thick beds of red silty sandstone and red shale which cannot be readily distinguished from those of the underlying Dog Creek shale where the latter is not anhydritic. For this reason, the lower part of the interval assigned herein to the Whitehorse may include the Dog Creek shale.

LEONARDIAN SERIES

Nippewalla group. The Nippewalla group, as defined on the surface, consists in descending order of the Dog Creek shale, Blaine formation, Flowerpot shale, Cedar Hills sandstone, Salt Plain formation, and Harper sandstone. Of these, only the Blaine formation could be readily identified in all wells on this section. The identity of the formations other than the Blaine is suggested by the lithologic sequence in a few wells, but is generally obscured by facies changes. The Nippewalla group maintains a rather uniform thickness of 400 to 500 feet along the line of this section, and offers no evidence for or against an unconformity at its top. Therefore conformable relations between this group and the overlying rocks are shown in the accompanying cross section.

The Dog Creek shale and the Blaine formation have been described by Norton[3] as "a single gypsiferous formation both at the surface and underground, in Kansas, either one thickening at the expense of the other depending on the presence or prior removal of anhydrite or gypsum." Norton has used the combined term "Blaine-Dog Creek" for this sequence wherever the lower massive anhydrite bed is overlain by red anhydritic shale. The upper red anhydritic shale is not present in the wells on this section. Its absence causes doubt as to whether the Dog Creek shale is absent or, if it is present, whether it is represented by a part of the underlying thick anhydrite bed termed "Blaine" or by a part of the overlying shale and sandstone assigned to the "Whitehorse." The term "Blaine formation" is thus provisionally applied in this cross section to the anhydrite sequence. Here it consists of 18 to 120 feet of thick-bedded white to buff finely crystalline anhydrite interbedded with thin layers of red shale. In well 3, however, the Blaine is represented by a white coarsely crystalline dolomite bed, approximately 63 feet thick. The Blaine is an excellent subsurface key bed except in wells 7, 8, and 9. In these wells, it is exceptionally thin-bedded and other thick anhydrite beds, which probably represent a facies of the Salt Plain formation, can be mistaken for the Blaine.

The Flowerpot shale, Cedar Hills sandstone, Salt Plain formation, and Harper sandstone are

[3] Norton, G. H., 1939, Permian red beds of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 23, no. 12, p. 1801.

represented by an irregular sequence of thick beds of red sandy shale, fine silty sandstone, orange coarse-grained sandstone, anhydrite, and salt. Facies changes in relatively short distances are so common in these formations that separation of them on the basis of lithologic character is of little value and has not been attempted in this study.

Sumner group. The Sumner group, the top of which is reportedly marked by a minor unconformity, comprises the Stone Corral dolomite, the Ninnescah shale, and the Wellington formation. This group ranges in thickness from 154 feet in well 9 to 556 feet in well 3. The Stone Corral dolomite, 8 to 60 feet thick, is composed of white to buff granular anhydrite and thin beds of dolomite in wells 2, 3, 5, 6, and 7 where it is typically developed. In well 1, it is represented by a thin white to pink finely crystalline limestone containing a minor amount of anhydrite; in well 8, it is a thin anhydrite bed; and in well 9, it is interbedded anhydrite, salt, and dolomite. The Stone Corral dolomite is not as readily identified in eastern Colorado as in western Kansas, owing to its irregularity and to the presence of other unnamed anhydrite beds.

Below the Stone Corral dolomite is a sequence of thick beds of red sandstone and red shale interspersed with thin beds of dolomite and anhydrite. This sequence, 100 to 500 feet thick, represents the westward extension of the Ninnescah shale and the Wellington formation of Kansas. The differentiation of these formations in eastern Colorado is very difficult because of their continental character, but a tentative division has been made in wells 4 to 8. In these wells, the Ninnescah shale is 118 to 204 feet thick and the Wellington formation is 113 to 237 feet thick. The Ninnescah consists primarily of thick beds of red shale and red fine-grained sandstone; the Wellington includes similar thick beds plus thin beds of salt, dolomite, and anhydrite. North of well 8, the Wellington formation seems to have been overlapped by the Ninnescah shale, as indicated in well 9 where beds of red shale and sandstone tentatively identified as the Ninnescah shale rest directly on a thick bed of dolomite and anhydrite in the Chase group. It is not clear from the logs of wells on this cross section whether this thick dolomite and anhydrite bed is equivalent to the Barneston formation in the middle of the Chase group, as it seems to be in Nebraska (E. C. Reed, personal communication), or is equivalent to some higher formation in the Chase group. If it is equivalent to the Barneston formation, the upper beds of the Chase group must have been removed by erosion near well 9. This condition would support the statements of Condra and Reed[4] that an important unconformity is present at the base of the Ninnescah shale in Nebraska and Kansas. The absence of the Wellington formation in well 9, however, is not by itself necessarily indicative of post-Wellington erosion as this formation thins northward along this section and may not have been deposited in the area of well 9. The writer tentatively has followed Condra and Reed and has indicated an unconformity at the base of the Ninnescah largely because of the irregular relations of the Ninnescah and Wellington in western Kansas and eastern Colorado. It does seem likely, however, that this unconformity is of less importance in western Kansas than in Nebraska.

WOLFCAMPIAN SERIES

Chase and Council Grove groups, undifferentiated. The Chase and Council Grove groups are not readily differentiated along the line of this section; they have a combined thickness ranging from 333 feet in well 7 to 472 feet in well 6. Both groups are present in all wells except well 1 where the Sumner group overlaps the Arbuckle limestone. The top of the Chase group in wells 2 to 8 has been indicated tentatively at the top of a thin bed of dolomite and anhydrite that seems to lie at the same stratigraphic position as the Nolans limestone of western Kansas. The top of the Chase group in well 9 is marked by about 85 feet of interbedded buff very finely granular dolomite and white to pink granular anhydrite, which is considered by some geologists to be the Barneston

[4] Condra, G. E., and Reed, E. C., 1943, The geological section of Nebraska: Nebr. Geol. Survey Bull. 14, pp. 24, 29, pl. 10.

formation including the Fort Riley and Florence limestone members. Beneath the uppermost dolomite and anhydrite beds of the Chase group there is an irregular sequence of thick beds of red sandy to limy shale and red fine-grained sandstone separated by thin beds of buff to pink finely granular dolomite, cream-colored to pink sandy limestone, white granular anhydrite, and salt. The boundary between the Chase and Council Grove groups lies somewhere within this interval. The base of the Council Grove group, which is also the base of the Foraker limestone, is easily recognized in wells 4 to 9. The Foraker limestone consists of 50 to 70 feet of gray-buff fossiliferous porous to oölicastic slightly cherty limestone in wells 7, 8, and 9. Southward it grades into a sequence of alternating limestone and shale beds in wells 5 and 6, and farther south into buff to red sandy slightly cherty dolomite in well 4. The Foraker is not identifiable in wells 2 and 3; there the base of the Council Grove group has been indicated at the top of a red limy shale bed that resembles the Admire group.

Admire group. The Admire group, which rests unconformably on Pennsylvanian rocks, ranges in thickness from 95 feet in well 9 to 255 feet in well 4, and thus exhibits a regional thinning toward the north. It is absent in well 1 ,as are most of the older rocks. The Admire group consists primarily of red shale and red limy shale associated with thin beds of limestone and sandstone. A sandstone about 20 to 30 feet thick and containing weathered limestone and chert fragments is present at the base of the Admire in wells 2, 3, and 4.

PENNSYLVANIAN SYSTEM

Rocks of the Pennsylvanian System are present in wells 9 to 2, ranging in thickness from about 1,000 feet in well 9 to about 2,500 feet in wells 3 and 2. Southward from well 9 to well 2, they grade from typical marine beds of limestone and shale into a near-shore facies of thin-bedded limestone, red limy shale, and arkosic sandstone. The Virgilian, Missourian, Desmoinesian, Atokan, and Morrowan Series are present in all wells except well 9, where the Atokan Series seems to be absent, and except in well 1, where Permian beds rest on the Arbuckle limestone.

VIRGILIAN SERIES

Wabaunsee group. The Wabaunsee group, comprising the youngest Pennsylvanian rocks, is separated by unconformities from the Admire group above and the Shawnee group below. The Wabaunsee consists chiefly of alternating beds of limestone and shale in the northern wells, and red limy shale and sandstone in the southern wells. The thickness of the group increases southward from 67 feet in well 9 to 250 feet in well 3, and decreases southward from well 3 to 162 feet in well 2. Some limestones in the group contain many specimens of brachiopods and fusulinids.

Shawnee group. The Shawnee group, lying unconformably beneath the Wabaunsee group, is 210 to 292 feet thick and consists predominantly of thick beds of limestone separated by thin beds of fine-grained limy sandstone, and red, gray, and black shale. The limestones contain brachiopods, crinoids, and fusulinids, and are mostly light buff to gray and finely crystalline to dense. Thin beds of oölitic and oölicastic limestone are present in all wells; beds of dolomitic limestone and dolomite are present at the base of the group in a few wells. White to tan dense chert, some of which contains fusulinids, is common in the limestone beds in wells 4 to 9, but is lacking in those beds in wells 2 and 3. Red limy shale and sandstone beds make up a greater proportion of the group in the southern wells than in the northern ones.

Douglas group (Virgilian) and Pedee group (Missourian), undifferentiated. Either or both the Douglas and Pedee groups may be represented by the irregular sequence of gray limy sandstone and maroon, green, and black shale that intervenes between the Shawnee and Lansing groups in wells 2 to 9. The shale beds in some wells contain weathered limestone and chert fragments that serve as a valuable aid in determining the eroded top of the underlying Lansing group, a potential oil reservoir. The Douglas and Pedee unit ranges in thickness from 24 feet to 48 feet along the line of this section.

MISSOURIAN SERIES

Lansing, Kansas City, and Bronson groups, undifferentiated. The Lansing, Kansas City, and Bronson groups are usually regarded as a unit by subsurface geologists in Kansas because of the impracticability of distinguishing the individual groups or formations. This unit is composed chiefly of thick beds of cream-colored to gray-buff cherty finely crystalline limestone and thin beds of red, gray, and black shale. In wells 2 and 3, however, the limestone beds are less dominant and most of the unit consists of red limy shale and red fine-grained sandstone. Beds of oölitic, oölicastic, and fossiliferous limestone are common in this unit, and some beds of dolomite are present in well 8. The combined thickness of the Lansing, Kansas City, and Bronson groups along the line of this section ranges from 247 to 417 feet.

DESMOINESIAN SERIES

The Desmoinesian Series is characterized by beds of dark-colored limestone and shale in the northern wells on this section; it exhibits a marked change of facies southwest of well 4, and grades into a sequence of red limy shale, thin-bedded limestone, and fine-grained sandstone in well 3, and then into beds of feldspathic sandy limestone, feldspathic sandstone, and red gray shale in well 2. The top of the series is generally marked by beds of red and green shale, and red sandstone that contain fragments of limestone, chert, and feldspar indicative of the unconformable relations between the Desmoinesian and Missourian Series. The base of the series is well defined by an arkosic sandstone in wells 2 and 3, and by a gray-brown micaceous sandstone in well 4. The base is less distinct in wells 5 to 9 where it has been arbitrarily drawn at the base of a dark-colored dense limestone that in some wells overlies green and black shale and a thin bed of dolomite, and in others overlies green and black shale and thin layers of anhydrite. The thickness of the Desmoinesian Series as thus delimited ranges from 338 to 425 feet.

The Desmoinesian Series is divided into the Marmaton group and the Cherokee shale; these units have been separated only in wells 5 to 9 where the Fort Scott limestone at the base of the Marmaton group can be identified. The Marmaton group, 138 to 165 feet thick in wells 5 to 9, consists of gray to gray-buff finely crystalline to dense limestone beds, fine-grained limy sandstone beds, and gray, black, red, and green shale beds. Many of the limestone beds contain brachiopods, fusulinids, oölites, and gray to black chert. The coral *Chaetetes* is common in the lower part of the group. The basal formation of the group, the Fort Scott limestone, is characterized by a relative abundance of brachiopods, fusulinids, pyrite, and black dense chert. The Marmaton grades laterally into red limy shale and feldspathic sandstone in wells 2 and 3.

The Cherokee shale, 218 to 400 feet thick in wells 5 to 9, is characterized by beds of gray, red, and black shale and dark-colored limestone. Gray to black chert, oölites, and fossils are present in some of the limestones. Like the overlying Marmaton, the dark shale and limestone beds of the Cherokee grade laterally into red, gray, and green limy shale and sandstone in wells 2 and 3. The base of the Cherokee shale in well 9, as shown on the cross section, is considered tentative until confirmed by additional data.

ATOKAN SERIES

Rocks tentatively considered as the equivalent of the Atoka formation of Oklahoma are present in wells 2 to 8 inclusive where they range in thickness from 95 feet in well 8 to 863 feet in well 3. These rocks are treated as a series in this report following the suggestion of Spivey and Roberts[5] that the name "Atoka" be elevated to series rank. In wells 5 to 8, the Atokan rocks, 95 to 185 feet thick, form a sequence of brown to black dense cherty limestone and black shale containing one or two thin beds of anhydrite and dolomite near the top. This sequence thickens to 522 feet in well 4 primarily by an increase in the amount of black shale. In well 3, the Atokan rocks reach their maximum thickness of 863 feet, most of which is ar-

[5] Spivey, R. C., and Roberts, T. G., 1946, Lower Pennsylvanian terminology in central Texas: Am. Assoc. Petroleum Geologists Bull. vol. 30, no. 2, pp. 185-186.

kosic sandstone and red and gray shale containing lesser amounts of limestone. This arkosic facies is present in well 2 also, but is only 465 feet thick. The identification of Atokan rocks in this area is confirmed by fusulinids examined by Henbest, but the delimitation of these rocks is only tentative as the fusulinids found in the samples were not numerous enough to bracket the boundaries closely. The boundaries are thus drawn arbitrarily where unconformities seem to be indicated by the samples.

MORROWAN SERIES

A sequence of black shale, green shale, cream-colored glauconitic and crinoidal limestone, and white calcareous sandstone which overlies the Mississippian rocks with angular discordance in the Stanolind Oil and Gas Company No. 1 Patterson well in sec. 23, T. 22 S., R. 38 W., Kearny County, Kansas, has been assigned by Thompson[6] to the Morrowan Series on the basis of fusulinids. This sequence, traced westward into southeastern Colorado on a previously published cross section[7], is readily recognized in wells 2 to 8 on this cross section. It may also be represented in well 9 where beds of green and black shale overlying the Mississippian rocks have been tentatively classified as undifferentiated Atokan and Morrowan rocks because of the lack of either fossil or lithologic evidence for series differentiation. The thickness of the Morrowan rocks ranges from 237 to 332 feet in wells 5 to 8 and from 398 to 462 feet in wells 2 to 4 indicating the existence of an early Pennsylvanian structural trough or basin near the south end of this section. The Morrowan rocks show an increased amount of sandstone and shale in wells 2 and 3.

MISSISSIPPIAN SYSTEM

The Mississippian System in eastern Colorado is made up chiefly of thick beds of light-gray to buff limestone, dolomitic limestone, and dolomite, some of which contain distinctive cherts and oölites. A fine- to coarse-grained calcareous sandstone bed is generally present at the base. The classification of these beds into series and formations, principally on the basis of lithic characteristics, follows that used by Lee[8] for the most part. Both the upper and lower boundaries of the system are defined by major angular unconformities; several formational boundaries within the system are marked by minor unconformities. Southward along the line of this cross section, the Mississippiian rocks range in thickness from 168 to 452 feet between wells 9 and 5, and from 452 to 368 feet between wells 5 and 2. Mississippian rocks are absent in well 1.

MERAMECIAN SERIES

St. Genevieve limestone. The uppermost formation of the Meramecian Series, the Ste. Genevieve limestone, is present in the structurally low area in Bent, Prowers, and southern Kiowa Counties between wells 2 and 6. Its maximum thickness is 80 feet in well 5 in northern Prowers County. This formation consists of cream-colored to gray-buff finely crystalline, finely oölitic, and finely arenaceous limestone containing traces of glauconite.

St. Louis limestone. The St. Louis limestone ranges from 114 to 162 feet in thickness in wells 2 to 7, and is absent in wells 1, 8, and 9. It consists chiefly of buff to gray-buff slightly cherty finely crystalline to dense limestones; finely crystalline oölitic limestones predominate at the top and bottom and dense limestones predominate in the middle part of the St. Louis. A dark buff very finely granular bed of dolomite, 5 to 20 feet thick, is present about 30 to 40 feet above the base in several wells. The base is generally marked by gray-buff finely crystalline limestone containing gray to black slightly mottled dense chert. In contrast to the Ste. Genevieve limestone, the St. Louis is not sandy and it contains larger oölites. Some glauconite and a few brachiopods and crinoids commonly are found near the top.

---

[6] Thompson, M. L., 1944, Pennsylvanian Morrowan rocks and fusulinids of Kansas: Kansas Geol. Survey Bull. 52, pt. 7.

[7] Maher, J. C., 1947, *op. cit.*

[8] Lee, Wallace, 1940, Subsurface Mississippian rocks of Kansas: Kansas Geol. Survey Bull. 33, pl. 7.

———, 1943, The stratigraphy and structural development of the Forest City basin in Kansas: Kansas Geol. Survey Bull. 51, p. 66.

Spergen and Warsaw limestones, undifferentiated. Owing to the seeming facies changes within the Spergen and Warsaw limestones and to the lack of fossil evidence, no attempt has been made to separate these two formations. This sequence, present in wells 2 to 9, ranges in thickness from 128 feet in well 3, where both the Spergen and Warsaw limestones are well represented, to 67 feet in well 9, where most of the Spergen limestone seems to be absent. The lithologic character of the beds in this sequence differs considerably from well to well, ranging from gray-buff slightly cherty and oölitic limestone to brown resinous finely granular dolomite. In wells 4 and 5 the Spergen-Warsaw unit is about 90 percent dolomite; in well 3 it is about 80 percent limestone; and in well 2 the lower half is gray silty limestone and gray shale, which has been referred to the Kinderhookian Series by some geologists. Gray dense mottled or fossiliferous chert is common in the middle and near the base of the unit. The foraminifer *Endothyra,* commonly is present in the Spergen limestone on the outcrop and is present near the middle of the unit in some wells.

OSAGIAN SERIES

Keokuk and Burlington limestones, undifferentiated. Because of similar lithologic character, the Keokuk and Burlington limestones are considered as a unit on this cross section. This unit in Kansas has been commonly termed "Osage" or "Boone" by the oil geologists. It is present in all the wells on this section except well 1, and ranges in thickness from 20 feet in well 9 to 97 feet in well 4, which is structurally low. The beds of this unit consist mainly of gray-buff to buff finely granular dolomite containing much white devitrified chert. However, the beds in well 6 are composed entirely of dolomitic limestone rather than dolomite, probably as a result of facies change. White to grayish-white dense chert, glauconite, calcite, drusy quartz, and crinoid stems are common in the samples from these beds. The gray spicular and glauconitic chert which in most wells characterizes the lower 20 to 30 feet of the unit is a valuable aid in distinguishing the Keokuk-Burlington unit from the Viola limestone in this area.

KINDERHOOKIAN SERIES

Gilmore City limestone. The Gilmore City limestone in its typical development is characterized by large oölites or pisolites in beds of cream to buff finely crystalline noncherty limestone. Some of the limestone beds are soft and have an "oatmeal" texture that is distinctive. The thickness of the Gilmore City ranges from 18 feet in well 3 to 75 feet in well 9. It is not present in well 1, and could not be separated from the "Misener sand" in well 4 because of the finely powdered condition of the samples.

In wells 7, 8, and 9, a brown noncherty dense limestone, about 5 to 15 feet thick, and a brown finely granular noncherty dolomite, about 15 to 20 feet thick, underlie the typical buff very cherty glauconitic finely granular dolomite beds easily recognized as belonging to the Keokuk and Burlington limestones. Both the brown limestone bed and the underlying brown dolomite bed are included in the lower part of the Keokuk-Burlington unit by some geologists. Little or no evidence is at hand to prove or disprove this correlation, but the writer prefers to exclude the brown limestone and dolomite beds from the Keokuk-Burlington unit at present for two reasons: (1) the glauconitic chert found in the basal beds of the Keokuk-Burlington unit in wells 2, 3, 4, 5, and 6 is present in wells 7, 8, and 9 above the two brown limestone and dolomite beds; (2) southward from well 9, the upper brown limestone bed seems to pass from a dense into an oölitic facies, which gradually replaces the underlying brown dolomite bed and resembles the Gilmore City limestone as delimited by Lee[9] in western Kansas. It is possible that the brown limestone and dolomite beds in wells 7, 8, and 9 may be older than Keokuk and Burlington and still younger than the Gilmore City but, for lack of evidence, they are included in the Gilmore City limestone in this report.

[9] Lee, Wallace, 1940, *op. cit.*

"Misener sand." A thin bed of white calcareous sandstone composed of fine to coarse subround quartz grains associated with green shale and glauconite intervenes between the Mississippian and Ordovician limestones and dolomites in all the wells on this section. Some gray finely granular dolomite is included in this unit in well 3. The "Misener sand" ranges in thickness from 5 feet in well 9 to 35 feet in well 3. This sand resembles the Simpson sandstone, and has been particularly confusing in wells 2 and 6. Although there is little doubt now that the sand in well 6 is "Misener," the same correlation in well 2 is not so certain. This latter well was drilled in 1928; cable tools were used below a depth of 3,985 feet. The samples obtained from the Mississippian and Ordovician rocks are good to the base of the Keokuk and Burlington limestones, but below that depth they contain considerable cavings indicating that some trouble may have been experienced with water from the underlying sandstone. The lithologic sequence as taken from these samples shows 15 feet of dark-green shale underlain by 20 feet of coarse-grained pyritic sandstone and yellow, green, and purple shale. The samples from the next 45 feet beneath this sand consist of pink finely crystalline dolomite, yellow, green, and purple shale (suggestive of the Harding sandstone of the Front Range), and coarse sand grains. This lower 45-foot interval can be interpreted in two ways: (1) the shale and sand represent cavings, and the first occurrence of the pink finely crystalline dolomite marks the top of the Arbuckle limestone or (2) the lower interval is the Harding sandstone. The first interpretation is shown tentatively on the section, but may have to be revised when additional wells are drilled near by. It seems certain, however, that the cherty dolomite above the "Misener sand" is not the Viola limestone as earlier believed. The glauconitic chert in this dolomite is similar to that in the lower beds of the Keokuk and Burlington sequence throughout the area.

ORDOVICIAN AND CAMBRIAN SYSTEMS

All the wells on this section penetrated rocks of Ordovician or Cambrian age, but only wells 1, 7, 8, and 9 reached Pre-Cambrian rocks. Wells 1 and 9, at opposite ends of the cross section where Ordovician rocks seem to be absent, penetrated 83 and 117 feet, respectively, of rocks of probable Cambrian age before entering the pre-Cambrian complex, whereas wells 7 and 8, near the middle of the cross section, drilled through 450 and 404 feet, respectively, of both Ordovician and Cambrian rocks before reaching pre-Cambrian schist. Important unconformities are present at the top of the Viola limestone, the Arbuckle group, and the Pre-Cambrian complex.

BEDS OF TRENTON AGE

Viola limestone. The term Viola limestone is used herein, in accordance with common usage in Kansas, to refer to the buff to gray-buff finely crystalline to granular very cherty dolomite resting on the Simpson rocks in some places and on the Arbuckle limestone in other places. The true relationship of this sequence to the Viola limestone of the Arbuckle Mountains of southern Oklahoma or to the Galena limestone of the upper Mississippi Valley has not been established. The Viola limestone, 50 to 87 feet thick, is present in wells 4, 5, and 6 near the middle of the section, but seems to be absent in wells 1, 2, and 3 at the south end of the cross section and in wells 7, 8, and 9 at the north end. It is possible that a thin bed of buff finely crystalline to finely granular dolomite containing bryozoa and some cream-colored banded chert in well 7 and a similar thin dolomite bed containing white dense to fossiliferous chert in well 8 may represent the western edge of the Viola rather than the uppermost bed of the Arbuckle group as shown herewith. However, these dolomite beds resemble those typical of the Arbuckle group except for the concentration of chert, and the writer is inclined to regard this chert concentration as the result of ground-water action at the top of the Arbuckle beds when they were exposed to erosion.

BEDS OF BEEKMANTOWN AND CROIXIAN AGE

Arbuckle limestone and Bonneterre dolomite. All wells on this section penetrated rocks of Arbuckle or Bonneterre age, but only wells 1, 7, 8, and 9 reached Pre-Cambrian rocks. The thickness of the Arbuckle-Bonneterre rocks ranges from 32 feet in well 9 to 435 feet in well 7. The general sequence of beds of these rocks is illustrated by well 7; it includes in descending order (1) about 60 feet of buff finely crystalline noncherty dolomite with about 5 feet of medium-grained subangular feldspathic sandstone at its base; (2) about 115 feet of light-buff to pink finely granular to finely crystalline dolomite, the base of which contains oölites, crinoids, and white dense chert and rests on a thin medium-grained feldspathic sandstone; (3) about 150 feet of gray-buff finely crystalline to coarsely crystalline, slightly oölitic, dolomite; (4) about 70 feet of gray coarsely crystalline glauconitic dolomite, and about 50 feet of pinkish-buff to red coarsely crystalline glauconitic sandy dolomite with traces of sphalerite in some wells. The beds of subdivision 4 are commonly referred to the Bonneterre dolomite.

Lamotte sandstone. The Lamotte sandstone at the base of the Cambrian System is called also the Reagan sandstone and the Sawatch sandstone; it is present in wells 7, 8, and 9 where it is respectively 16, 48, and 85 feet thick. A 3-foot dolomitic sandstone, or very sandy dolomite, on top of the Pre-Cambrian granite in well 1 is tentatively designated Lamotte although it is difficult to distinguish such a thin bed from a sandy facies of the lower part of the Bonneterre dolomite. The Lamotte sandstone consists of white coarse subrounded quartz grains which generally show evidence of secondary growth, and the lower part contains a few subrounded feldspar grains. Glauconite is common throughout the sandstone. In some wells, the grains in the upper part of the formation are cemented with dolomite.

PRE-CAMBRIAN ROCKS

Pre-Cambrian rocks were penetrated by four wells. Well 1 drilled 152 feet into pink granite and schist; wells 7, 8, and 9 penetrated 23, 14, and 26 feet respectively of mica schist.

STRUCTURAL FEATURES

This cross section follows a devious course northeastward along the major structural feature of eastern Colorado known as the Las Animas[10] arch or Sierra Grande arch. The Las Animas arch is well defined in the exposed Cretaceous rocks as mapped by Darton[11], Dane and Pierce[12], and Aurand[13], but its expression in the buried Paleozoic formations, discussed as early as 1921 by Rich[14] and Lee[15], remains relatively obscure because data on the subsurface rocks are available for only a few widely separated wells. The relation of the Las Animas arch to the Apishapa arch, which trends southeastward from the Wet Mountains to intersect the Las Animas arch in Las Animas County, is also obscure for the same reason. Concerning the relations of these two arches, Dane and Pierce state: "It does, however, seem plausible that the Apishapa anticline, which separates the Trinidad-Raton and Denver Basins, represents a recurrence of folding on the major structural axis developed earlier by the rise of the Pennsylvanian land mass, which probably had a similar trend to that of the Apishapa anticline. Although the suggestion occurs at once that the Sierra Grande uplift is due to a similar recurrent folding, there has so far been no evidence of a trend of this northeasterly direction in a buried older ridge."

The altitude of the pre-Pennsylvanian rocks along the line of this section ranges from about 3,100 feet above sea level in well 1 at the south

[10] The name "Las Animas arch" is used in this report in accordance with the usage shown on the Tectonic map of the United States prepared by the National Research Council and published by the American Association of Petroleum Geologists in 1944.

[11] Darton, N. H., 1906, Geology and underground waters of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Prof. Paper 52, pl. 26.

[12] Dane, C. H., and Pierce, W. H., 1933, Geology and oil and gas prospects in part of eastern Colorado: U. S. Dept. Interior Press Release June 8.

[13] Aurand, H. A., 1933, Structure map of eastern Colorado and parts of adjacent states: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 4.

[14] Rich, J. L., 1921, A probable buried mountain range of early Permian age east of the present Rocky Mountains in New Mexico and Colorado: Am. Assoc. Petroleum Geologists Bull., vol. 5, no. 5, pp. 605-08.

[15] Lee, W. T., 1921, Concerning granite in wells in eastern New Mexico: Am. Assoc. Petroleum Geologists Bull., vol. 5, no. 2, pp. 163-167.

end to nearly 1,800 feet below sea level in well 9 at the north end. Most of the difference in altitude occurs between wells 1 and 2 where the beds dip steeply, or are faulted downward, to the northeast into a trough or basin filled with arkosic beds of the Morrowan and Atokan Series. It is apparent from the stratigraphy between wells 1 and 2 that the area of well 1 was structurally high at the beginning of Pennsylvanian time and possibly earlier, but the relation of this high area to the Las Animas arch and to the Apishapa arch is not clear. Between wells 3 and 4, the pre-Pennsylvanian beds are essentially horizontal, but from well 4, on the east side of the Las Animas arch as mapped on the Dakota sandstone, the pre-Pennsylvanian beds rise gradually northward to well 7, which is on the axis of the Las Animas arch. Northward from well 7, the pre-Pennsylvanian rocks dip gently northward and thin considerably to well 9. The thinness of the Mississippian and Ordovician beds in well 9 suggests that the area at the north end of the cross section was relatively high at the end of both the Mississippian and Ordovician Periods.

OIL AND GAS

Most of the oil- and gas-bearing strata of western Kansas, including the Lamotte sandstone, Arbuckle limestone, Viola limestone, Mississippian limestones, "Misener sand," basal Cherokee sandstone, and limestones of the Lansing, Kansas City, and Shawnee groups, are present in eastern Colorado along the line of this cross section. Although commercial quantities of oil have not been found in these rocks in Colorado, numerous shows of oil have been reported in the Pennsylvanian formations. Conditions favorable to the accumulation of petroleum exist between wells 1 and 2, where the Mississippian and older beds have been truncated or faulted, and thick Pennsylvanian sandstones wedge out against uplifted Ordovician, Cambrian, and Pre-Cambrian rocks. Between wells 6 and 8, there are favorable structural and stratigraphic conditions—the area is structurally high, some sandstones are present in the lower Pennsylvanian beds, the Ste. Genevieve and St. Louis limestones are truncated and sealed by Pennsylvanian beds, and the "Misener sand" is relatively thick. North of well 8, the lower Pennsylvanian sandstones and the "Misener sand" wedge out, the Mississippian limestones and the Ordovician and Cambrian dolomite beds are truncated, and the Lamotte sandstone is thick and coarse-grained. These conditions would favor the accumulation of oil in any local anticlinal structures that may exist between wells 8 and 9. In most of eastern Colorado, the possibility of oil accumulations in lower Pennsylvanian sand bodies deposited along shorelines or in channels exists but the presence and character of such sand bodies cannot be predicted from the present data.

STATE GEOLOGICAL SURVEY OF KANSAS

Recent Publications

BULLETIN 40. Geology and Ground-Water Resources of Morton County, Kansas, by Thad G. McLaughlin, 126 pages, 1942. **Mailing charge, 25 cents.**

BULLETIN 41. 1942 Reports of Studies (Ten parts issued separately). **Mailing charge, 10 cents each part.**

BULLETIN 42. Exploration for Oil and Gas in Western Kansas During 1941, by Walter A. Ver Wiebe, 123 pages, 1942. **Mailing charge, 25 cents.**

BULLETIN 43. Geology and Ground-Water Resources of Ford County, Kansas, by Herbert A. Waite, 250 pages, 1942. **Mailing charge, 25 cents.**

BULLETIN 44. Geophysical Investigations in the Tri-State Zinc and Lead Mining District, by J. J. Jakosky, R. M. Dreyer, and C. H. Wilson, 151 pages, 1942. **Mailing charge, 25 cents.**

BULLETIN 45. Geology and Ground-Water Resources of Meade County, Kansas, by John C. Frye, 152 pages. **Mailing charge, 25 cents.**

BULLETIN 46. Coal Resources of the Douglas Group in East-Central Kansas, by Arthur L. Bowsher and John M. Jewett, 94 pages, 1943. **Mailing charge, 25 cents.**

BULLETIN 47. 1943 Reports of Studies (Four parts issued separately). **Mailing charge, 10 cents each part.**

BULLETIN 49. Geology and Ground-Water Resources of Hamilton and Kearny Counties, Kansas, by Thad G. McLaughlin, 220 pages, 1943. **Mailing charge, 25 cents.**

BULLETIN 50. Ground Water in the Oil-Field Areas of Ellis and Russell Counties, Kansas, by John C. Frye and James J. Brazil, 104 pages, 1943. **Mailing charge, 25 cents.**

BULLETIN 51. The Stratigraphy and Structural Development of the Forest City Basin in Kansas, by Wallace Lee, 142 pages, 1943. **Mailing charge, 25 cents.**

BULLETIN 52. 1944 Reports of Studies (Seven parts issued separately). **Mailing charge, 10 cents (parts 1-5, 7), 25 cents (part 6).**

BULLETIN 53. McLouth Gas and Oil Field, Jefferson and Leavenworth Counties, Kansas, by Wallace Lee and Thomas G. Payne, 193 pages, 1944. **Mailing charge, 25 cents.**

BULLETIN 55. Geology and Ground-Water Resources and Finney and Gray Counties, Kansas, by Bruce F. Latta, 272 pages, 1944. **Mailing charge, 25 cents.**

BULLETIN 56. Exploration for Oil and Gas in Western Kansas During 1944, by Walter A. Ver Wiebe, 112 pages, 1945. **Mailing charge, 25 cents.**

BULLETIN 57. Oil and Gas in Eastern Kansas, by John Mark Jewett and George E. Abernathy, 244 pages, 1945. **Mailing charge, 25 cents.**

BULLETIN 58. Stratigraphy of the Marmaton Group, Pennsylvanian, in Kansas, by John Mark Jewett, 148 pages, 1945. **Mailing charge, 25 cents.**

BULLETIN 59. Geology and Ground-Water Resources of Thomas County, Kansas, by John C. Frye, 110 pages, 1945. **Mailing charge, 25 cents.**

BULLETIN 60. 1945 Reports of Studies (Four parts issued separately). Mailing charge, 10 cents each part.

BULLETIN 61. Geology and Ground-Water Resources of Grant, Haskell, and Stevens Counties, Kansas, by Thad G. McLaughlin, 221 pages, 1946. **Mailing charge, 25 cents.**

BULLETIN 62. Exploration for Oil and Gas in Western Kansas During 1945, by Walter A. Ver Wiebe, 112 pages, 1946. **Mailing charge, 25 cents.**

BULLETIN 63. Coal Resources of the Wabaunsee Group in Eastern Kansas, by Walter H. Schoewe, 144 pages. **Mailing charge, 25 cents.**

BULLETIN 65. Geology and Ground-Water Resources of Kiowa County, Kansas, by Bruce F. Latta, 151 pages, 1948. **Mailing charge, 25 cents.**

BULLETIN 66. Geology and Ground-Water Resources of Scott County, Kansas, by H. A. Waite, 216 pages, 1947. **Mailing charge, 25 cents.**

BULLETIN 67. Kansas Clay, Dakota formation, by Norman Plummer and John F. Romary, 241 pages, 1947. **Mailing charge, 25 cents.**

BULLETIN 68. Exploration for Oil and Gas in Western Kansas During 1946, by Walter A. Ver Wiebe, 112 pages, 1947. **Mailing charge, 25 cents.**

BULLETIN 69. Geology and Ground-Water Resources of Seward County, Kansas, by Frank E. Byrne and Thad G. McLaughlin, 140 pages, 1948. **Mailing charge, 25 cents.**

GLIMPSES FROM RESOURCE-FULL KANSAS, by John C. Frye, John M. Jewett, and Walter H. Schoewe, 48 pages, 1946. **Mailing charge, 5 cents.**

STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 64

1946 REPORTS OF STUDIES

PART 1. PETROGRAPHIC COMPARISON OF PLIOCENE AND PLEISTOCENE VOLCANIC ASH FROM WESTERN KANSAS, by Ada Swineford and John C. Frye, pp. 1-32, pl. 1, figs. 1-4, April 15, 1946.

PART 2. SILICIFIED ROCK IN THE OGALLALA FORMATION, by John C. Frye and Ada Swineford, pp. 33-76, pls. 1-8, fig. 1, July 1, 1946.

PART 3. GROUND-WATER CONDITIONS IN ELM CREEK VALLEY, BARBER COUNTY, KANSAS, by Charles C. Williams and Charles K. Bayne, pp. 77-124, pls. 1. 2, figs. 1-9, September 16, 1946.

PART 4. STRIP-MINED AREAS IN THE SOUTHEASTERN KANSAS COAL FIELD, by G. E. Abernathy, pp. 125-144, pls. 1-3, fig. 1, November 15, 1946.

PART 5. GROUND-WATER CONDITIONS IN ARKANSAS RIVER VALLEY IN THE VICINITY OF HUTCHINSON, KANSAS, by Charles C. Williams, pp. 145-215, pls. 1-6, figs. 1-11, December 30, 1946.

PART 6. CRETACEOUS STRATIGRAPHY OF THE BELVIDERE AREA, KIOWA COUNTY, KANSAS, by Bruce F. Latta, pp. 217-260, pls. 1-3, figs. 1-4, December 30, 1946.

BULLETIN 70

1947 REPORTS OF STUDIES

PART 1. COAL RESERVES IN KANSAS, by G. E. Abernathy, J. M. Jewett, and W. H. Schoewe, pp. 1-20, figs. 1, 2, April 30, 1947.

PART 2. MAGNETIC SURVEY OF THE BALA INTRUSIVE, RILEY COUNTY, KANSAS, by Robert M. Dreyer, pp. 21-28, figs. 1-4, June 15, 1947.

PART 3. THE LATE PLEISTOCENE LOESSES OF CENTRAL KANSAS, by John C. Frye and O. S. Fent, pp. 29-52, figs. 1-3, pls. 1-2, September 15, 1947.

PART 4. CEMENTED SANDSTONES OF THE DAKOTA AND KIOWA FORMATIONS IN KANSAS, by Ada Swineford, pp. 53-104, figs. 1-3, pls. 1-7, November 15, 1947.

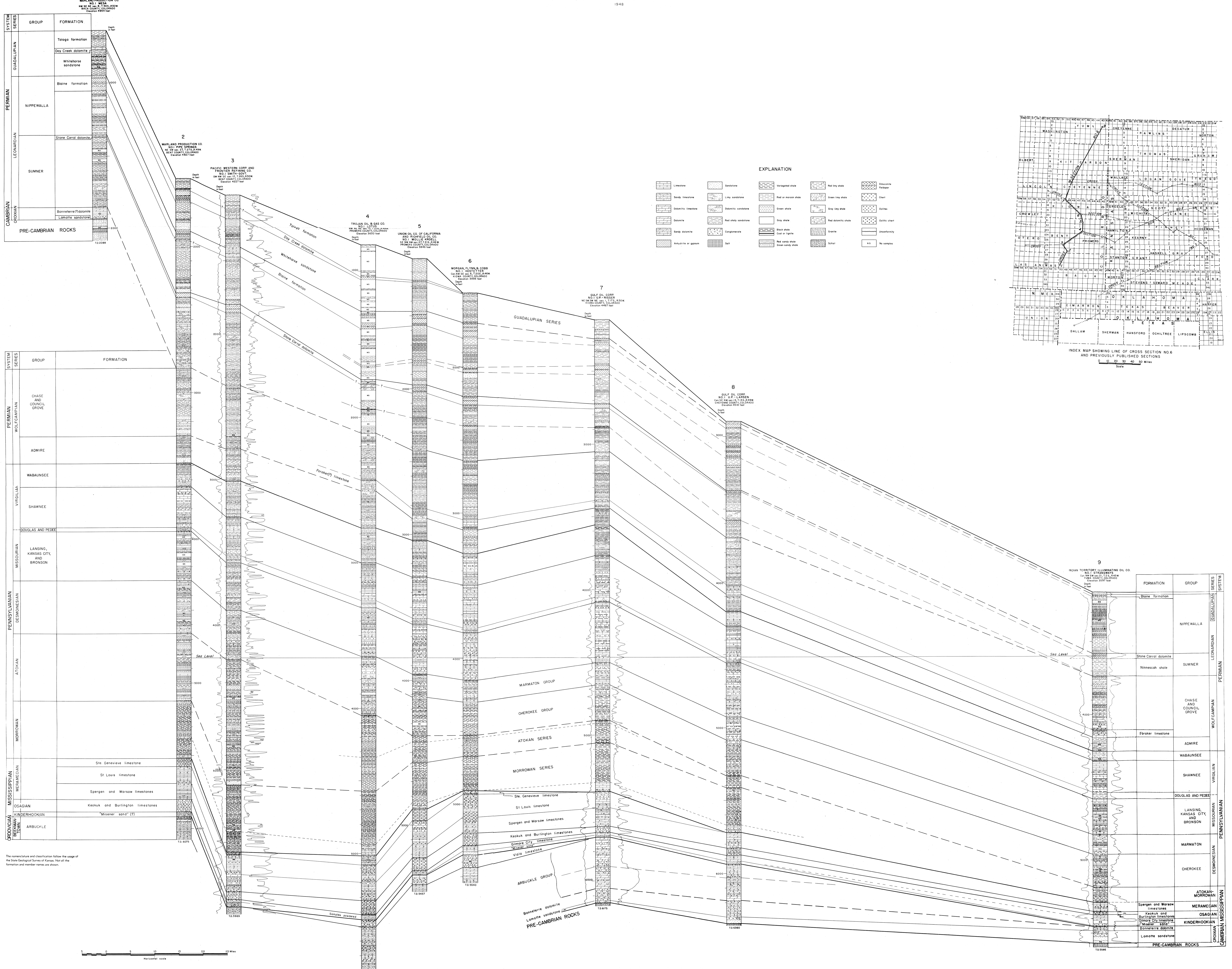
PART 5. MAGNETIC SURVEY OF SOUTHEASTERN CRAWFORD COUNTY, KANSAS, by Robert M. Dreyer, pp. 105-115, pls. 1-3, December 15, 1947.

University of Kansas
State Geological Survey of Kansas

Prepared by Geological Survey, United States Department of the Interior, with cooperation of State Geological Survey of Kansas

1948

Oil and Gas Investigations
Preliminary Cross Section No.6



The nomenclature and classification follow the usage of the State Geological Survey of Kansas. Not all the formation and member names are shown.

SUBSURFACE GEOLOGIC CROSS SECTION FROM BACA COUNTY, COLORADO, TO YUMA COUNTY, COLORADO

BY JOHN C. MAHER

Drafting of cross section by Catheleen W. Saint