KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 66-10

STRATIGRAPHY OF MISSISSIPPIAN ROCKS IN WESTERN KANSAS

by

Edwin D. Goebel

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66-10

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IN

WESTERN KANSAS

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A.B., Augustana College, 1949
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Submitted to the Department of
Geology and the Faculty of the
Graduate School of The University
of Kansas in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

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September, 1966

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ABSTRACT

Mississippian rocks, all marine and all in the subsurface, underlie an area of 35,000 square miles (91,000 sq. km) in western Kansas. In ascending order, Kinderhookian, Osagian, Meramecian, and Chesteran rocks are recognized. In different localities, some formations are absent from various parts of the columnar section; the breaks represent local and regional disconformities. Thicknesses of lithostratigraphic units range from zero on the flanks of the Central Kansas Uplift to more than 1,700 feet (518m) for the entire sequence in the Hugoton Embayment. Unconformities set off dominantly carbonate Mississippian rocks (excluding the Chattanooga Shale) from Pennsylvanian rocks above and Cambrian to Devonian rocks below.

Lithology, distribution, and thickness of Mississippian rock units were established by study of sample cuttings, cores, acetate peels, thin sections, and mechanical logs from 1,000 wells.

Conodont faunas recovered as acetic acid insoluble residues from cores are correlated with conodont biostratigraphic zones of the type area of Mississippian rocks. Part of the study area once contained Devonian rocks, which were subsequently eroded. Evidence of this is the presence of reworked Devonian and Kinderhookian conodonts preserved in Kinderhookian rocks.

Concentrations of glauconite, silicified fossil fragments, and secondary sulfide minerals in acid residues constitute lithic features which support identification of some lithostratigraphic units.

Kinderhookian rocks were deposited on a flat surface. Lowermost Kinderhookian rocks, composed of a thin clastic zone, are interpreted as resulting

from transgressive deposition from the north at the beginning of the Mississippian. Next above occurs a sequence of dolomitic and oolitic limestone beds.

Southern Kansas was tilted toward the south in early Osagian time, a reversal from Kinderhookian time. The lower Osagian rocks, locally present in western Kansas, consist of red and green crinoidal to semicrinoidal limestone with minor amounts of fossiliferous chert, and argillaceous limestone. The upper Osagian rocks are fossiliferous to non-fossiliferous, calcareous and dolomitic chert beds with intercalated shales; there is widespread development of chalky tripolitic chert (cotton rock).

An indistinct unconformity separates Osagian from Meramecian rocks. Meramecian rocks are dominantly carbonate; oolitic and pellet-type limestone is more abundant than crinoidal and semicrinoidal limestone or dolomite.

The primary sediment source of Osagian and Meramecian rocks was organic. Similar conditions of deposition prevailed in late Kinderhookian, Osagian, and early Meramecian time. Sediments were probably deposited in warm, shallow seas. Thin intraformational conglomerate beds, quasi-brecciated limestone beds, and local beds of anhydrite are known in upper Meramecian rocks. An increased content of clastic rocks in upper Meramecian strata marks a change in sediment source. Siliceous sediments were provided from areas of provenance from the Central Kansas Uplift and the Las Animas Arch. In Chesteran rocks, sandstone, siltstone, and thin limestone beds predominate.

Erosion in late Chesteran and pre-Desmoinesian time stripped Mississippian rocks from structurally high areas leaving a pre-Pennsylvanian surface of irregular topographic highs and lows. Mapping the areal extent of Mississippian lithostratigraphic units is complicated by local development of karst topography as well

as thinning due to erosion. Diagenetic alterations and facies changes also complicated the problem of establishing lateral stratigraphic equivalents. Dolomitization, silicification of fossils, and chertification are widespread.

The southern end of the Central Kansas Uplift was uplifted in early Mississippian time. Post-Mississippian faulting occurred locally in southwestern Kansas.

A normal sequence of Osagian and Meramecian rocks was deposited in south-central Kansas. The term Cowley Formation should be dropped; the cherty "Cowley" facies is developed only locally.

Types of chert have limited use in establishing regional lithologic equivalency except as gross lithologic features or in areas of close control. Clay-minerals, trace elements, facies, and sulfide mineralization need additional investigation.

INTRODUCTION

Scope and Purpose

Mississippian rocks are widely exposed in the Midcontinent and have been studied locally and regionally in great detail. Outcrops in Kansas are confined to a small area of less than two townships in Cherokee County in the extreme southeastern part of the state. Westward, the Mississippian rocks in Kansas are preserved unconformably beneath Pennsylvanian rocks in basinal areas and are the source of much oil and gas. The study area in western Kansas (Fig. 1) comprises approximately 35,000 square miles (91,000 sq. km), in which the sequence of the Mississippian rocks (Fig. 2) is known only from sample cuttings, cores, and mechanical logs.

Accelerated exploration for petroleum reserves in recent years has vastly increased the information available about Mississippian rocks. The new data include cores and improved mechanical logs. This study was undertaken with the aspiration of refining the new data, seeking especially information useful for lithostratigraphic correlation, and for interpreting the geologic history of the Mississippian rocks. The goal of the project was expanded knowledge and thus more detailed classification of lithostratigraphic units; particular attention was given to reexamination of lithic criteria used in earlier classifications.

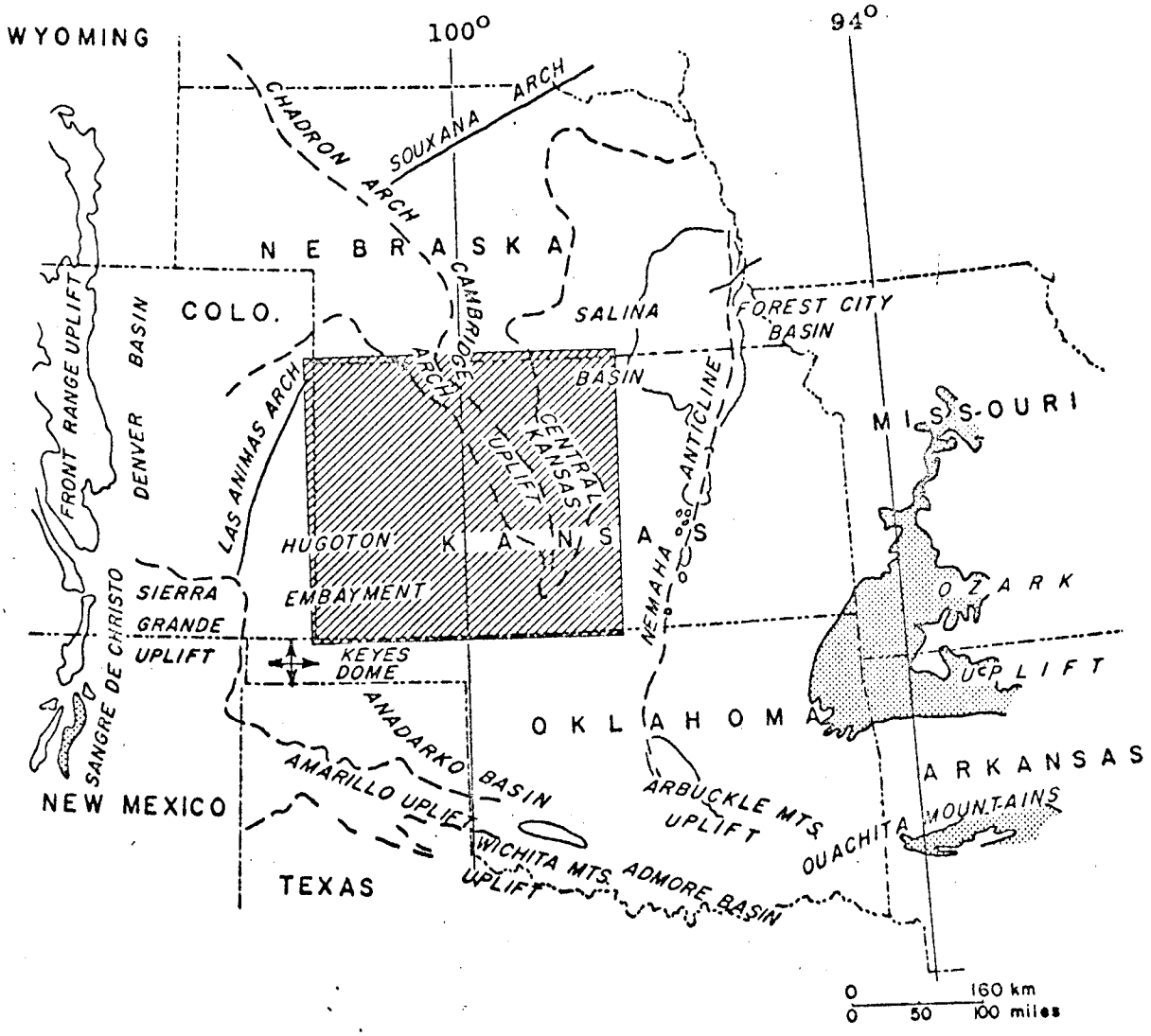


Figure 1.-- Index map of western Kansas and adjacent areas showing area studied, generalized pre-Pennsylvanian structural features, and areas of outcropping (stippled) Mississippian rocks. (Base map from Fox and Sheldon, 1957; adapted from Carlson, 1963, Merriam, 1963, and Jordan and Rowland, 1959.)

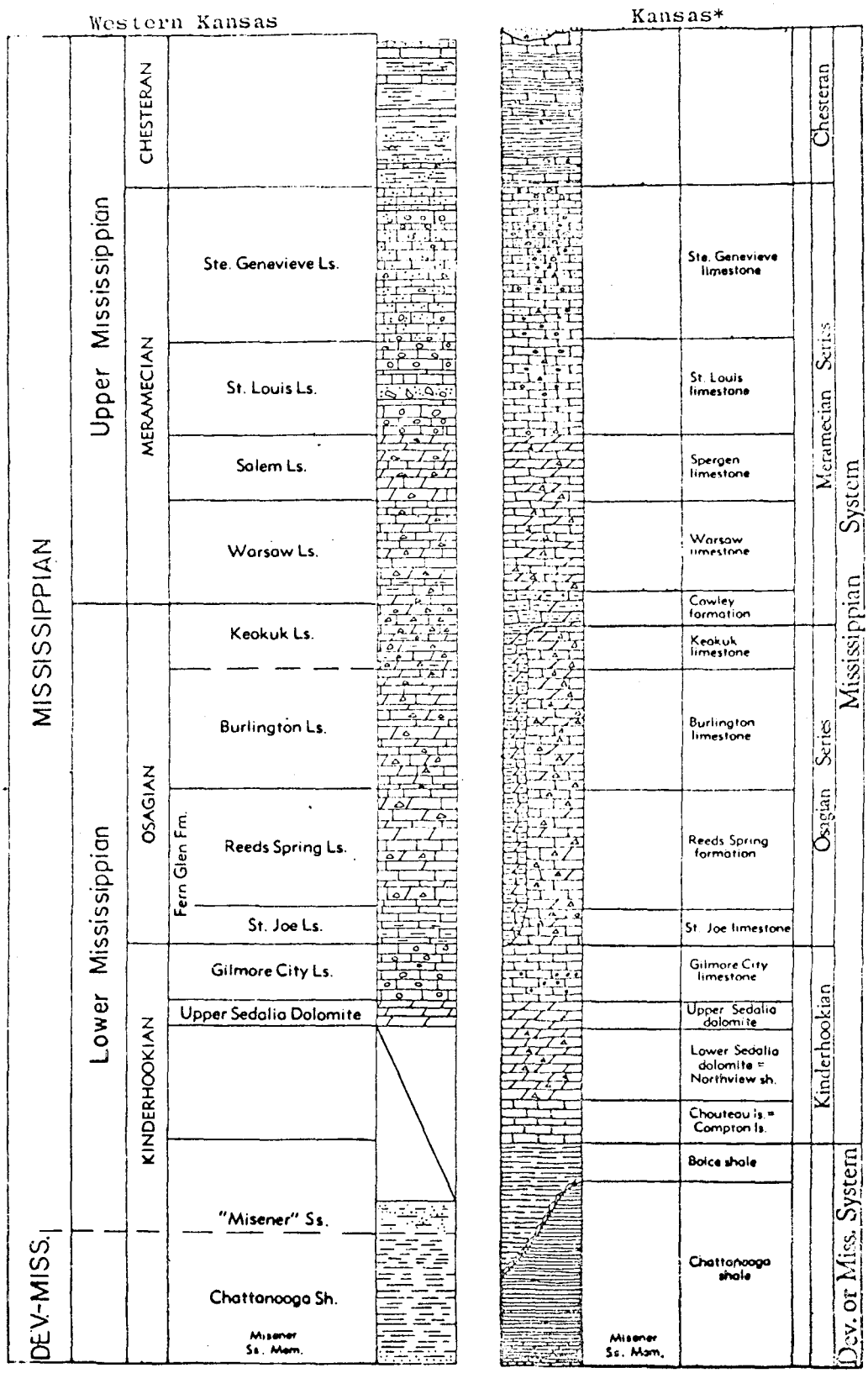


Figure 2.--Composite columnar sections and classifications of Mississippian rocks for western Kansas (this report) and Kansas. (Kansas section*, includes western Kansas, from Moore and others, 1951; Jewett, 1959.)

Methods and Procedures

Field Methods

The type Mississippian section in the upper Mississippi River Valley was visited and studied, with special attention given to those localities studied by previous workers. Also, Mississippian outcrops in parts of Arkansas, Oklahoma, Colorado, Wyoming, Iowa, and Missouri were visited and sampled in order to make comparisons and for background material.

Laboratory Methods

Lee (1940), working mostly with cable tool samples, used unique hydrochloric acid insoluble residues in establishing stratigraphic equivalence of Mississippian rocks in Kansas with outcrops in Missouri. Most of the exploratory boreholes in western Kansas have been drilled with rotary tools, and the mixed nature of sample cuttings from these holes restricts their usefulness in studies of insoluble residue materials.

When acetic acid is used to digest carbonate rocks, phosphatic material is preserved. Collinson and others (1962) used this circumstance for recovery of conodonts on rocks from the type area of the Mississippian. Thompson and Goebel (1963) in a pilot study of conodonts used acetic acid on cores of dominantly carbonate rocks (Meramecian) from western Kansas.

Because acetic acid residues differ somewhat from hydrochloric acid residues, comparisons with Lee's work are not totally valid. Nevertheless, acetic acid was used in this study because of the demonstrated abundance of conodonts in some Kansas Mississippian rocks (Thompson and Goebel, 1963) and their usefulness in biostratigraphic determinations. The handicap introduced by using acetic

acid rather than hydrochloric acid was more than offset by the recovery of phosphatic microfossils. Distribution and abundance of conodonts is given in Appendix A.

It was judged that the dependability of lithic features established by earlier workers (Lee, 1940, 1956; Maher and Collins, 1949; Clair, 1948) as criteria for subdivision of Mississippian rocks in Kansas was best tested by studies of cores from these rocks. This investigation was primarily concerned with and based upon information gained from the study of such cores. Drilling companies seldom core a long continuous rock section. It was necessary, therefore, to assemble a collection of Mississippian rock cores. The core remnants from which Girty (1940) and Thompson and Goebel (1963) recovered mega- and microfossils served as the starting interval in aggregating a composite rock section judged representative of the Mississippian rocks in western Kansas. A registry of cores studied by the author or cores used by other workers is presented as Table 1. Core distribution is shown in Figure 3.

In general, the laboratory procedure for the preparation of insoluble residues set forth by Ireland (1958) was followed but was modified as described by Collinson (1963) for maximum recovery of phosphatic materials.

Rock cores from boreholes were sawed longitudinally with special effort to maintain correct orientation and depth markings for each segment. One-half of the core was selected for acetic acid digestion; the other half of the core was preserved for study of megafossils. The weight of each segment of core to be dissolved in acid was recorded before crushing to a maximum size of 25 mm. Acid residues were weighed and recorded graphically for comparisons between cores. Residues judged too large for satisfactory mechanical picking of microfossils were set aside for separation with tetrabromoethane. Conodonts (specific

Table 1.-- Registry of cores studied.

Company and Lease	Location*	County	Stratigraphic Interval
Texas No. 1 Dougherty	23- 6-33W	Thomas	Mississippian?
Phillips No. 2 Goodland	10-10-39W	Sherman	Arbuckle
Sinclair Oil No. 1 Mercer	28-10-40W	Sherman	Kinderhookian
Texas Co. No. 1 F. L. Smith	30-11-36W	Logan	Keokuk, Gilmore City, Upper Sedalia?, Arbuckle
Phillips No. 1 Monument Prospect	8-12-34W	Logan	Upper Sedalia, Arbuckle
Wycoff Bros. No. 1 Teeter "A"	26-13-30W	Gove	Keokuk
Argo Oil Co. No. 1 Hocker-Smith[2]	19-14-29W	Gove	Pennsylvanian, St. Louis
Alma and McNeeley No. 1 Watchorn[1,2]	13-15-33W	Logan	Ste. Genevieve, St. Louis, Salem
Trigg et al No. 1 Nimocks[1,2]	16-16-28W	Lane	Salem
Mobil Oil Co. No. 1 Elsasser Heirs	29-18-22W	Ness	Warsaw, Keokuk
Mid-Continent No. 1 Collins[2]	24-20-26W	Ness	Warsaw, Pennsylvanian
Mobil Oil Co. No. 1 Winans	32-20-27W	Lane	Warsaw
Atlantic Oil Co. No. 1-A Mark[1,2]	28-20-33W	Scott	Ste. Genevieve?, St. Louis, Salem, Warsaw, Keokuk
Atlantic Oil Co. No. 1 Thornbrough	16-21-35W	Kearny	St. Louis
Mobil Oil Co. No. 1 E. Salmans	3-22-22W	Hodgeman	Warsaw
Western Petro. No. 1 Brown "A"	30-24-14W	Stafford	Ordovician?
Western Petro. No. 1 Hoffman	8-25-17W	Edwards	Osagian, Kinderhookian
McKnab Lindsay Kuhn-Devlin	19-26-34W	Finney	St. Louis
White Eagle No. 7 "A" U.S.A.	31-26-34W	Finney	St. Louis
White Eagle No. 1 U.S.A.	14-26-35W	Kearny	Ste. Genevieve, St. Louis
Northern Natural Gas No. 2 Fralick "A"	14-27-20W	Kiowa	Warsaw?, Keokuk
Mull-Mobil Oil Co. No. 1 Matkin	16-27-21W	Ford	Salem
Cities Service No. 1 Kells "B"	5-28-34W	Haskell	Ste. Genevieve, St. Louis
Helmerich and Payne No. 1 Eubank[2]	28-28-34W	Haskell	Ste. Genevieve, St. Louis
Mobil Oil Co. No. 1 Anderson Trust	27-31-35W	Stevens	Chesteran
Kessler and Thier No. 1 Wolfje[1]	17-33- 6W	Harper	St. Louis?
Sinclair Oil and Gas No. 1 Colburn "A"	9-33-11W	Barber	St. Louis?, Warsaw?
Sinclair Oil and Gas No. 1 Circle	14-33-11W	Barber	Keokuk, Burlington
Sinclair-Prairie No. 1 Alice Gentry[1]	1-33-15W	Barber	Burlington, Fern Glen, Viola
Sincliar-Prairie No. 1 Exchange Bank	27-33-19W	Comanche	St. Louis, Salem, Burlington?, Fern Glen, Viola
Mobil Oil Co. No. 1 Cunningham Est.	13-34-37W	Stevens	St. Louis
Sinclair Oil and Gas No. 1 Helmley	3-35-10W	Barber	Warsaw

* All townships south

[1] Reported by Girty in Lee, 1940.

[2] Reported by Thompson and Goebel, 1963.

gravity 2.84--3.10) are composed mostly of calcium phosphate of the apatite type. These were separated from material of lower specific gravity.

Acetic, hydrochloric, and as necessary for chert, hydrofluoric acids were used in preparing acetate peels. Thin sections were prepared of rocks from which acetate peels were judged unsatisfactory. Photographic prints of the peels and thin sections were studied in conjunction with examination of rock residues. Thin sections, acetate peels, and percentage weight loss logs are in repository at the Kansas Geological Survey.

Sample Examination

Sample logs from 1,000 wells were used in this study. Samples of rotary cuttings from boreholes used by previous investigators of western Kansas Mississippian rocks and many selected sets of cuttings from more recent drilling were examined. Many of the lithologies in available sample logs could not be verified by examination of the "well-picked-over" rock remnants in the sample bags. Repeated examination of sample cuttings of some classic and important wells has resulted in the removal of pertinent lithic features from the permanent records. Contributing to the deterioration of the value of the sample cuttings is the common practice of removing portions of the samples for calcite-dolomite determinations. Lithic features in some sample logs are now often only discernible in offset wells. Unfortunately, some sample logs are from critical areas lacking offset drilling, and in these cases reliance on the log is necessary. The observations made on the attrition of samples also apply to logs of commercial sample log services.

Mississippian rocks in western Kansas are dominantly carbonate. Use of mechanical log descriptions for interpretation of lithologic correlation is generally

unreliable in rock sections dominated by carbonate lithology.

The sample logs prepared for this investigation are on file at the Kansas Geological Survey.

Residue Logs

Preparation of residue logs followed the procedures set forth by Ireland (1958). Residue terminology used also follows Ireland (1947, 1958). Residue logs allowed easy and quick comparisons of some rock intervals judged as lateral equivalents. Selected representative rock and mineral residue logs are presented in Appendix B. Residues and residue logs are filed with the Kansas Geological Survey.

Previous Studies

Earlier investigators who studied Midcontinent Mississippian rocks before widespread exploratory drilling occurred reported mostly on the lithology of the outcrops, the megafossils, and regional geologic relationships. Later workers carried the study of the Mississippian rocks into the subsurface by examination of well cuttings.

A chronologic history of rock classifications is presented in Table 2. Major contributions to the knowledge of the stratigraphy of western Kansas include: a geologic report of Mississippian rocks in Kansas by Lee (1940) which included extension of surface formation names to subsurface units; a report by Girty (1940) on megafossils from cores; stratigraphic cross-sections by Maher (1946, 1947), Edson (1947), Collins (1947), Lee (1949, 1953); and a regional geologic study of pre-Pennsylvanian rocks by Maher and Collins (1949). Other significant and useful studies which bear on the Mississippian rocks of western Kansas include: a regional study of the Midcontinent (Hiestand, 1935); an insoluble residue study in central

Kansas (Hiestand, 1938); a study of lithologic criteria useful for identification of formations (Clair, 1948); reports on the stratigraphy and structural development of the Salina Basin (Lee and others, 1948; Lee, 1956); regional stratigraphic studies of the Hugoton Embayment (Veroda, 1959; Beebe, 1959); a report on conodonts from the Meramecian Stage (Thompson and Goebel, 1963); a study of Mississippian rocks of Nebraska (Carlson, 1963); and geologic reports on oil and gas fields (Kansas Geological Society, 1965).

Acknowledgments

The most important tangible contribution to this report was made by the administrators of the Kansas Geological Survey over the past 40 years. Through their foresight and effort, valuable collections of well logs, sample cuttings, cores, and mechanical logs were preserved. These form the basic materials of this study.

The Kansas Geological Society, acting through the Well Log Bureau, collected some of these subsurface materials. The petroleum industry in Kansas with the help of the Kansas Geological Survey made possible a reference library of many thousands of subsurface sections. Duplicate sets of little used sample cuttings were made available by donations of company sample and core collections to the Kansas Geological Survey in 1959, when the petroleum industry presented a gift of some $35,000 to The University of Kansas Endowment Association for land and storage facilities in Wichita. Many of these duplicate sets were used, and practically every petroleum exploration company with offices in Wichita deserves thanks for their special contributions.

Companies and individuals who donated core sections to the Kansas Geological Survey include, alphabetically: Atlantic Oil Production Company;

B. W. Beebe; Carter Oil Company (Humble); L. H. Cornell; R. W. Dougherty; Louise Jordan, Oklahoma Geological Survey; N. C. Knapp, Mobil Oil Company; Phillips Petroleum Company; M. F. Pryor; Sinclair Research Company; and Texaco, Inc. (Texas Company).

The most important intangible contribution given this study was faith and encouragement expressed indirectly by faculty members of The University of Kansas Department of Geology. Professor H. A. Ireland supervised the work throughout and provided special guidance in the preparation of the final report. Drs. Wakefield Dort, Jr., Roger L. Kaesler, and Jay Earl Anderson of the Department of Geology and David Simonett of the Department of Geography read the manuscript and made valuable contributions.

Consultations and exchange of ideas with geologists of the Kansas Geological Survey were helpful. Research-oriented petroleum industry geologists gave freely of their time and opinions. Personnel of the Mississippian Paleo-Tectonic-Mapping Project of the United States Geological Survey were helpful. Names of individuals listed alphabetically from these three categories are W. L. Adkinson, F. J. Adler, M. P. Carlson, L. C. Craig, F. C. Foley, P. F. Franks, W. W. Hambleton, W. E. Hill, Jr., P. L. Hilpman, J. M. Jewett, Wallace Lee, R. P. Lehmann, E. D. McKee, D. F. Merriam, Betty Skip, G. F. Stewart, T. L. Thompson, and R. L. Walters.

Charles Collinson (Illinois Geological Survey), Brian Glenister (State University of Iowa), Gilbert Klapper (Pan American Petroleum Corp.), and others made tentative identification of some little known conodont genera. Collinson also supplied manuscript copy on conodonts from the Keokuk, Warsaw, and Salem rocks of the upper Mississippi River Valley (later published as Rexroad and Collinson, 1965).

The Kansas Geological Survey provided funds and equipment for the study.

TECTONIC FRAMEWORK

Kansas is part of the craton of North America, and a relatively thin mantle of less than 9,500 feet (2,895m) of sedimentary rocks covers the Precambrian basement complex. The Mississippian rocks in western Kansas are the thickest and most widespread of pre-Pennsylvanian units except for the Cambro-Ordovician Arbuckle Group. Mississippian rocks overlap older rocks from the southeast part of the trough of the Anadarko Basin in Oklahoma northwestward to the Hugoton Embayment in Kansas and rest successively on the Woodford Shale (Chattanooga Shale), Hunton Group, Viola Limestone, and Arbuckle Group. The depth to the top of the Mississippian ranges from less than 4,200 feet (1,280m) in the northern part of the Hugoton Embayment to 20,000 feet (6,096m) in the trough in Oklahoma. Mississippian rocks exceed 1,700 feet (518m) in thickness in southwestern Kansas. Post-Mississippian sedimentary rocks consist of many units which rest nearly parallel one above the other.

Pre-Mississippian Structural Features and Paleogeology

The pre-Mississippian surface in the area of this investigation is thought to have been as presented in Figure 4. Pre-Mississippian structures of western Kansas are difficult to recognize because subsequent deformation has altered their shape. Also, removal of pre-Mississippian rocks by erosion opens to speculation the areal extent and distribution of entire systems of older rocks.

Previous workers (Moore and Jewett, 1942, fig. 7, p. 6; Moore and others, 1951, fig. 44, p. 113; Jewett and Merriam, 1959, fig. 7, p. 25; and Merriam, 1963, fig. 100, p. 183), depicting the major structural features of Kansas in pre-Mississippian

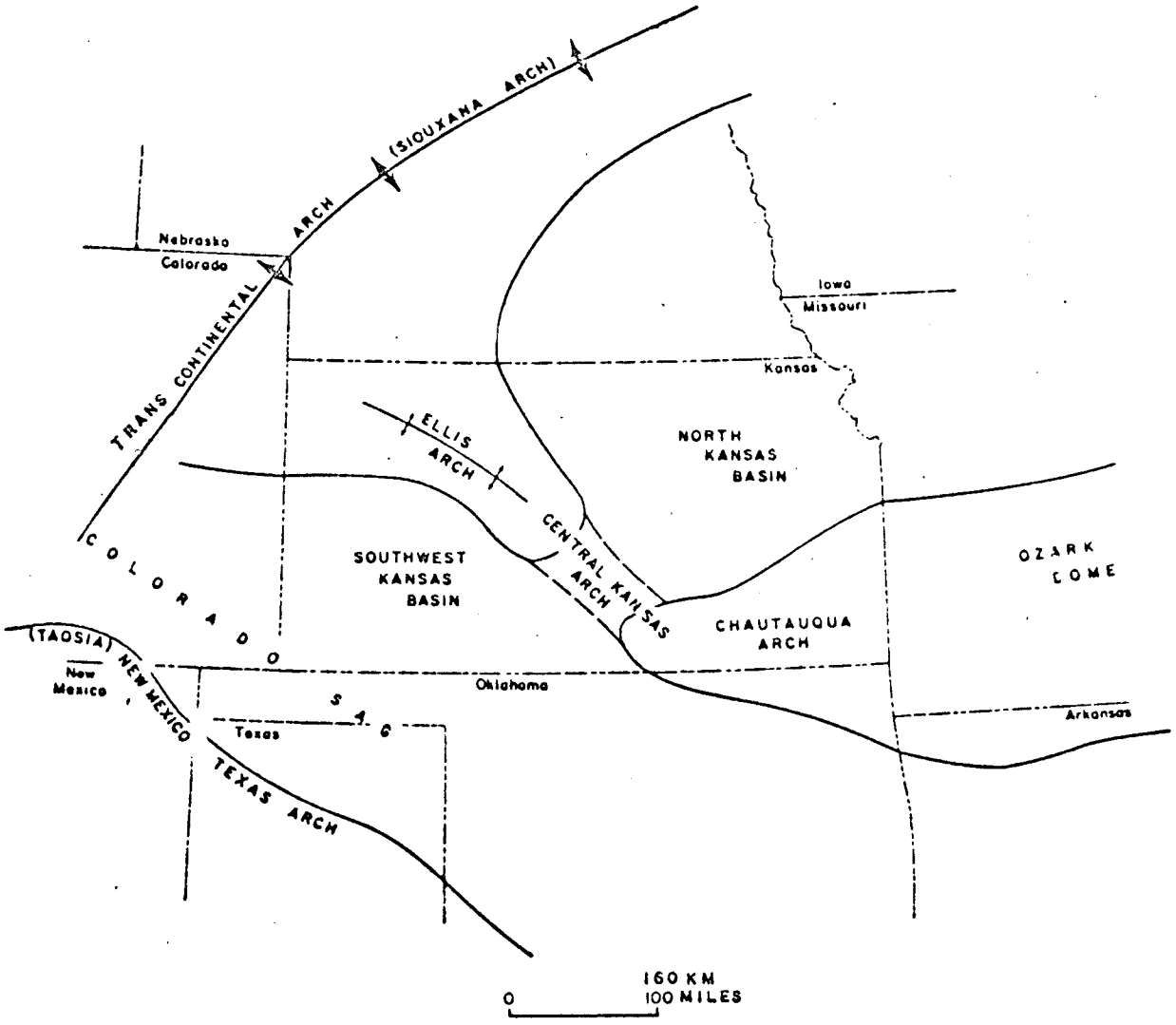


Figure 4.--Pre-Mississippian structural features (restored) of western Kansas and adjacent areas (from Moore and Jewett, 1942; Eardley, 1962; and Merriam, 1963).

time, showed a Southwest Kansas Basin and an Ancestral Central Kansas Uplift. Merriam (1955) made little distinction between the terms Hugoton Embayment and Southwest Kansas Basin. The Southwest Kansas Basin as reported by Merriam (1963, p. 183) is a major pre-Mississippian structural element that represents an early development of the Hugoton Embayment in southwestern Kansas. Differentiation between pre-Mississippian and post-Mississippian structural features is important to the context of this investigation. In defining the Southwest Kansas Basin, Moore and Jewett (1942, p. 46) stated:

> Southwest of the Ellis Arch and west of the Chautauqua Arch is a basinal area of pre-Mississippian date which is designated as the Southwest Kansas Basin. Little is known except that "Hunton" (Silurian-Devonian) and a thick section of Ordovician rocks are present in this region.

Subsequent investigators reported Silurian-Devonian rocks absent from western Kansas (Moore and others, 1951, p. 112). Moore and Jewett (1942) also named the Ellis Arch and reported:

> Southwest of the North Kansas Basin, in the region now defined as belonging to the Central Kansas Uplift, Mississippian rocks are absent and Lower Pennsylvanian strata rest directly on Ordovician-Cambrian or locally on Precambrian rocks. The strike of anticlinal folds in these pre-Pennsylvanian rocks differs materially from the axis of the Uplift as a whole. These folds are interpreted as pre-Mississippian in age. They are aligned with folds in the Chautauqua Arch area and they seem best interpreted as older in origin than other features of the Central Kansas Uplift. The area is here designated as the Ellis Arch, in order to differentiate it from the Central Kansas Uplift, main features of which are post-Mississippian in origin.

Lee and others (1948, pl. 5) referred to the Ellis Arch as the Ancestral Central

Kansas Uplift. Rich (1933, p. 796) coined the term Central Kansas Arch and included much of the Ellis Arch and part of the Chautauqua Arch. The age of the Ellis-Central Kansas Uplift is suggested in a map of pre-Pennsylvanian structure (adapted from Lee, 1956, and Merriam, 1961, by Levorson, 1960) in which the Mississippian was represented as overlapping the eroded and truncated edges of the Maquoketa (Upper Ordovician) on the east flank of the arch and overlapping the Viola and Simpson (Middle Ordovician) on the west side. This suggests that part of the uplift occurred in pre-Mississippian time (Levorson, 1960, p. 97).

The Colorado Sag (Fig. 4) southwest of Kansas was reported by Eardley (1962, pl. 5) as a seaway and an area of accumulation of sediments during Devonian time. MacLachlan (1961, p. 415) referred to this feature as the Colorado Strait and reported it as a seaway and as an extension from the Anadarko Basin of Oklahoma. Many investigators have considered the Southwest Kansas Basin and its post-Mississippian counterpart, the Hugoton Embayment of the Anadarko Basin, as occupying a continually down-warping area.

The Upper Ordovician, Silurian, and Devonian rocks were reported absent from the Hugoton Embayment (Maher and Collins, 1949; Moore and others, 1951). Maps of Kansas showing the restoration of inferred pre-Mississippian paleogeology by Moore and Jewett (1942, fig. 6), Jewett and Merriam (1959, fig. 6), and Merriam (1963, fig. 97) displayed widespread distribution of Viola Limestone over most of western Kansas. An area including the Cambridge Arch and Decatur, Rawlins, and Cheyenne Counties west of the arch is inferred to have been structurally high, exposing Middle Ordovician (Simpson) to Precambrian rocks to erosion.

The following problems concerning the deposition of Mississippian rocks in western Kansas come to light from the previous discussion of the tectonic framework. If Upper Ordovician, Silurian, and Devonian rocks were deposited in what many authors believe was a continually subsiding basin throughout the Paleozoic history of the region, then some mechanism is needed to explain the subsequent removal of these sediments. This report presents evidence of a phantom or ghost horizon of reworked Devonian fossils in Kinderhookian rocks in part of western Kansas. Some non-abraded Devonian forms are reported in younger Mississippian rocks. It seems unlikely that all Silurian and Devonian rocks could have been removed completely from the area even by peneplanation. Perhaps they remain unidentified.

Post-Mississippian Structural Features

Mississippian rocks are preserved in western Kansas in a tectonic framework as delimited primarily by post-Mississippian structural features. As shown in Figure 1, the study area includes most of the Hugoton Embayment. A major change in structural development of western Kansas took place near the end of Mississippian time. Many of the structures that began to develop at the end of the Mississippian or the beginning of the Pennsylvanian now define the structural framework.

Maher and Collins (1948) defined the Hugoton Embayment as a large shelf-like extension of the Anadarko Basin. The eastern edge of the basin is limited by the Pratt Anticline, Central Kansas Uplift, and Cambridge Arch. The western side is formed by the Las Animas Arch of eastern Colorado and the Sierra Grande Uplift. The Hugoton Embayment extends into the Panhandle area of Oklahoma and north Texas as the Anadarko Basin.

The Pratt Anticline (too small to show on Fig. 1) occupies parts of Stafford, Pratt, and Barber Counties on the southern end of the Central Kansas Uplift. It has a broad southward plunging nose which separates the Sedgwick Basin on the east from the Hugoton Embayment on the west. Farther south in Oklahoma this structure dies out and the Sedgwick Basin merges with the Hugoton Embayment on the northeast flank of the Anadarko Basin. Lee (1953) reported that the Pratt Anticline began to form in early Paleozoic time and deformation occurred again in pre-Desmoinesian time. Substantiating evidence for early Mississippian formation of the southern end of the Central Kansas Uplift is presented in my report.

Post-Paleozoic movements did not materially alter the Mississippian rocks of western Kansas. After and possibly during the deposition of Tertiary rocks, western Kansas rocks were tilted eastward (Merriam, 1963, p. 179).

FOSSILS FROM WELL CORES

Megafossils

Most Mississippian megafossils recovered from western Kansas well cores are large shell fragments and occasional small shells large enough to allow tentative generic identification. Megafossils are abundant in certain parts of the Meramecian rocks. As Girty (1940) pointed out, many Mississippian genera have long ranges, and a list of genera would have little usefulness as evidence for age determination. Some megafossils identifiable to species have been recovered from cores in western Kansas Mississippian rocks, but much work remains to be done on them. Collections of megafossils from outcrops of Mississippian rocks in Missouri are well known through the work of Moore (1928, 1935), Laudon (1931, 1937), Kaiser (1950), and Spreng (1952). Faunas from that area have been used widely for biostratigraphic zonation because much material is available and contains specimens identifiable to species level.

Megafossils from Mississippian rocks of western Kansas are known mostly from the work of Girty (1940). Faunas studied by Girty consisted of fragments of bryozoans and brachiopods, and a few whole corals. These faunas were interpreted as Meramecian in age.

Fragments of fossils are one of the dominant lithic features of the Mississippian rocks studied in cores from western Kansas. These are mostly crinoid columnals or ossicles, brachiopod shells, and bryozoan fronds. Whole siliceous sponge spicules, corals, gastropods, and ostracodes are found.

Moore (1938) reported on the use of fragmentary crinoidal remains in stratigraphic paleontology and presented a possible classification of crinoid ossicles, but no attempt was made in my study to apply that classification.

Several Osagian and Meramecian units consist predominantly of crinoidal to semi-crinoidal limestone.

Microfossils

Some of the cores with which Girty (1940) worked were reexamined in a pilot study to search for conodonts (Thompson and Goebel, 1963). These cores were used a third time in the present study and their locations are indicated in Table 1.

The presence of Endothyra in the Salem Limestone in Kansas has been observed by previous workers (Clair, 1948; Lee, 1953) who used them as indicative of the formation. The endothyroid foraminifers studied in detail by Zeller (1950) from surface exposures were found to consist of a variety of species useful as biostratigraphic guides throughout Mississippian rocks. The usefulness of endothyroids has been reaffirmed by work in Mississippian rocks in Arizona by McKee and Skip (1965, unpublished manuscript, U.S.G.S.). Specimens of Endothyridea in some thin sections of Mississippian rocks are noted later in my study, but such a small number of specimens was present that no attempt was made to identify them beyond the generic level. A few free Endothyra were observed in sample cuttings.

The Chattanooga Shale which is included with the Kinderhookian rocks in my report contains the spore case Sporangites huronensis. Spore-like bodies were recovered in acid residues from Kinderhookian rocks in some western Kansas cores.

Conodonts

Megafossils, because of their larger size and limited occurrence, have not been used extensively in delineating biostratigraphic zones in the subsurface Mississippian rocks in Kansas. Researchers have considered microfossils a better

tool for studying this section of rock. The use of conodonts as guide fossils within the type area of the upper Mississippi River Valley demonstrates the practicability of these forms as tools of correlation where biostratigraphic zones (Figs. 5, 6, and 7) have been identified by Collinson and others (1962).

Although phylogenetic relationships of the conodonts have been the subject of great controversy in the past, these fossils now constitute one of the more important groups of microfossils used as guide fossils (Jones, 1956; Lindström, 1964). Jones reported conodonts as excellent guide fossils from the Lower Ordovician to the Middle Triassic. They attained their maximum development in late Devonian and early Mississippian time. Collinson (1963), working in the standard Mississippian section, found that conodonts are widely distributed in these carbonate rocks and in such abundance that they are extremely useful for biostratigraphic zonations. Conodonts have special significance to my investigation because they were distributed in a wide variety of depositional environments and are therefore useful in correlating facies.

Conodonts are extremely abundant in Lower Mississippian rocks, especially in Kinderhookian rocks. The characteristic species contained in rocks of early Mississippian age are easily distinguished from those found in rocks of late Devonian age (Fig. 5 and Pl. 1). Conodonts are not especially abundant in the Upper Mississippian rocks but are present in sufficient quantity and well enough distributed to be useful in stratigraphic investigations (Rexroad and Collinson, 1963).

The stratigraphic ranges of some conodont genera and selected species recovered are given in Plate 1 (pocket). Identities of some Meramecian species reported in Appendix A are known through the work of Thompson and Goebel (1963)

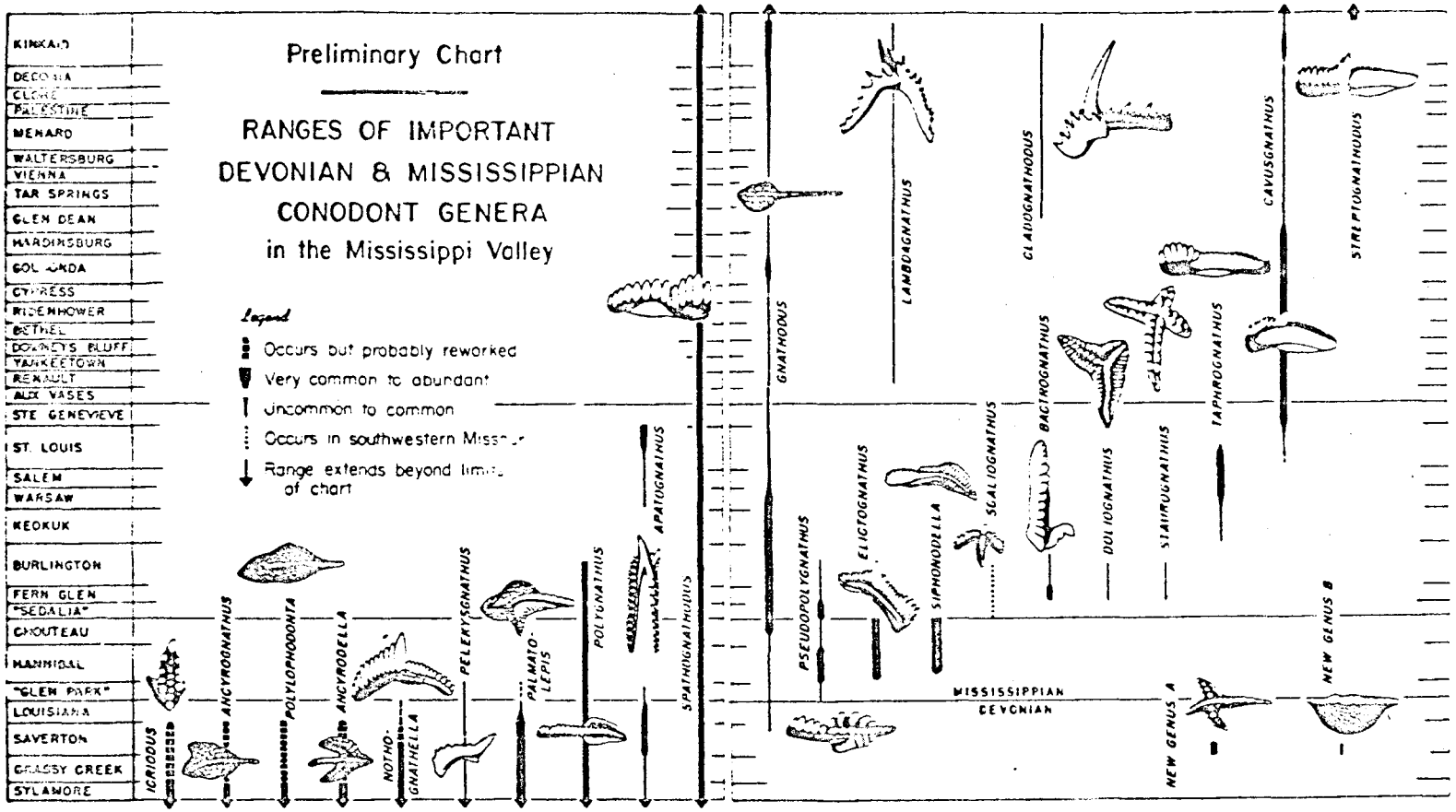


Figure 5.-- Ranges of important Devonian and Mississippian conodont genera in the Mississippi Valley (from Collinson, Scott and Rexroad, 1962).

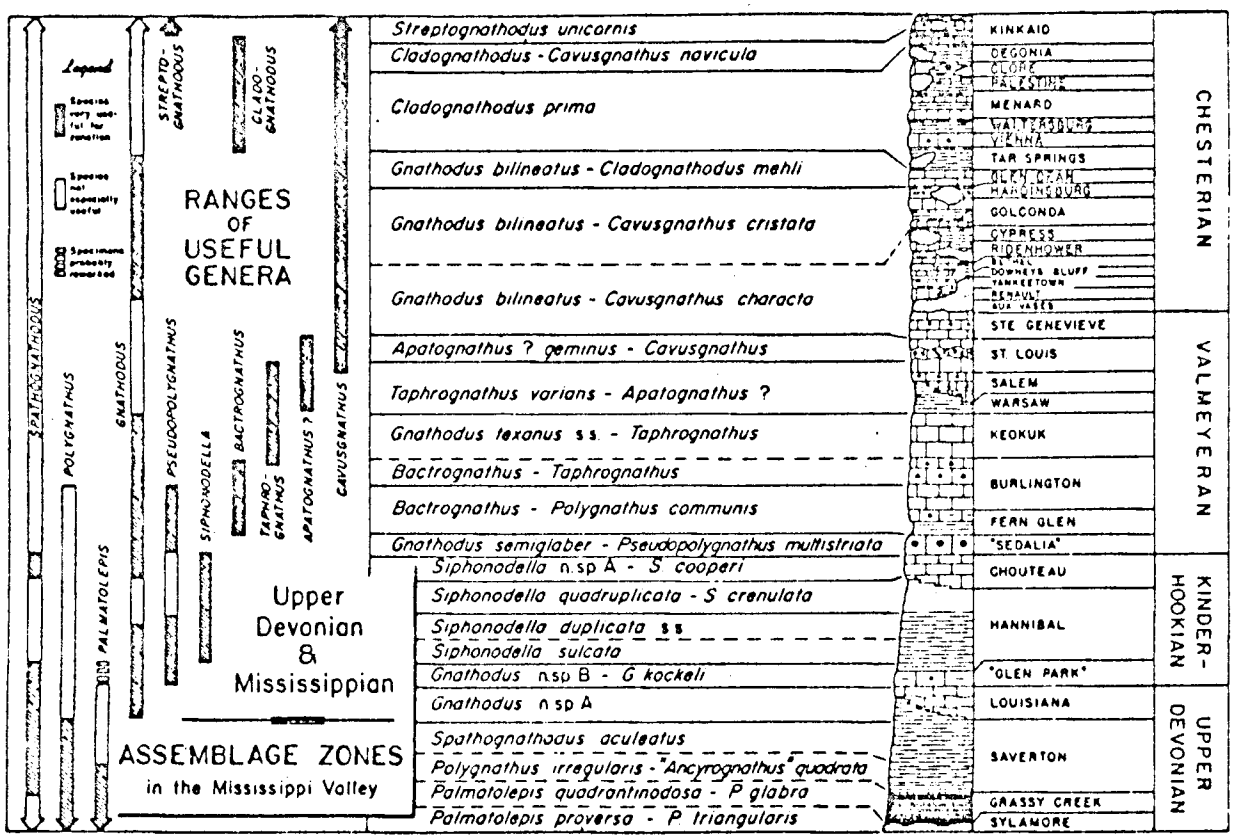


Figure 6.-- Ranges of useful genera and Upper Devonian and Mississippian Assemblage Zone of conodonts in the Mississippi Valley (from Collinson, Scott and Rexroad, 1962; Siphonodella n. sp. A changed to S. isosticha by Rexroad and Scott, 1964).

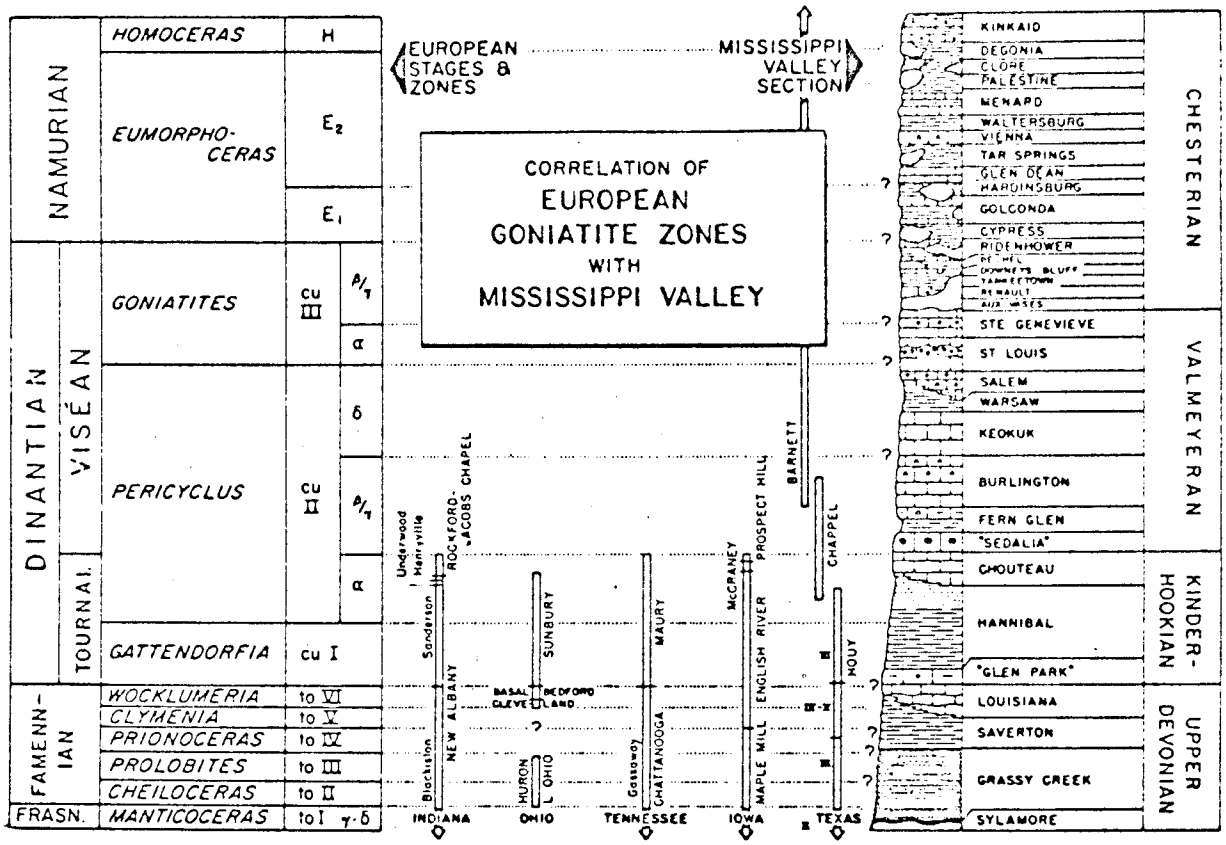


Figure 7.-- Correlation of European Goniatite zones with conodont zones of the Mississippi Valley and other sections in central United States (from Collinson, Scott and Rexroad, 1962).

and Thompson (1965). The identification herein of some Meramecian specimens and other Mississippian conodonts to generic or in special cases to specific level is the responsibility of the author. Pre-Mississippian conodonts listed in Appendix A have the characteristics of the simple blade-like and bar-like forms of pre-Devonian specimens. It is difficult to distinguish Silurian from older conodonts.

Limestone and dolomite, because they may be dissolved in acid, are the most suitable rock types for recovery of undamaged conodont specimens; but abundant occurrences of conodont specimens have been discovered in a quartz-sandstone bed. Useful faunas have been recovered from cherty limestone, dolomite, shale, and shaly sandstone beds in my study.

The occurrence of conodonts with scolecodonts is well documented in the literature, an occurrence that is confirmed in my study. Arenaceous Foraminifera were observed and noted in some residue material but judged of no specific correlation value, because of the small numbers and distribution.

Mixed Conodont Faunas

Two kinds of naturally mixed conodont faunas of special importance to the stratigrapher who wishes to put conodonts to a practical use result from stratigraphic leaks and stratigraphic admixtures (defined in Appendix C). The recognition of a mixed fauna is dependent upon knowledge of stratigraphic range and establishing that the older faunas are reworked. The youngest group of conodonts present in a mixed fauna affixes the age of the fauna. The presence of older conodonts in a mixed fauna testifies to the former existence of an older stratigraphic unit.

This paper utilizes the principle of stratigraphic admixtures as evidence for the former presence of Devonian or Silurian rocks in parts of western Kansas.

GENERAL STRATIGRAPHY

The Mississippian System in Kansas is divided into the Chesteran, Meramecian, Osagian, and Kinderhookian Stages (Table 3; Fig. 2). The Lower Mississippian includes the Kinderhookian and Osagian and the Upper Mississippian the Meramecian and Chesteran. In the type section in the upper Mississippi Valley, the Mississippian is divided into the Kinderhookian, Valmeyeran, and Chesterian.

Most of the rock deposited during Mississippian time in Kansas is cherty and noncherty dolomite, limestone, and dolomitic limestone (Pls. 3-7). Exceptions to this generality are the Chesteran sandstone and shale beds; the sandy limestone strata of the Ste. Genevieve Limestone (upper Meramecian); the green and red shales and reddish semicrinoidal and crinoidal limestone and argillaceous limestone in the Fern Glen Formation (lower Osagian in south-central Kansas); and the sandy and shaly phase of lower Kinderhookian rocks.

The present thickness and distribution of the Mississippian rocks reflect post-Mississippian structural deformation. Lee (1940) and Maher and Collins (1949) thought that during Mississippian time deposition extended over the Central Kansas Uplift. Erosion at and near the end of Mississippian and during early Pennsylvanian time reduced the Mississippian surface but preserved the greatest thicknesses of Mississippian deposits in basins.

Lee (1939, p. 10), in describing chert deposition on the eroded surface of the Mississippian limestone strata, observed that differentiation between chert weathered in place, residual chert, and reworked chert was not everywhere possible. The top of prominent cherty material was considered as the top of the Mississippian rocks in my study even through some cherty material might have developed in early Pennsylvanian time.

Map Intervals	Stages	KANSAS			
		Western*	North Central	Northeastern	Southeastern
Overlying Units		Morrowan-Cherokee Pennsylvanian	Cherokee Gp. Pennsylvanian	Cherokee Gp. Pennsylvanian	Cherokee Gp. Pennsylvanian
D	Chesteran	Chesteran rocks undifferentiated			Batesville? Ls.
C	Meramecian	Ste. Genevieve Ls. / St. Louis Ls. / Salem Ls. / Warsaw Ls. ("Cowley" facies)	Salem Ls. / Warsaw Ls.	Ste. Genevieve Ls. / St. Louis Ls. / Salem Ls. / Warsaw Ls.	Warsaw? Ls.
B	Osagian	Keokuk Ls. / Burlington Ls. / Fern Glen: Reeds Spring Ls., St. Joe Ls.	Keokuk Ls. / Burlington Ls. / Fern Glen: Reeds Spring Ls., St. Joe Ls.	Keokuk Ls. / Burlington Ls.	Keokuk Ls. / Burlington Ls. / Fern Glen: Reeds Spring Ls., St. Joe Ls.
A	Kinderhookian	Gilmore City Ls. / Upper Sedalia Dol.? / "Kinderhook"	Gilmore City Ls. / Upper Sedalia Dol. / ? / ? Boice Sh.	Gilmore City Ls. / Upper Sedalia Dol. / Chouteau Ls. / Boice Sh.	Lower Sedalia Dol.-Northview Sh. / Compton Ls.
		Viola Ls. Ordovician	Chattanooga Sh. Misener Ss. Dev. and Miss.	Chattanooga Sh. Dev. and Miss.	Chattanooga Sh. Dev. and Miss.

*Western Kansas defined as in Fig. 1.

Table 3. --Classification of Mississippian rocks in Kansas.

Locally, the residual chert ("Chat") at the top of the Mississippian sequence may be as much as 50 feet thick, and on the southwestern flank of the Cambridge Arch it overlies beds as old as the Cambro-Ordovician (Arbuckle Group). In western Kansas, where Chesteran and Morrowan sandstone and shale beds are preserved, little residual Mississippian chert was found. On the western flank of the Central Kansas Uplift, beveled Osagian and Kinderhookian rocks directly underlie Pennsylvanian rocks. Toward the southwest, into the Hugoton Embayment, successively younger Mississippian rocks underlie successively older Pennsylvanian rocks. On the east flank of the Sierra Grande Uplift, onlap resulted in Meramecian rocks directly overlying the Cambro-Ordovician Arbuckle Group (Maher and Collins, 1949). Carlson (1963) reported areas in southwestern Nebraska where Mississippian rocks rest on Cambrian rocks.

"Cowley" Problem

Lee (1940) described the Cowley Formation (Fig. 2) as dark or gray limestone containing dark chert, black to gray silty dolomitic limestone, or brown dolomite containing large amounts of dark and gray microfossiliferous chert. He identified the formation next below Meramecian rocks in a restricted area in southern Kansas from Cowley to Comanche Counties. Lee (1940) interpreted the unit as comprising deposits that filled a basin eroded in Osagian rocks and noted a locally developed distinctive glauconite zone at the base. The glauconite consisted mostly of dark-green clastic grains in silty and siliceous dolomite. Lee distinguished a light-green, earthy textured glauconite at the base of the overlying Warsaw Limestone, occurring as void-fillings in limestone and dolomite, especially in fossil molds and in the centers of crinoid segments. The highly variable nature

of the Cowley Formation led some geologists (Beebe, 1959) to interpret the Cowley as a facies of Osagian rocks and the Chattanooga Shale.

Much of the controversy regarding the Cowley as detrital deposition in a basin eroded in Osagian rocks or as local facies variations of Osagian and Meramecian rocks is resolved by identification of localized diagenetic changes in the rocks. Paleontological evidence presented later in my paper supports the facies concept. Future reference in my study will use "Cowley" (in quotes) when referring to rocks assigned by Lee (1940) to the Cowley Formation. Chertification of Osagian and Meramecian rocks resulting in "Cowley" lithology was widespread in south-central Kansas and masks the identification of lithostratigraphic units.

ROCKS OF DEVONIAN-MISSISSIPPIAN AGE

Chattanooga Shale

The Chattanooga Shale and its correlatives extend almost continuously throughout much of the interior of North America (Weller and others, 1948). There is no unanimity of opinion concerning the age assignment of the unit. The shale separates undoubted Devonian and Mississippian rocks.

Subsurface Character in Kansas

A sequence of black, gray, and red shale beds of questionable age overlies limestone and dolomite beds of unquestioned Devonian age in central and northeastern Kansas and underlies limestone beds of definite Mississippian age (Table 3). The lowest shale, the Chattanooga, extends into part of the area under investigation in south-central Kansas.

The Chattanooga Shale is probably of Devonian age in some areas but in others includes part of the Kinderhookian. The Woodford Shale of part of Major County, Oklahoma, (south of Barber and Harper Counties, Kansas) is a lateral equivalent of the Kansas Chattanooga Shale. From a core it is known to contain a siphonodellid conodont fauna (Kinderhookian) above a palmatolepid zone (Devonian) (Klapper, letter, June 11, 1965).

The Chattanooga Shale, typically a black fissile shale in southern Kansas, grades into gray shale northward (Moore and others, 1951). The shale is silty, pyritiferous, and in some places dolomitic. Spore cases (Sporangites huronensis) are sparsely disseminated throughout but are most common in basal beds. In the Salina Basin the shale is finely micaceous, less silty, and more argillaceous than to the south and east.

The Misener Sandstone Member at the base of the Chattanooga Shale (Table 3) is erratic in distribution. It exceeds 30 feet (9m) in thickness on the eastern flank of the Central Kansas Uplift. West of the Central Kansas Uplift, where the Chattanooga Shale is absent, the term "Misener" (Fig. 2) has been applied by petroleum geologists to a bed of sandstone beneath rocks of known Mississippian age and above rocks of known Ordovician age.

The term "Kinderhook" has been widely accepted by most petroleum geologists for Chattanooga Shale and the Boice Shale when present (Fig. 2). The term "Kinderhook" has also been used for oolitic limestone in western Kansas equivalent to the Gilmore City.

Distribution and Thickness

The distribution of the Chattanooga Shale in Kansas (including the Boice Shale where present in northeastern Kansas) is shown in Figure 8. In the subsurface of parts of southern Kansas within my study area, the Chattanooga Shale ranges in thickness from zero in Comanche County to 50 feet (15m) in Barber County.

Stratigraphic Relationships

The Chattanooga Shale rests unconformably on rocks ranging from Devonian to early Ordovician age (Figs. 9A and 9B) and is unconformably overlain in north-central and northeastern Kansas by the Boice Shale, elsewhere by Mississippian carbonate or chert rock units (Chouteau to the Burlington) and by Pennsylvanian rocks.

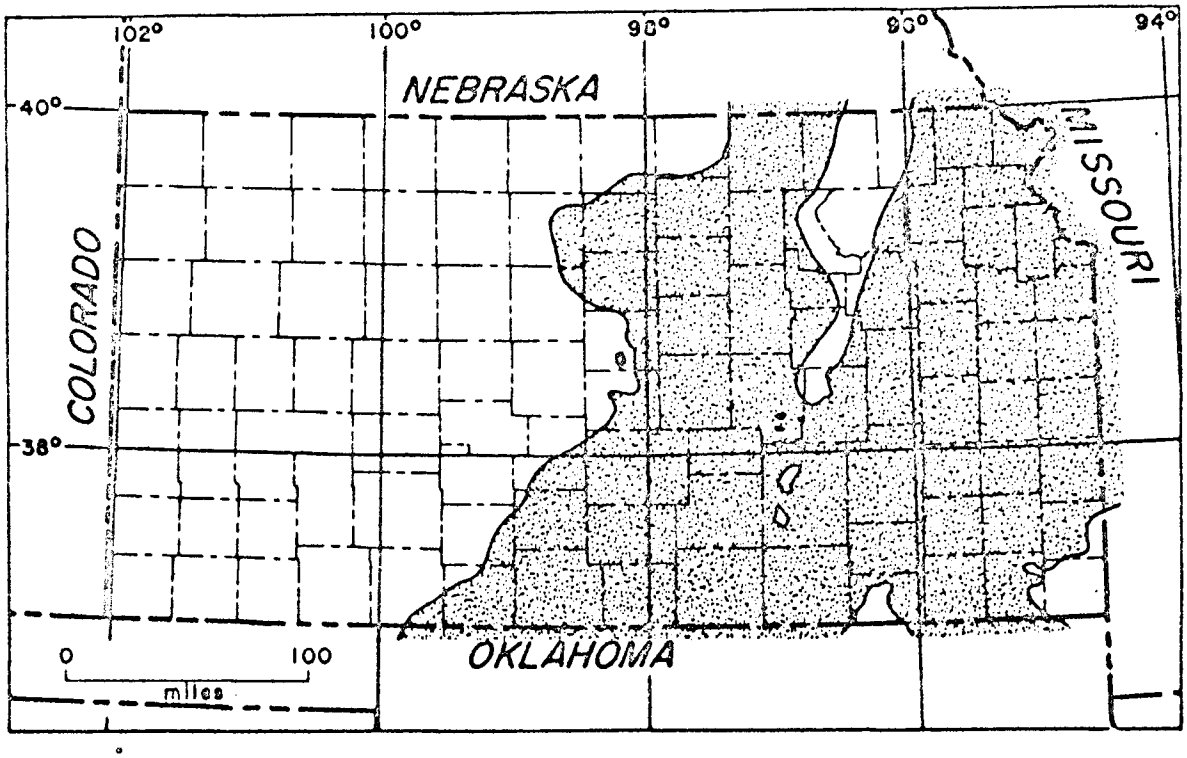
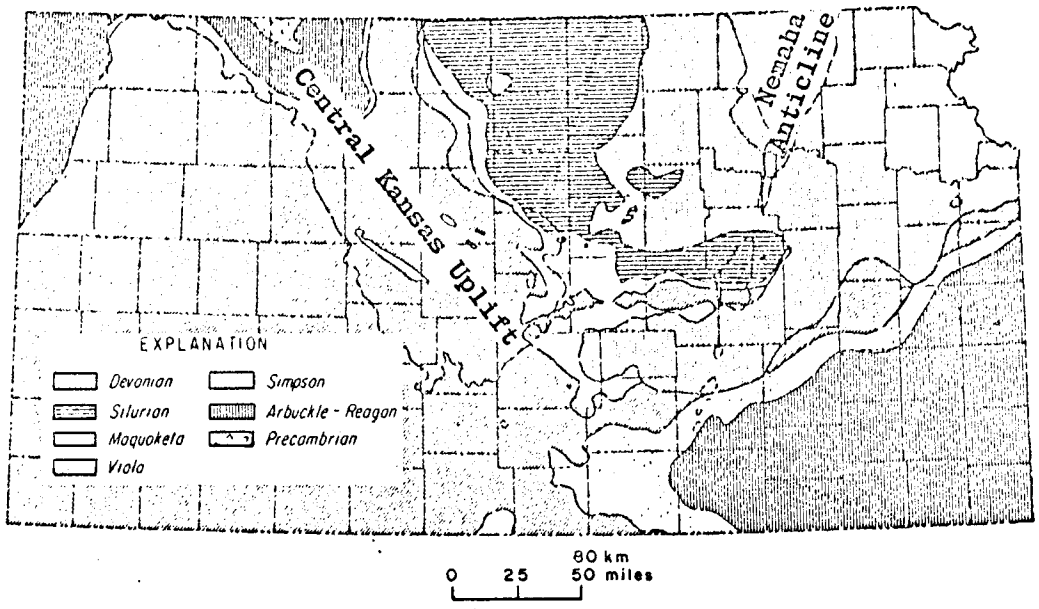


Figure 8.--Map showing subsurface distribution of Chattanooga Shale in Kansas (from Merriam, 1963, fig. 73).

Devonian-Mississippian Rocks West of Kansas

A pre-Mississippian paleogeologic map of the western part of my study area, and Colorado, Wyoming, and parts of adjacent states (Fig. 10A) shows the distribution of Ordovician and Silurian rocks. The distribution map (Fig. 10B) of Devonian rocks indicates probable maximum extent along the Transcontinental Arch northwest of Kansas in eastern Colorado. Haun and Kent (1965) reported an apparent disconformity between Devonian and Mississippian formations in this region and reported clastic sediments in basal Mississippian beds. Probably some Devonian

A



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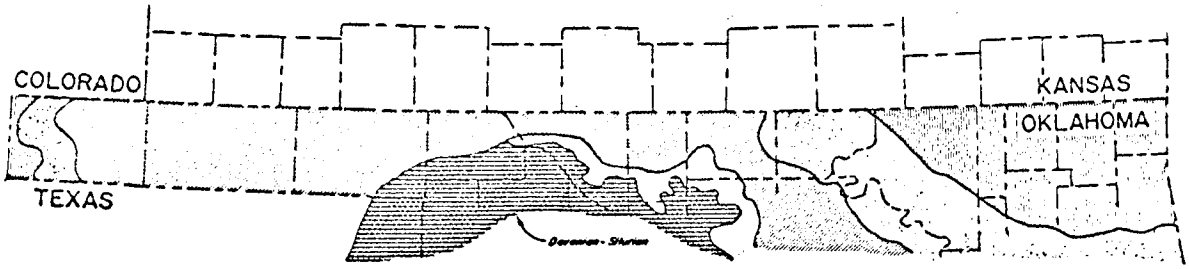


Figure 9.-- (A) Map of Kansas showing rocks underlying Chattanooga Shale or inferred position in pre-Chattanooga time where Chattanooga is absent. (In part from Lee and Merriam, 1954; Merriam, 1955; Lee, 1956; and Merriam, 1963). (B) Map of northern Oklahoma showing rocks underlying Woodford Shale, same key as in (A) (adapted from Tarr and others, 1965).

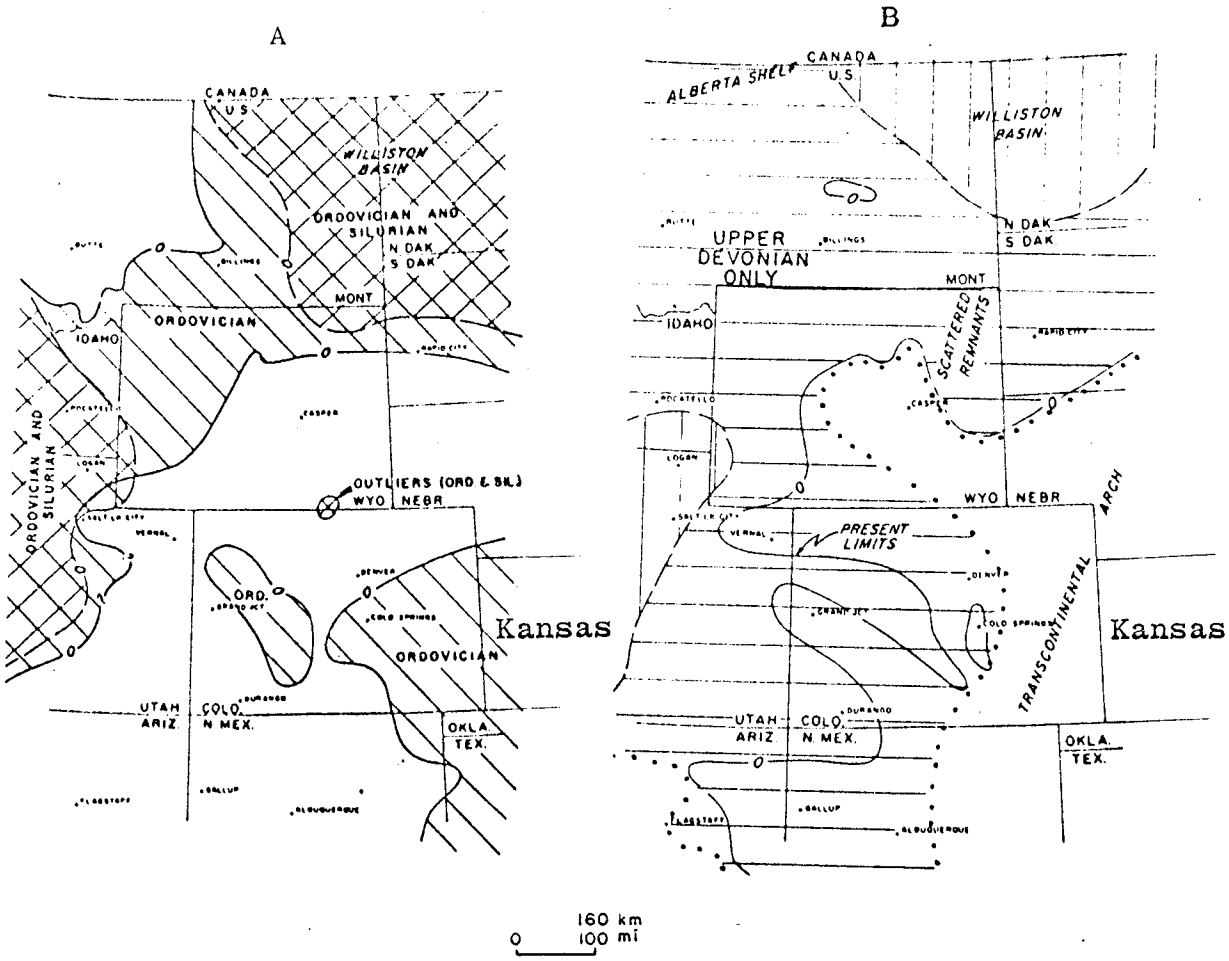


Figure 10.--Distribution maps of Ordovician, Silurian, and Devonian rocks in Colorado, Wyoming, and adjacent areas. (A) Ordovician-Silurian (from Haun and Kent, 1965; after Chronic and Ferris, 1961, 1963, Hintze, 1959, Rush, 1963, Sandberg and McMannis, 1964, Sloss and others, 1960, Stoyanow, 1936). (B) Devonian distribution map. Dotted lines indicate possible maximum extent, vertical lines show limits of Upper Devonian rocks (from Haun and Kent, 1965; after Eardley, 1963, McKee, 1951, Rothrock, 1960, Sandberg and Hammond, 1958, Sloss and others, 1960).

sediments were removed from marginal areas where Mississippian now rests on older rocks.

Assignments of exposed lithologic units in Colorado to the Devonian, Lower Mississippian, or Devonian-Mississippian have been made by various authors. Maher (1953) reported the absence of rocks of either Kinderhookian or Osagian age in the area of the Front Range; but later (Maher, 1958) called the Williams Canyon Limestone either Devonian or Mississippian (Table 2).

The name Chaffee was first applied to Devonian rocks in central Colorado (Parting Quartzite Member overlain by the Dyer Dolomite Member) equivalent to the Ouray and Elbert Formations of southwestern Colorado. The term Chaffee was modified by Knight and Baars (1957) on fossil evidence to include rocks of early Mississippian age. In central Colorado, the Chaffee was assigned by Rold (1950) to the Upper Devonian. MacLachlan (1961) extended the term Chaffee from central Colorado into the subsurface of eastern Colorado to the Kansas border. He correlated the Gilmore City or "Kinderhook" limestone with the upper part of the Chaffee (carbonate) at the outcrop. In the subsurface of eastern Colorado, the Chaffee, as used by MacLachlan (1961), included oolitic limestone beds in the upper portion and a mixed sand, shale, and dolomite unit in the lower portion. Maher (1958) placed these rocks in the Kinderhookian. MacLachlan interpreted the lithologic unit present in the subsurface as having the same relationships as the surface Chaffee Formation; that is, transitional from late Devonian to early Mississippian.

The age and stratigraphic relations of lower Mississippian and older Paleozoic rocks in the western part of the Hugoton Embayment in eastern Colorado are imperfectly known.

Devonian-Mississippian Rocks in Western Kansas

The thin clastic interval of rock in western Kansas above the Viola Limestone but below known Kinderhookian limestone strata represents preserved rocks deposited during the interval from Late Ordovician to Early Mississippian time. The Chattanooga Shale, or the "Kinderhook Shale" of oil field terminology, is unreported in most of western Kansas. Because Chattanooga Shale, where present eastward, probably represents the approximate lateral stratigraphic equivalent, this clastic rock interval and the Chattanooga Shale constitute a lithostratigraphic unit mappable as Kinderhookian rocks in my report (Map Interval A, Pl. 2, Table 3).

In cross-section A-A' (Pl. 3, Sheet 1) from Clark County to Harper County the Chattanooga Shale is shown as generally decreasing in thickness westward between wells 15 and 10. The shale was not discernible in the samples and cores in well 10. Except for well 14, where Maquoketa Shale (Upper Ordovician) is present, the Chattanooga Shale lies over Viola Limestone (Middle Ordovician) and is overlain by rocks of early Osagian age. From well 10, westward along cross-section A-A' through well 7 (Pl. 3, Sheets 1 and 2) no Chattanooga Shale is present. Gray-green, siliceous, dolomitic, shaly to argillaceous rock containing scattered blebs of dark-blue opaque chert (well 10) is assigned to the Fern Glen Formation. Cores from this rock interval contained early Osagian microfossils. This interval of rock contains the lithology described by Lee (1940) as the Cowley Formation.

In wells 53, 54, and 9 in Ford and Clark Counties just west of the Pratt Anticline (cross-section B'-E, Pl. 4), Kinderhookian rocks and Chattanooga Shale are absent. Here also rocks of early Osagian age (Fern Glen) lie next above the Viola Limestone. From well 53 in Ford County, oolitic limestone diagnostic of

the Gilmore City Limestone is present toward the north and northwest in western Kansas.

In the Olson No. 1 Fowler borehole in Ford County (sec. 26, T. 27 S., R. 22 W.) southwest of the Central Kansas Uplift, Lee (1953) identified 40 feet of sandy and silty limestone and sandstone that included grains of weathered chert next above Viola Limestone as basal clastics of early Osagian age. Oil field terminology for this interval of rocks is "Misener" sandstone, even though the true Misener Sandstone is the basal member of the Chattanooga Shale (Table 3).

Southwest of the Central Kansas Uplift (Edwards and Pawnee Counties), where Upper Ordovician, Silurian, and Devonian rocks are unreported, the rocks between the Mississippian carbonate beds and the Viola Limestone differ from the Chattanooga Shale ("Kinderhook" of oil fields) in east-central Kansas areas. In Edwards and Pawnee Counties, the rocks consist of greenish-gray and rusty-brown shale interstratified with sandy shale and beds of sandstone in the upper part as well as at the base. Dolomite, locally cherty, occurs in the middle of the formation in some wells on the flank of the Central Kansas Uplift (Lee, 1956). The lithology of these rocks is so strikingly different from the Chattanooga beds farther east as to suggest a basal Mississippian clastic deposit distinct from the Chattanooga (Lee, 1956).

Conodont Evidence of Age

Rock cores of the Western Petroleum No. 1 Hoffman well (Pl. 8, in pocket) in Edwards County (Fig. 3) yielded conodonts which provided evidence on the age of the rock interval referred to by Lee (1956, p. 64) as Mississippian basal clastics. The Kinderhookian rocks in the core consist of shaly sandstone overlain by shale.

Below the core are two thin cherty, chalky, shaly limestone layers and a shaly sandstone and a well-sorted, fine-grained basal sandstone. Details of core lithology and residues are given in the captions of Plate 8.

Appraisal of the conodonts recovered from the insoluble residue portion of this Kinderhookian rock core indicates a mixed fauna of Late Devonian and Kinderhookian genera. Elictognathus and Siphonodella are genera known only from the Kinderhookian. Icriodus, Palmatolepis, and Polylophodonta are known only from the pre-Mississippian (Pl. 1 and Figs. 5, 6). The chart (Appendix A) showing the distribution of genera by footage does not give a true indication of the numbers of reworked specimens and fragments of conodonts recovered in the insoluble residue portion of this core, because only selected specimens were mounted. More than 400 identifiable fragments and specimens (most demonstrating rounding) were recovered from the sandy portion of the core.

The conodonts seemingly substantiate Lee's interpretation of the "unique rock" in the Edwards and Pawnee Counties area as being between the base of known Mississippian limestone beds and the Viola Limestone. The presence of Elictognathus and Siphonodella with Devonian conodonts in the mixed fauna allows the conclusion that Devonian rocks were the source of the Devonian fossils. Along with Kinderhookian rocks the Devonian rocks were reworked by a sea younger than late Kinderhookian.

The interval with more than 85 percent chert residue above 4,527 feet depth (Pl. 8) is assigned to the Osagian rocks on the basis of lateral continuity with Mississippian "Chat" and occurrence above rocks of Kinderhookian age. Sample examination above 4,496 feet shows that the Pennsylvanian basal conglomerate lies next above the Mississippian chert here.

Limestone and dolomite cores from the Sinclair Oil No. 1 Mercer well, in Sherman County, in northwestern Kansas (well 18, Pl. 5 and Table 1) also have significance in relation to Devonian-Mississippian rocks. The conodont fauna of this core (distribution tabulated in Appendix A) consists of seven specimens of Scaphignathus (Pl. 1), one specimen each of Ozarkodina and Polygnathus?, and one specimen of Scolopodus. The specimens exhibit little evidence of abrasion.

Scaphignathus according to Müller (1962, p. W246) has been described only from Upper Devonian rocks in Germany (the Prolobites-Platyclymenia Zone of Europe) (Fig. 7). Collinson (letter, Feb. 24, 1965) observed similar specimens in the European section. Klapper (conference at Lawrence, Kansas, May, 1965) observed similarities of Kansas specimens with specimens of Australian Scaphignathus.

The presence of Devonian Scaphignathus in the No. 1 Mercer core does not necessarily indicate a Devonian biostratigraphic zone or preserved Devonian rocks. Maybe it indicates that Scaphignathus lived into the Kinderhookian in Kansas, but only through Upper Devonian in Germany. Reworking of pre-existing Devonian rocks (without abrasion of the specimens) and incorporation of the acid resistant phosphatic microfossils into Kinderhookian rocks is also a feasible conclusion. The interval in the Mercer well from 5,400-5,580 feet is assigned to the Kinderhookian rocks because of lateral continuity of lithology from other wells. Because of the relevance of the information from the Mercer core to the possible extent of Devonian rocks in northwestern Kansas, the core is discussed in this section of my report rather than in the chapter on the Kinderhookian Stage.

The upper part of a core (5,488-5,668 feet, total core) from Phillips No. 2 Goodland well was logged by a commercial logging company as Mississippian (well 20, Pl. 5). The core, because of its proximity, was expected to provide

paleontological evidence on the correlation problem of Devonian fossils occurring in the Mercer core. However, conodont specimens recovered from the residues of the Goodland core are known only from rocks of Ordovician age. In the No. 2 Goodland well as in the No. 1 Mercer well, approximately 150 feet (46m) of oolitic dolomitic limestone was logged next above the core as Gilmore City Limestone (Kinderhookian) on the basis of lateral continuity.

A 6-foot (1.8m) core (Table 1) recovered from 4,651-4,661 feet depth in the Texas No. 1 Dougherty in adjacent Thomas County (sec. 23, T. 6 S., R. 33 W.) also was expected to provide paleontological evidence on the age of Mississippian rocks. Unfortunately, the rock in the core was mostly silicified, an occurrence which is abnormal for the Kinderhookian rocks in the region, and did not break down in the laboratory procedure.

One fragment of a small specimen of Palmatolepis was observed from Ste. Genevieve Limestone residues of the Kells "B" core (well 42, Pl. 7), and one specimen was found in the Warsaw Limestone residues in the No. 1-A Mark well (well 39, Pl. 7). Palmatolepis is known only from rocks of Devonian age (Pl. 1, Figs. 5 and 6). In these two wells, the specimens could be interpreted as representing reworking of Devonian sediments--a "phantom formation." Possibly, the genus ranges into much younger rocks than previously reported. One questionable Scaphignathus was identified at 5,185 feet in the Texas Co. No. 1 F. L. Smith well (well 22, Pl. 5) with an associated fauna of conodonts that indicated Kinderhookian age.

KINDERHOOKIAN STAGE

Outcrops and Extensions of Rock Names into Kansas

Kinderhookian rocks are exposed on the northern flanks of the Ozark Uplift across central Missouri (Fig. 1), in the Mississippi River Valley bluffs between Missouri and Illinois, and in a northwest-southeast belt in central Iowa.

Classification of Kinderhookian rocks in these and other areas pertinent to western Kansas are given in Table 2. Lee (1940) and Moore and others (1951) extended formation names into Kansas from these areas. The sequence and the general relationships of stratigraphic divisions are shown in diagrammatic section in Figure 11. The left side of the figure represents the eastern border of Kansas.

Moore and others (1951) identified the Compton as the lowest limestone formation of the Kinderhookian in Kansas (Fig. 2), and correlated the Northview Shale with the Lower Sedalia Dolomite. This practice is followed in the classification presented in Table 3. The Upper Sedalia Dolomite, a noncherty or sparsely cherty, buff to gray dolomite overlies the Lower Sedalia in northeastern Kansas but overlaps it westward into the Salina Basin, where the Upper Sedalia rests on the Chattanooga.

Clair (1948) applied the term Chouteau Formation to the lowermost Mississippian rocks (Kinderhookian?) in southwestern Kansas, suggesting their lithologic(?) equivalency with the Northview (Shale?) and Compton (Limestone?) of eastern Kansas. Lee (1953) regarded Clair's Chouteau sequence and the lower part of Maher and Collins' (1949) Kinderhook Group as the Fern Glen Formation (Osagian). The formations of the Kinderhookian Stage in various parts of Kansas are summarized in Table 3. In western Kansas, the upper member of the Sedalia Dolomite and the Gilmore City Limestone are recognized overlying the undifferentiated Devonian-

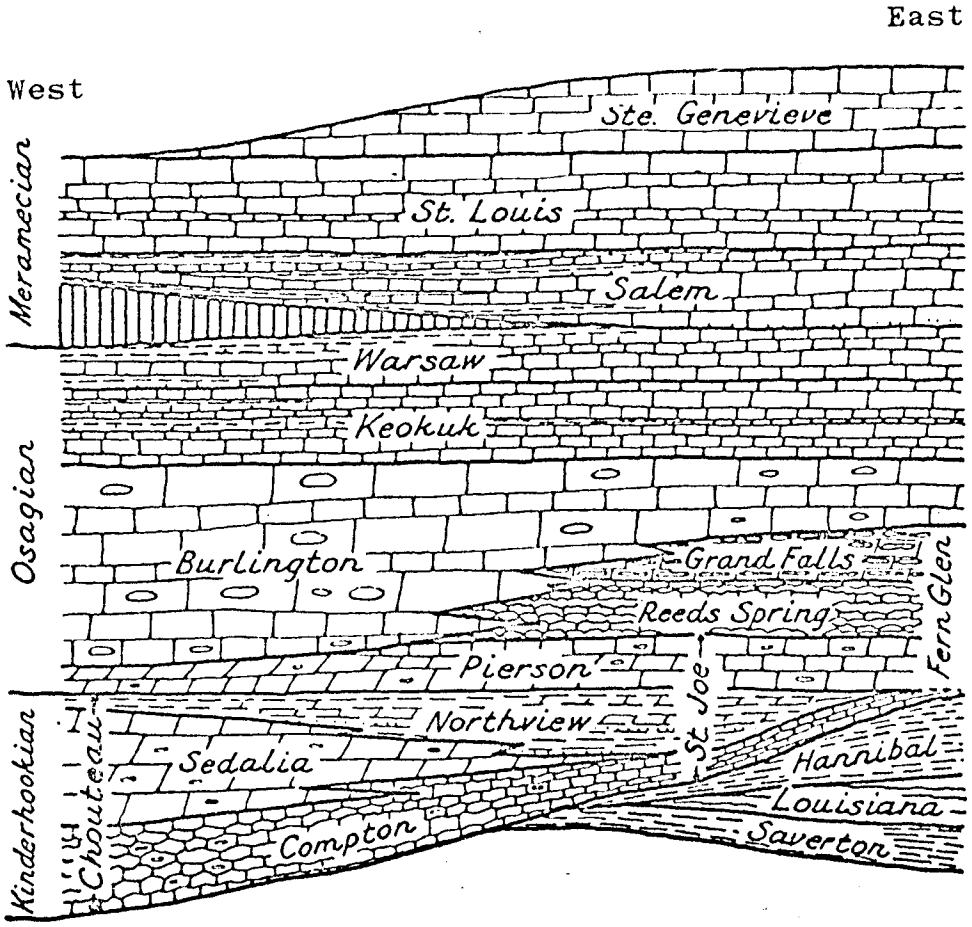


Figure 11.-- Diagrammatic section of pre-Chesteran Mississippian rocks of the Ozark region showing dominance of carbonate deposits. The sequence and general relationships of stratigraphic divisions are indicated (from Moore, 1957, fig. 1).

Mississippian rocks and the "Kinderhook," described previously.

Gross Lithologic Features, Thickness, and Distribution in Western Kansas

The gross lithology of a composite section of Kinderhookian rocks in western Kansas is a sequence composed of a relatively thin, sandy to dolomitic limestone or shaly sandstone unit (0-70 feet [21m] thick) at the base, overlain by fossil-fragmental limestone interbedded with oolitic limestone. Although some of the carbonate sequence may be clastic, I refer to only the sandy beds as clastic. The clastic beds are composed locally of well-sorted sand, the oil field "Misener." In local distribution, an oolitic, calcareous dolomite or a saccharoidal dolomite is present in the lower part of Kinderhookian rocks above dolomites of Cambro-Ordovician age; this interval is assigned to the upper member of the Sedalia Dolomite. In some areas, no sandy beds are present. In these areas, as well as where the upper member of the Sedalia Dolomite is present, the easily recognized and widespread oolitic Gilmore City Limestone is developed.

The thickness and distribution of the Kinderhookian rocks in western Kansas are shown in Plate 2A. They are absent from the area of the Central Kansas Uplift, from part of the Pratt Anticline, and from parts of Barber, Clark, Comanche, Edwards, Ford, Gray, and Meade Counties. In eastern Rice County the Kinderhookian rocks (Interval A, Table 3), which include Chattanooga Shale where present, are up to 250 feet (76m) thick. West of the Central Kansas Uplift, the thickness of Kinderhookian rocks generally is less than 100 feet (30m) and rarely exceeds 150 feet (46m).

A thin shale interval that overlies the Viola Limestone is assigned to the

Kinderhookian rocks (cross-section A-A', Pl. 3, well 6). Westward the shale increases in sand content and in thickness and is beneath the oolitic limestone of the Gilmore City. Locally, a cherty dolomitic limestone overlies the shaly sandstone and is recognized as the Gilmore City.

Starting in well 52 (cross-section B'-E, Pl. 4) Kinderhookian rocks (Gilmore City Limestone and thin basal clastics) are recognized northward to where pre-Pennsylvanian erosion has removed them on the Central Kansas Uplift. The upper member of the Sedalia Dolomite is locally present below the Gilmore City in northwestern Kansas, and the basal clastics are poorly developed or absent.

Sedalia Dolomite

Upper Member of the Sedalia Dolomite

The upper member of the Sedalia Dolomite is a buff to brown, locally gray, generally noncherty saccharoidal dolomite. It was mapped by Lee (1956) as far west in Kansas as Smith County in the Salina Basin (Fig. 12). Westward from Johnson County in northeastern Kansas the member thins from 30 feet (9m) to less than 10 feet (3m) in Smith County. It is separated by disconformities above and below in the Salina Basin (Lee, 1956). In Smith County, in part of my study area, it overlies the Chattanooga Shale and is overlain and overlapped westward by the Gilmore City Limestone (Fig. 12).

Carlson (1963) regarded Lee's (1956) Upper Sedalia (Table 2) as a lithologic and stratigraphic equivalent of the upper portion of the Eagle City-Iowa Falls beds of the Hampton Group in southwestern Nebraska but reported no disconformity with the overlying Gilmore City. The Hampton occupies the same stratigraphic position as Maher's (1948) "Misener" sand of oil field usage. Carlson

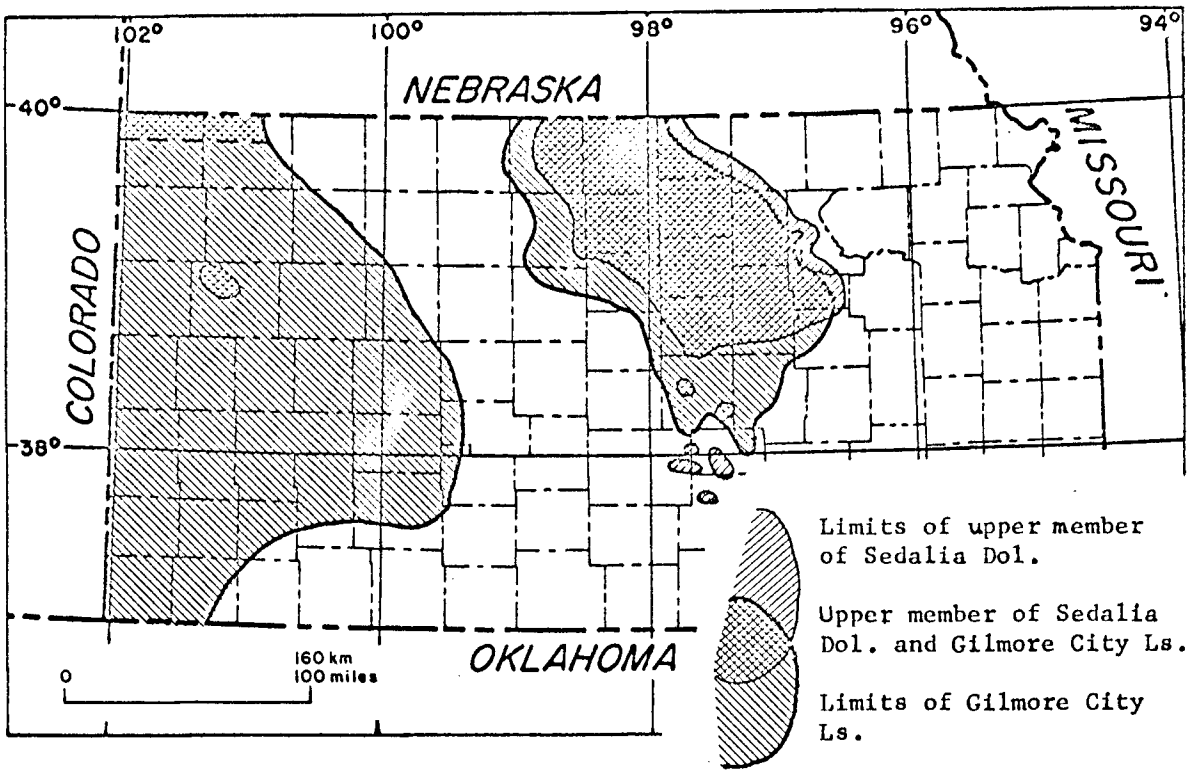


Figure 12.-- Map of Kansas showing distribution of Gilmore City Limestone and upper member of Sedalia Dolomite in the Salina Basin (in part from Lee, 1956) and western Kansas.

extended part of the Hampton into northwestern Kansas.

Lithology and distribution in western Kansas.--In stratigraphic cross-section C-C' (Pl. 6), the upper member of the Sedalia Dolomite is extended (locally) from Dundy County, Nebraska, into Cheyenne County, Kansas.

Lee (1940, p. 45), from meager evidence of one cross-section using widely spaced wells, concluded that Gilmore City Limestone overlies pre-Chattanooga rocks in western Kansas. Evidence from cores in northwestern Kansas studied by me contradicts this conclusion. The upper member of the Sedalia Dolomite is recognized in my study, but the distribution is unknown. The distribution of the

upper member of the Sedalia in the Salina Basin and the local identification in western Kansas is shown in Figure 12.

The Texas Co. No. 1 F. L. Smith (Pl. 9 and well 22, Pl. 5) and the Phillips No. 1 Monument Prospect (well 23, Pl. 5) cores in Logan County had about 15 feet of dolomite (Upper Sedalia) above the Arbuckle Group. The Upper Sedalia contained an abundant Kinderhookian conodont fauna (siphonodellid). Distinguishing dolomite beds of the Upper Sedalia where they overlie dolomites of the Arbuckle Group is difficult because of gross lithologic similarities. Presence of a distinctive Kinderhookian microfauna in cores aids in identification of rocks of Kinderhookian age.

In southwestern Nebraska, Carlson (1963) distinguished the Hampton from the underlying Bonneterre (Cambrian) on the basis of sandy non-glauconitic dolomite. However, the feature was not useful in differentiating the upper member of the Sedalia from the Bonneterre Dolomite in Kansas.

Core and residue data.--In the Texas Co. No. 1 F. L. Smith in Logan County (Pl. 9), finely crystalline, brown, honeycombed dolomite containing abundant molds of crinoid ossicles and ooliths is assigned to the Upper Sedalia Dolomite. Details of the acid residues from the core are summarized in the captions of Plate 9 and described in Appendix B. In the lower one foot of the core, the residue is generally greater than 40 percent and includes pyrite, sphalerite, glauconite, anhydrite, and galena. This concentration and association of minerals may be useful in marking the bottom of Kinderhookian rocks.

A siphonodellid (Kinderhookian) conodont fauna (Figs. 5 and 6), including Elictognathus and Polygnathus, was recovered from the core (Appendix A). Also

a specimen of Scaphignathus (known previously only from rocks of Devonian age) was found. Recovery of the specimen from an oolitic limestone allows the possibility that it is reworked although the specimen exhibits little evidence of rounding. Arenaceous Foraminifera and scolecodonts also were recovered in residues to 5,200 feet, and these may be of value in future studies.

Scolopodus (Appendix A) dominated the pre-Silurian faunas recovered from below 5,268 feet in the core (Pl. 9). This evidence helps to differentiate older rocks (Cambro-Ordovician) from rocks of Kinderhookian age.

In the Phillips Petro. Co. No. 1 Monument Prospect well, also in Logan County, a Kinderhookian core (5,290-5,321 feet depth) consists of alternating beds of oolitic limestone, dolomitic and semicrinoidal limestone, and dolomite. A part of these rocks is assigned to the Upper Sedalia Dolomite (well 23, Pl. 5). Sample cuttings from an interval above the core (5,160-5,290 feet) consist of cream to buff colored, slightly dolomitic, oolitic limestone, characteristic of the Gilmore City Limestone.

Pyrite makes up the largest part of the insoluble residue, but traces of sphalerite and galena occur. Traces of glauconite were observed at 5,309-5,311 and from 5,320-5,323 feet. Erratic occurrence of anhydrite was observed in the residue. Needle-shaped, brassy crystals were recovered in the residue from this core at 5,321 feet. Examination revealed that these crystals were localized in vugs and fractures. Some needles selected for spectrographic determination were found to consist mostly of iron. These needle-like crystals are identified here as marcasite, but resemble the millerite reported from the Fern Glen residues in Missouri by Grohskopf and McCracken (1949, p. 22).

Scolecodonts were found from 5,290 to 5,300 feet. The contact between the Kinderhookian and Ordovician is placed at 5,321 feet on the basis of residues, the siphonodellid fauna above (Appendix A), and the presence of Belodus and Scolopodus (pre-Silurian faunas) in abundant quantities below.

Gilmore City Limestone

Outcrops and extension of names into Kansas.--The Gilmore City Limestone, which crops out in central Iowa, was established as a formation by Laudon (1933). The Gilmore City is not recognized in outcrops along the upper Mississippi River Valley or in northern Missouri. In the type locality the Gilmore City is overlain unconformably by St. Louis Limestone and underlain unconformably by the Iowa Falls Member (Hampton) of Laudon (1933). Assignment of Late Kinderhookian age on faunal grounds by Laudon (1933; 1935, p. 246) is disputed by some paleontologists who place it in the Osagian (Carlson, 1963).

The Gilmore City was extended from the outcrop area in central Iowa, across Nebraska, and into northwestern Kansas by Carlson (1963). In the Nebraska subsurface, the Gilmore City is mapped as sublithographic to granular limestone with rare occurrences of dolomite and sporadic vertical and lateral distribution of oolitic zones (Carlson, 1963, p. 18). It is the most extensive Mississippian unit in Nebraska and because of its distinctive lithology, the Gilmore City is an important marker bed in the subsurface. Carlson (1963, p. 26) reported that the Gilmore City in southwestern Nebraska ranges in thickness from 8 to 30 feet (2 to 9m) and thins to the northwest. Carlson identified lower Keokuk-Burlington rocks and Pennsylvanian beds above the Gilmore City and Hampton at the Kansas border.

Lee (1956) extended the use of the name Gilmore City into the Salina Basin from Nebraska (Fig. 12) and recognized a limited distribution of the Gilmore City in the central part of western Kansas (1940). Lee (1956) traced the Gilmore City, which is unconformable below the Burlington (Osagian), into the Kansas portion of the Salina Basin and found it to be--"a relatively pure, occasionally cherty, granular limestone composed of worn fragments of finely broken calcareous fossils, with or without ooliths, embedded in a crypto-crystalline matrix." Lee described fragments of green argillaceous shale as a minor constituent of the Gilmore City. Various sizes and shapes of gray ooliths contained in a matrix of the same color also were included in the Gilmore City by Lee (1956, p. 77). In the Salina Basin, the percent by volume of insoluble residues from the Gilmore City is low to negligible and characteristically consists of loose aggregates of fine quartz crystals and thin finely drusy crusts and microscopic mammillary and columnar flakes of chalcedonic chert.

Lithology and distribution in western Kansas.--The lithology which Carlson (1963, p. 26) reported as a distinguishing feature of the Gilmore City in southwestern Nebraska carries into western Kansas as far south as northern Meade County but was not found in parts of Barber, Clark, Comanche, Ford, Kiowa, and Pratt Counties (Fig. 12). Characteristically, the Gilmore City is an oolitic limestone (Pl. 9). West of the Central Kansas Uplift, gray, faintly yellow, and buff to gray oolitic limestone beds are widespread beneath cherty Osagian rocks. Some limestone strata are semigranular and composed largely of finely-broken fragments of fossils cemented with a soft, opaque, gray limestone matrix. In places the oolitic limestone beds contain a large portion of subangular elongated grains. Size and shape of ooliths vary; they are gray to black in color and some have black centers. Where the Gilmore City is

thin and not oolitic, it is distinguished from the St. Joe Member of the Fern Glen Formation (Table 3) by the darker color and argillaceous character of the St. Joe.

In cross-section A-A' (Pl. 3, Sheet 1), Gilmore City oolitic limestone was found in wells 1 through 3. Evidence of the southern limit of the oolitic limestone in Kansas is presented in well 3, the Mobil Oil Co. No. 1 Cunningham Est. well. Here, about 30 feet (9m) of oolitic limestone is logged above approximately 70 feet (21m) of sand and sandy shale. The 70-foot (21m) interval of sand and sandy shale is assigned to "Kinderhook" (Kinderhookian rocks). The oolitic limestone in wells 1-3 can be traced northward and is so shown in stratigraphic cross-sections (Pls. 4-7). The clastic interval below the Gilmore City disappears northward before well 41 in Finney County (Pl. 7), although a thin clastic interval, probably assignable to the "Misener" sandstone (Kinderhookian rocks), occurs in well 24. The important point in the absence of the clastic interval of "Kinderhook" or "Misener" sandstone in northwestern Kansas is that, over large areas, the Gilmore City Limestone is mapped above a carbonate unit, either the Viola Limestone or the Arbuckle Group. There is little evidence of a detrital zone accumulation between the rocks of known Mississippian age and the older rocks.

Lee (1940) in describing residues from sample cuttings from the Gilmore City in western Kansas mentioned that the percent by volume was small and included fine quartz crystals in loose aggregates and thin, finely drusy crusts. He logged small quantities of yellowish semi-translucent chert in the Gilmore City Limestone from residues from the Watchorn and McNeely No. 1 Spangler well (sec. 23, T. 20 S., R. 33 W., Scott County, well 3, pl. 7, Lee, 1940). Reexamination of these residues failed to reveal the presence of the chert Lee described. Chert occurs locally and sparsely in the sample cuttings of the Gilmore City Limestone (wells 1

and 51). It is tan to cream, ordinary, and semi-translucent. Possibly these occurrences represent contaminated cuttings or concentration of residual Ordovician chert. Generally, the most reliable characteristics of the Gilmore City lithology in samples are the presence of oolites and the absence of chert. Dolomitic limestone and dolomite occur locally in the Gilmore City.

Core and residue data. --The oolitic limestone so characteristic of the Gilmore City Limestone is verified in a core from the Texas No. 1 Smith well in Logan County in northwestern Kansas (Pl. 9). Residue features are summarized in the captions of Plate 9; details are given in Appendix B. Residues include a distinctive conodont fauna (Appendix A), which is correlated with the fauna reported in Kinderhookian conodont biostratigraphic zones of the type area.

Upper boundary of the Gilmore City Limestone.--The upper boundary of the Gilmore City Limestone is picked on the basis of first appearance of oolitic limestone or on absence of cherty limestones. In southwestern Nebraska the top of the Gilmore City forms an extensive erosional surface beneath Pennsylvanian rocks (Carlson, 1963, p. 26) and is also in contact with the lower Keokuk-Burlington as well as Pennsylvanian beds. In western Kansas, Osagian rocks overlie Kinderhookian rocks unconformably.

Lee (1940, cross-section F-F', pl. 7) identified the Burlington Limestone above the Gilmore City Limestone in a number of wells in the central part of western Kansas. None of the northwestern Kansas cores examined during my investigation yielded conodont faunas that would indicate the presence of a biostratigraphic zone that could be correlated with the conodont zones of the Burlington Limestone of the type area. This evidence indicates an unconformity. In the Teeter well core (Pl. 5,

well 24) in Gove County, the Keokuk Limestone lies above the Gilmore City. In the core from a well in Barber County in south-central Kansas (the Circle well, well 13, Pl. 3, Sheet 2), a conodont fauna indicates an early Osagian biostratigraphic zone. The Burlington Limestone is identified in that core; however, Gilmore City and Upper Sedalia are not present.

Fossils from Kinderhookian Rocks

Although an abundant siphonodellid fauna (Appendix A), limited to the Kinderhookian, is known from cores in northwestern Kansas, subdivision of the fauna into finer biostratigraphic zones is not possible at this time. A conodont fauna has not been reported from exposed Gilmore City rocks although residue work is under way by Wayne Anderson (State College of Iowa). Fragments of Siphonodella from spot samples (Goebel collection, Kansas Geological Survey) have been recovered. Anderson (1965) reported a siphonodellid fauna from the Hampton (Maynes Creek) of Iowa, which underlies the Gilmore City Limestone. Conodonts are unreported from cores of the Gilmore City Limestone in Iowa and Nebraska.

Siphonodella crenulata, S. quadriplicata, and S. lobata range only into the lower Kinderhookian (upper Chouteau) in the type locality according to Collinson and others (1962). The presence of these species with S. cooperi in Gilmore City Limestone and the upper member of the Sedalia (Fig. 2) in northwestern Kansas may be accounted for on the basis of three interpretations. Some could be from reworked sediments occurring in the oolitic and fossil-fragmental limestone lithology. The formations may transgress time. Also, the range of the genera may be longer (into younger Kinderhookian rocks) in Kansas.

The Siphonodella isosticha-S. cooperi Assemblage Zone of Rexroad and Scott (1964) was determined by Collinson and others (1962, p. 21) as occupying the upper part of the Chouteau Formation of the Mississippi River Valley; they correlated it with the upper part of the European Lower Carboniferous Cu IIα Zone (Fig. 7). The limits of the assemblage zone coincide with common occurrence of S. isosticha and the abundant occurrence of S. cooperi. Gnathodus delicatus is abundant in the upper part of the zone but does not range above the zone. Some characteristic species of the zone listed by these authors include Polygnathus communis, P. inornata, Spathognathodus curvatus, and Elictognathus lacerata. This assemblage zone is one in which gnathodids and siphonodellids are abundant and Elictognathus is slightly less abundant. In the Mississippi River Valley the upper limit of this zone coincides with the Kinderhookian and the Valmeyeran boundary as defined by the Illinois Geological Survey.

Fewer gnathodid specimens were recovered from cores from northwestern Kansas (Appendix A) than the abundance suggested by Collinson and others (1962) as present in the Siphonodella isosticha-S. cooperi biostratigraphic zone. A dearth of gnathodid specimens is noted in the S. quadriplicata-S. crenulata Assemblage Zone (Collinson and others, 1962). The former assemblage zone, occurring near the top of the Hannibal Formation, includes the lower part of the Chouteau Formation in the type locality.

Other fossil material recovered as insoluble residue from Kinderhookian rocks in my study includes fragments of silicified brachiopods, crinoid ossicles, and scolecodonts. Chonetes cf. C. shumardianus (5,305 feet), Spirifer sp. (5,304 feet) and Punctospirifer sp. (5,307 feet) are brachiopods from the upper member of Sedalia Dolomite of the Phillips No. 1 Monument Prospect (well 23, Pl. 5).

Fenestrellina or Fenestralia were identified at 5,295 feet and 5,305 to 5,308 feet. Crinoid ossicles are also prominent in the core.

Residue Analysis

Insoluble mineral residues from some cores of Kinderhookian rocks in western Kansas have characteristics similar to residues recovered from these rocks in adjacent areas. The residues from carbonate rocks are less than 5 percent by weight and composed of silicified fossil fragments, pyrite, marcasite, sphalerite, galena, glauconite, anhydrite, doubly terminated euhedral quartz crystals, traces of soft black shale, and minor amounts of beekite. From clastic Kinderhookian rocks, residues are up to 95 percent by weight and composed of variegated shales, clay-size particles, and frosted, fine- to medium-grained, medium- to well-sorted sand. Minor quantities of glauconite, pyrite, and marcasite are present. Phosphatic fossil material (mostly conodonts) is an important element of the residues from both carbonate and clastic rocks. Scolecodonts are also present.

Residues from sample cuttings of carbonate Kinderhookian rocks characteristically consist of loose aggregates of fine quartz crystals. Detrital heavy minerals were not found in cores or sample cutting residues. These residue characteristics are similar to those of the Gilmore City and the Sedalia Dolomite in the Salina Basin. Residues from the Chattanooga Shale are characterized by micaceous shale and chitinous spore cases.

Environmental Interpretations

Evidence for Kinderhookian Transgression

The lithologic sequence of most of western Kansas Kinderhookian rocks fits well into the mechanics of the transgressive marine process as defined by Visher (1965, p. 56). The process of transgressive [illegible]tation is erosion and redeposition of a thin sediment zone by wave action. King (1951) observed that this reworking is probably effective to a depth of only a few feet. Because of this limited depth, it is probably difficult to derive much of the transgressive sediment from underlying sediments. Visher suggested that one means of developing transgressive sequences is by the addition of clastic detritus by longshore drift. Development of extensive transgressive deposits requires a close balance between the rate of sediment supply and the rate of transgression. Development of a subaqueous plain is possible where the gradient is such that wave energy is gradually dissipated (Keulegan and Krumbein, 1949). Visher (1965, p. 55) observed that if such a plain is the geomorphic form developed by a transgressive sea, it should be possible for a coarse clastic unit tens of feet thick to be developed. One of the physical characteristics of transgressive marine processes as set forth by Visher (1965) is high energy, indicated by coarse grain size and excellent sorting at the base of the sequence. In western Kansas this is represented by the erratically distributed but locally well-developed, well-sorted sand (the "Misener," Kinderhookian rocks). Transgressive sediments are observed to grade upward abruptly into finer-grained and more poorly sorted sediments (Visher, 1965), which represents a second physical characteristic. Abrupt transition upward into carbonates, without the development of the shaly part of the sequence, is common in the transgressive process; this feature is well met in western Kansas. Intercalated beds of oolitic and fossil-fragmental limestone in the Gilmore City

Limestone reflect alternating conditions of good and poor sorting. The lithic units developed by the transgressive process tend to be homogeneous and can be differentiated by criteria indicative of slow sedimentation, reports Visher, for example: glauconite, phosphates, and chemical precipitates. Glauconite and conodonts are present in this section of the Kinderhookian rocks in the Texas Co. No. 1 F. L. Smith and in the Phillips No. 1 Monument Prospect core residues. Biologic criteria erected by Visher include concentration of fish scales, shark teeth, phosphatic shell debris, and siliceous tests of various types of marine organisms. These biologic criteria are met by the rocks in northwestern Kansas. The widespread development of oolitic limestone beds as part of, but also above, transgressive deposits in western Kansas meets the conditions of agitated, relatively shallow water.

Environment of Deposition

The idea that oolites and many calcarenites form in a highly agitated shallow marine environment in which the water was saturated with calcium carbonate is well documented in the literature (Hatch and others, 1950). Limestone composed of fragments of brachiopods, crinoids, and bryozoans occurs mixed with ooliths and pellets and with erratic beds of oolitic limestone in the Gilmore City Limestone. Perhaps the Gilmore City was deposited in an environment in the Kinderhookian sea where various invertebrate animals lived on favorable areas such as bare rock surfaces, and after death or intense storm were scattered and mixed with the accumulating ooliths.

Shifting of the physical conditions of oolite deposition in time and space helps explain the distribution of the Gilmore City Limestone both vertically and laterally from central Iowa to southwestern Kansas. Probably the unit was even more widespread before removal by erosion.

Diagenesis

Diagenetic changes have occurred in Gilmore City oolites, such as radial overgrowths surrounding the ooliths. These are probably due to recrystallization or inversion of aragonite to calcite, but they attest to a secondary origin. Silicification of fossil fragments, preservation of limestone textures and relict molds of fossils in dolomite, and formation of secondary sulfide minerals (sphalerite, pyrite, marcasite, and galena) indicate diagenesis of Kinderhookian rocks in my study area.

Stratigraphic Relations and Discussion

Western Kansas

In Plates 5 and 6, the Kinderhookian rocks in northwestern Kansas are shown to consist of the Gilmore City Limestone overlapping southward over local occurrences of the upper member of the Sedalia, which in turn overlies the Arbuckle Group. The Viola Limestone underlies the Kinderhookian rocks in the southwestern part of western Kansas. A thin (0-70 feet, 0-21m) clastic interval of rocks occurs between the Gilmore City and Viola Limestone of western and southwestern Kansas (Pls. 3, 4, and 7).

Kinderhookian rocks northward in western Kansas are overlain by successively younger Osagian rocks (Pls. 4, 6, and 7). This marks an important unconformity below Osagian rocks.

Evidence presented in my report is in accord with Lee's conclusion (1940, p. 44) that the Gilmore City is absent in southern Ford County and to the southeast (Fig. 12). Also the Gilmore City is thin on the flanks and absent on top of the Central Kansas Uplift, probably because of late Mississippian erosion but possibly because of removal in early Mississippian time. In a cross-section from Meade to

Smith County, Kansas, Lee (1953) showed no Kinderhookian rocks in Meade and southern Ford Counties (wells 11 through 8, Adams, Rickers, Andrews, and Fowler). He recognized a cherty limestone, the Reeds Spring Member of the Fern Glen Formation (Osagian), resting on the cherty Viola Limestone (Ordovician). This same situation generally corresponds to areas of no Kinderhookian rocks as shown on Plate 2. In western Edwards County, in the B & G Smith well (Lee's well 7), Lee called Reeds Spring the uppermost Mississippian unit overlying a thin unit of Gilmore City (Kinderhookian), which in turn is overlain by the Viola Limestone. North of this well along cross-section B'-E (Pl. 4, well 49) distinction of Osagian formations was not possible, but in wells 45, 46, and 47 in Ness and Hodgeman Counties, undifferentiated Keokuk-Burlington is logged above the Gilmore City. Maher and Collins (1949) dated Lee's Reeds Spring interval of rocks in Meade County (the Adams and Rickers wells) as Kinderhookian. Maher and Collins (1949) recognized the great thickness of Kinderhookian rocks in the Hugoton Embayment in the Panhandle area of Oklahoma and included in isopachous maps Lee's Reeds Spring interval of Kinderhookian rocks.

Maher (1953, p. 2,483) reported that rocks of Kinderhookian age mark the base of the Mississippian in the Hugoton Embayment. He cited westward overlap at the base of the Mississippian as indicating that Mississippian seas advanced from the Anadarko Basin during Kinderhookian-Osagian time and finally covered the Apishapa-Sierra Grande Uplift in eastern Colorado in Meramecian time. My investigation revealed no evidence that Kinderhookian seas advanced westward from Kansas.

Related Areas

Hiestand (1938, p. 1,597) reported that the "Kinderhook Shale" (including Chattanooga) and Fern Glen Formation in south-central Kansas were deposited during a stage of slight crustal warping.

Lee (1956, p. 139) believed that the contact of the Chattanooga-Boice Shale sequence with the Mississippian limestones was exceptionally flat. At the end of Kinderhookian time the region was raised above sea level in the Salina Basin and during a period of relative stability the Kinderhookian formations were beveled. Along the southern margin of the Salina Basin, the Gilmore City rests disconformably on Chattanooga Shale or on outliers of the upper member of Sedalia Dolomite (Lee, 1956, p. 77). Northward, the Gilmore City locally is overlain by the St. Joe Limestone; farther north the Gilmore City is overlain by the Reeds Spring Limestone; and still farther north it is overlain by the lower zone of the Keokuk-Burlington. The Gilmore City in the Salina Basin is separated from overlying Osagian rocks by a conspicuous unconformity.

To the north of my study area, in southwestern Nebraska, Carlson (1963) reported that the Gilmore City is similar in distribution to the underlying upper part of Hampton Formation and that it is restricted to the south.

Maher and Collins (1949) reported the absence of Kinderhookian rocks on and adjacent to the Sierra Grande Uplift in eastern Colorado and on the highest part of the Keyes Dome in the Oklahoma Panhandle. They extended the Kinderhookian rocks over the Las Animas Arch at least as far as Lincoln County in Colorado.

Stratigraphic relationships of Kinderhookian rocks to the south of my study area are not totally resolved. Projection of isopachous lines on Plate 2A into the Oklahoma Panhandle indicates absence or thinning of Kinderhookian rocks.

Conclusions

In Kansas the transgression of the Kinderhookian sea was from the north. Evidence of Kinderhookian sea transgression from Nebraska, Iowa, and Missouri areas is generally compatible with evidence in Kansas. Elements of the Ellis Arch-Central Kansas Uplift, and Chautauqua Arch were probably overlapped by younger Kinderhookian rocks (Sedalia-Gilmore City). Also these features influenced and localized deposition of these rocks as well as older Kinderhookian rocks in Kansas. Localized post-Kinderhookian uplift in southern Kansas helped to remove Kinderhookian rocks in some areas. Post-Mississippian erosion of Kinderhookian rocks occurred where positive tectonic movements exposed them in the Pennsylvanian.

OSAGIAN STAGE

General Statement

Osagian rocks are known to extend widely over the Midcontinent region. They compose part of the blanket carbonate deposits which covered most of the Midcontinent and Rocky Mountain areas before removal from structurally positive areas in early Pennsylvanian time.

The term Osage was first applied by H. S. Williams (1891) to surface rocks in southeastern Iowa, to which he assigned the Keokuk Limestone and Burlington Limestone. Harris and Parker (1964) described these outcrops of Osagian rocks (Table 2) and included the Warsaw Limestone.

Figure 11 is a diagrammatic section of pre-Chesteran Mississippian rocks of the Ozark region showing the general relationship of the stratigraphic divisions. This illustration gives a regional insight into relationships of rocks of early Osagian age in Missouri and eastern Kansas.

Lee (1940) extended the terms St. Joe and Reeds Spring into southern Kansas from Missouri and later (1949, 1953, 1956) referred to them as formations of Fern Glen age. Moore and others (1951, p. 110) also followed this usage, describing the Reeds Spring Formation as conformable on but overlapping the St. Joe on the south flank of the Central Kansas Uplift. In my report, for all occurrences of Reeds Spring and St. Joe in Kansas, the usage preferred is as limestone members of the Fern Glen Formation (Fig. 2 and Table 3).

Lee (1940) extended to Kansas the terms Burlington and Keokuk from the surface Osagian rocks in the neighboring pertinent areas where they are widespread.

The Osagian, from lowermost to uppermost, consists of the St. Joe and Reeds Spring Members of the Fern Glen Formation, the Burlington Limestone, and the

Keokuk Limestone (Table 3). Middle Mississippian rocks in the type section (Osagian through Meramecian) are referred to the Valmeyeran by the Illinois Geological Survey (Fig. 6), but this designation is not followed in Kansas.

Lithology, Thickness, and Distribution in Kansas

In the past, Osagian rocks have been differentiated primarily on the character of included cherts and certain residue characteristics.

In Kansas Osagian rocks are predominantly carbonate and chert; in the Keokuk rocks and undifferentiated Keokuk-Burlington, chert is the dominant constituent. In western Kansas where cherty carbonates were exposed to early Pennsylvanian erosion, a thick residuum of weathered chert called "Chat", formed from silicified and cherty Mississippian rocks, occurs between the Osagian and Pennsylvanian strata and forms a broad band bordering the Central Kansas Uplift (Pl. 2D). This interval of residual chert is difficult to differentiate from transported chert. Abraded and corroded chert contained in the overlying conglomerate is called the Pennsylvanian "basal conglomerate." Geologists preparing isopachous maps involving the Mississippian-Pennsylvanian surface conventionally include chert interpreted as residuum with the Mississippian rock interval.

On Plate 2B, the pinch-out of Osagian rocks in western Kansas beneath the Pennsylvanian forms a rough outline of the Central Kansas Uplift. The Osagian rocks thicken southward to more than 600 feet (182m) in southern Meade and Clark Counties and are even thicker in the Anadarko Basin (Pl. 2B). The greatest thicknesses of Osagian rocks occur where Kinderhookian rocks are not recognized. Perhaps Osagian deposition filled this area of eroded Kinderhookian rocks. Across this area (cross-section A-A', Pl. 3 and cross-section B'-E, Pl. 4) there is no indication

of a clastic or detrital deposit above Viola Limestone. The cherty, dolomitic limestones and shales above the Viola rocks are here assigned to the Fern Glen Formation and Keokuk-Burlington Limestone.

Generally, oolitic Gilmore City Limestone is widespread below Osagian rocks in northwestern Kansas. This characteristic lithology of the Kinderhookian rocks was not observed in areas of thicker Osagian rocks (Pl. 2B). Until data to the contrary are available, the cherty interval above Viola Limestone in the latter area is assigned to the Osagian on the basis of lateral continuity with rocks assigned to the Fern Glen Formation to the east (Pl. 3, Sheet 2).

Northwest of the 200-foot (61m) isopach line (Pl. 2B) as far as the southern part of Trego, Gove, and Logan Counties (Fig. 3), Osagian rocks generally thin to 100 feet (30m) in thickness. Farther northwest, less than 100 feet (30m) of Osagian rocks are mapped; the distribution pattern is erratic. To the south, in southern Lane County and northeastern Finney County, Osagian rocks thin. Inliers of Kinderhookian rocks show through the Osagian subcrop pattern in some counties west of the Central Kansas Uplift (Pl. 2D).

Fern Glen Formation

St. Joe Limestone Member

Outcrops.--The St. Joe Limestone was first described by Hopkins (1893) in northern Arkansas, who regarded it as a member of the Boone Formation. The southwestern Missouri outcrops of the St. Joe Limestone resemble in lithology the southeastern Missouri outcrops of the lower part of the Fern Glen Formation (Spreng, 1961). It is a thin bedded, crinoidal limestone which locally includes interstratified beds of greenish and reddish calcareous shale and minor thicknesses of pink and reddish limestone.

Subsurface character in Kansas.--The subsurface characteristics of the St. Joe Limestone are similar to those at the outcrop. The St. Joe Limestone is semigranular in texture; the fragments are mostly crinoid ossicles. In the area of my report, chert is reported only in the lower limestone bed. A trace of glauconite was observed in samples.

Insoluble residues of the limestones from cable tool cuttings of the St. Joe in most places exhibit paper-thin flakes of greenish or gray shale. The erratically distributed reddish limestones reported by Lee (1940) in central Barber County were verified in my sample study of Lee's wells. The grayish, greenish, and dark-green shales near the base of the formation are common constituents of St. Joe in Barber County south of the Central Kansas Uplift.

In the Sinclair-Prairie No. 1 Alice Gentry well (Barber County), the calcareous green shale member (Pl. 10) is 50 feet (15m) thick and occurs 40 to 60 feet (12 to 18m) above the base of the formation (Lee, 1940). The Chattanooga Shale underlies the St. Joe in this well. Lee also reported that cores from this interval of shale exhibit thin sheets and streaks of crinoidal limestone. This core interval was not available for study, but sample cuttings from the same interval consisted of green, calcareous shale underlain by sparsely cherty limestone. No reddish-colored limestone was observed in the sample cuttings of the lower portion of the well.

Examination of cable tool samples from western Kansas, south of the Central Kansas Uplift, revealed much red and dark-colored shale and red crinoidal limestone interstratified with cherty limestone. The red coloring and the silt and clay in the limestone are considered evidence of a nearby shore line, reflecting the concurrent uplift of the Central Kansas Uplift.

Lee's (1940, p. 52) remarks on the problem of mapping the lower Osagian formations in that area are pertinent:

> The lithologic criterion [sic] for distinguishing the St. Joe, the rocks of late Fern Glen age, and the Burlington in this area are inadequate to distinguish these units with confidence.

In the study area, the St. Joe Member could be distinguished with confidence from the Reeds Spring Member only locally. Distinction between the Burlington and Fern Glen rocks is possible only in part of southwestern Barber County (Pl. 3, Sheet 2).

Lee (1949) logged limestone in both the St. Joe and Reeds Spring in the Pure Oil Company No. 1 Palmer well, sec. 10, T. 33 S., R. 10 W., in southern Barber County. To the northeast, also in Barber County, Lee logged limestone as the St. Joe and limestone and shaly limestone as the Reeds Spring in the Helmerich and Payne No. 1 Winters well, sec. 16, T. 32 S., R. 10 W. In Reno County in the Deep Rock No. 1 Whitmer well, sec. 10, T. 30 S., R. 9 W., cherty limestone is logged as Reeds Spring. My examination of sets of sample cuttings from these wells verifies these lithologic variations in the Fern Glen rocks.

The lithology of the abnormally thick St. Joe crinoidal limestones and fossil-fragmental limestones observed in sample study of some wells in south-central Kansas is similar to that of the bioherm phase of the St. Joe in outcrops. Lee (1940, p. 51) also suspected that abnormally thick bodies of noncherty limestones in the St. Joe in south-central Kansas were bioherms. Laudon (1939) noted the propensity of the St. Joe Limestone and its correlatives to have well developed bioherms over broad areas. Moore (1957) in a study of lithologies of the Mississippian carbonates of the Ozark uplift area indicated a somewhat local distribution of some Kinderhookian rocks and the Reeds Spring beds but made no special mention of bioherms.

Core and residue data. --The lithology of the Fern Glen interval in the Sinclair-Prairie No. 1 Exchange Bank core (Pl. 11) is typical of the "Cowley" facies, discussed in the section on Meramecian rocks. Possibly, some of the argillaceous gray to green shale in the lower part of this section is the St. Joe Limestone. Residues from the core are described in the caption of Plate 11 and include an assemblage of early Osagian conodonts (Appendix A). Possible silicified spore cases recovered as residues from the lower green and black shales resemble spores identified from the Chattanooga Shale to the east.

The Viola Limestone is recognized beneath the Fern Glen rocks in the Exchange Bank well. Residues (Pl. 11) include scolecodonts and conodonts. The occurrence of rocks of Ordovician age next below rocks of Osagian age is evidence of the absence of Kinderhookian rocks locally in my study area.

Thickness, area of deposition, and stratigraphic relations. --The St. Joe Limestone averages 15 feet (5m) in thickness in southeastern Kansas (Lee, 1940, p. 51). It is erratic in thickness westward but locally in Barber County measures more than 120 feet (37m) in sample study logs.

Lee (1940) reported St. Joe Limestone in southern Kansas along the Oklahoma border as far west as Clark County. In my study the westward extent could not be verified, although undifferentiated Fern Glen is mapped farther west than Clark County (Pl. 3, Sheets 1, 2). It pinches out northward in eastern and central Kansas, overlapping on a flat post-Kinderhookian surface (Lee, 1940, p. 48). The St. Joe also pinches out northward in southwestern Kansas. The upper member of the Fern Glen, the Reeds Spring Limestone, overlaps the St. Joe northward from the southern Kansas border. The distribution of the St. Joe Limestone is less widespread than

but similar to that of the Reeds Spring Limestone (Fig. 13); they outline Early Mississippian positive uplift in the area of the Central Kansas Uplift.

Reeds Spring Limestone

Outcrops.--The Reeds Spring Limestone is the upper member of the Fern Glen Formation. It was named by Moore (1928, p. 169) for outcrops in southwestern Missouri and northeastern Oklahoma as a member of the Boone Formation (Table 2).

Subsurface character in Kansas.--Although slightly saccharoidal and dolomitic in places, the Reeds Spring shows a westward increase of gray or buff, semigranular and fine-textured limestone. Spongy silica from insoluble residues of the lower part of the formation persists westward. In south-central Kansas, the greater part of the chert in the Reeds Spring is pale bluish or gray and semi-translucent or translucent. In insoluble residues, microscopic crusts of chalcedony are present. Limestone beds containing dark chert were referred to the Reeds Spring; semigranular limestones containing light-colored, semi-translucent, bluish chert were referred to rocks "of late Fern Glen age," by Lee (1940, p. 55). Probably one is a local variant of the other. The distinction was not observed in samples in my study area. As the Central Kansas Uplift is approached from the south, basal beds of the Fern Glen become dark gray and argillaceous. Southwest of the Central Kansas Uplift the Fern Glen consists mainly of cherty, semigranular limestone with interstitial dolomite. Chert is semi-translucent and chalcedonic, and in addition to pale-blue shades includes brown, dark-gray, and black, semi-translucent chert. Lee (1953) identified cherty limestone in his Meade County to Smith County cross-section as Reeds Spring (in wells 11-7).

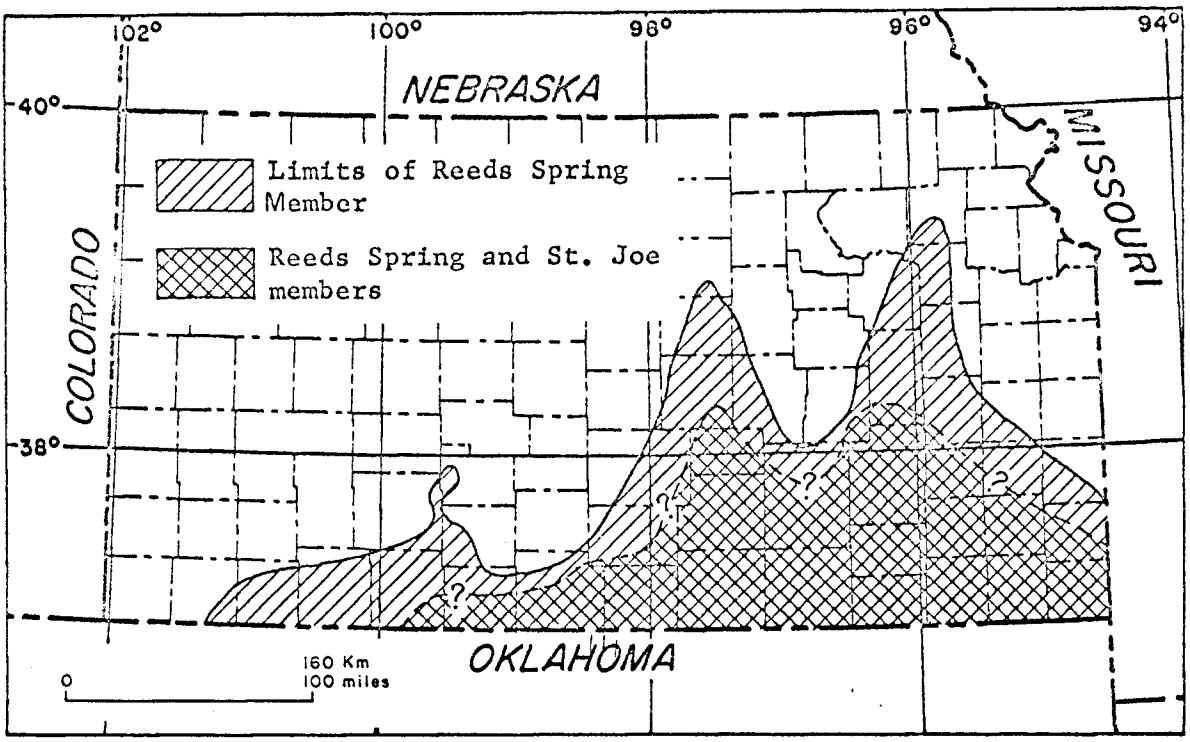


Figure 13.-- Map of Kansas showing distribution of St. Joe and Reeds Spring Members of Fern Glen Formation, Osagian (in part from Lee, 1940; 1953; 1956).

Core and residue data.--In the Sinclair-Prairie No. 1 Alice Gentry well in Barber County, the Reeds Spring Limestone (Pl. 10) is alternating thin beds of reddish (hematitic) and green-gray, semicrinoidal limestone. The rocks above 4,860 feet are assigned to the Burlington Limestone on the basis of lithology and high percentage of chert residue. Laudon (1937, p. 1,160) reported "a typical Burlington fossil (Pentremites elongatus Shumard)" a short distance below the contact with Pennsylvanian rocks in the core. Core descriptions and residue details of the Gentry well are given in the captions of Plate 10.

The groundmass of the thin semicrinoidal limestone beds of the Reeds Spring grades from reds to greens and grays. The groundmass ranges from nearly uniform fine-grained texture to medium-grained texture. The edges of the crinoid ossicles are not abraded, nor do they show evidence of recrystallization.

Many early Osagian conodonts, including Doliognathus, Gnathodus cuneiformis, Polygnathus communis, Bactrognathus, and Pseudopolygnathus (Pl. 1, and Figs. 5 and 6), were recovered as part of the insoluble residues from the Gentry core (Pl. 10). Numbers of specimens and distribution are given in Appendix A.

In the Sinclair-Prairie No. 1 Exchange Bank core (Pl. 11) from Comanche County, west of the Gentry core in Barber County, 100 feet (30m) of the Fern Glen Formation is mapped. The interval probably contains some Reeds Spring Limestone, but the typical Reeds Spring lithology is masked by the lithology of the "Cowley" facies. The resultant mixed type rock is a gray cherty, siliceous, argillaceous, calcareous shale which is very difficult to break down into small particles or to dissolve with acetic acid.

A thin bed of crinoidal limestone at 6,092 feet yielded a fauna of early Osagian conodonts including specimens of Gnathodus, Polygnathus communis, and

Pseudopolygnathus multistriata (Appendix A).

Biostratigraphic Zone

In the type region of the Mississippian rocks, Collinson and others (1962) extended the Bactrognathus-Polygnathus communis Assemblage Zone from the base of the Fern Glen Formation to the middle of the Burlington Limestone (Fig. 6). The lower limit of the zone is marked by the earliest occurrences of Bactrognathus hamata and B. excavata as well as the earliest abundance of Gnathodus cuneiformis and G. n. sp. (later designated G. texanus by Rexroad and Scott, 1964). The upper limit is marked by the youngest occurrence of Polygnathus communis. P. communis and Pseudopolygnathus are by far the most abundant in the zone in the type area.

Conodont specimens recovered from the Sinclair-Prairie No. 1 Alice Gentry core (Pl. 10 and Appendix A) indicate the Bactrognathus-Polygnathus communis Assemblage Zone is present. In contrast to the distribution of genera and species in the type section, there is a dearth of Pseudopolygnathus multistriata or Pseudopolygnathus in this core. A core of the lower part of the Fern Glen in this area might contain these genera in abundance. The Sinclair-Prairie No. 1 Exchange Bank well (Pl. 11) also contains a distribution of identifiable conodonts in the lower part of the Fern Glen Formation which correlate with the Bactrognathus-Polygnathus communis Assemblage Zone (Fig. 6) of the upper Mississippi River Valley area.

Distribution, Thickness, and Stratigraphic Relations

The distribution of Reeds Spring along with the St. Joe rocks is shown on Figure 13. Lee (1940, p. 56) first interpreted the relationship between distribution of "rocks of Fern Glen age" to known structural features as a strong reason to regard

structure as a controlling factor in determining the distribution of basal deposits of Fern Glen rocks. The wedge out of Fern Glen rocks beneath Burlington rocks on the east side of the Central Kansas Uplift is evidence of tectonic movement (Lee, 1940).

Lee (1953, p. 16) reported that southwest of the Central Kansas Uplift the contact of the Burlington Limestone is transitional to the Fern Glen. Lee reported that the Fern Glen rocks, if they had ever been present in the area of the Central Kansas Uplift, had subsequently been removed by erosion.

Lee (1940) reported that the red and dark-colored shale and red crinoidal limestone beds south of the Central Kansas Uplift, which are interstratified with cherty limestone beds, seemingly reflected a rising Central Kansas Uplift which provided clastics in early Osagian time. The distribution of the Fern Glen Formation (Fig. 13) suggests strongly that the southern part of the Central Kansas Uplift area was being gently deformed before or during the deposition of rocks of early Osagian age.

Fern Glen rocks are thicker in western Kansas than in eastern Kansas chiefly because of thickening of the St. Joe shaly beds. In southern Kingman County (well 5, Deep Rock No. 1 Whitmer, sec. 10, T. 30 S., R. 9 W.) Lee (1949) logged more than 100 feet (30m) of Fern Glen rocks of which about the upper 80 feet (24m) were designated as Reeds Spring. On Plate 3, the Fern Glen rocks are mapped as more than 190 feet (57m) thick in the Gentry well in Barber County; westward they thin to less than 100 feet (30m) thick in well 9 (Alma Oil Co. No. 1 Watkins) in Comanche County. Still farther west, they thicken to more than 200 feet (61m) in the Rickers well in Meade County.

The St. Joe is thought to be conformable beneath the Reeds Spring. The Reeds Spring overlaps the St. Joe and lies unconformably on older Mississippian rocks. The Reeds Spring seemingly is conformable below the Burlington in south-central Kansas (Lee, 1940).

Part of the sequence classified as Fern Glen Formation in southwestern Kansas has been correlated lithologically with the Chouteau Formation of Missouri (Clair, 1948). The conodont evidence from the Sinclair-Prairie No. 1 Exchange Bank core indicates that the rocks overlying the Viola (Ordovician) contain an early Osagian biostratigraphic zone, and not a Kinderhookian one.

Burlington Limestone

Outcrops.--Hall (1857) named the Burlington Limestone to replace the term "Encrinital Group of Burlington" which had been used by Owen (1852). In southeastern Iowa the Burlington is the lowermost formation of the Osagian and overlies rocks of Kinderhookian age (Harris and Parker, 1964). There, it is overlain by Keokuk Limestone. The Keokuk-Burlington formation boundary is not sharp and was placed at various horizons by earlier workers.

Subsurface characteristics.--The Burlington Limestone identified by sample study in the subsurface of Kansas is a white and gray semicrinoidal limestone interstratified with relatively thin beds of gray dolomite and limestone with minute granular dolomite crystals. Large quantities of chert are locally present, but the amount of chert is variable. The chert (Lee, 1940, p. 59) is even-textured, opaque, and gray, gray-white, or bluish white. Lee (p. 60) mapped the Burlington as the most widespread of the Mississippian limestone formations in Kansas. He stated that it was removed from the southeastern part of Kansas before the deposition of the Keokuk;

and in parts of most of the southern tier of counties from Montgomery County to Clark County it was removed by erosion that preceded the deposition of the Cowley Formation.

Lee (1940, 1956) described and tentatively correlated lower and upper lithostratigraphic units of the Keokuk-Burlington sequence in the subsurface of Kansas with the Burlington Limestone and the Keokuk Limestone. The lower unit of the Keokuk-Burlington sequence in the Salina Basin consists of white, opaque chert which occurs in well cuttings as blocky fragments with more or less tabular surfaces (Lee, 1956). Insoluble residues of samples from the lower unit contain quartz crystals and drusy quartz. Dolomoldic chert is observed in some dolomitic beds.

In the upper unit of the Keokuk-Burlington sequence in the Salina Basin, the chert is white, rough, and pitted, and breaks into subangular fragments. Microfossiliferous chert occurs in some areas in the middle and upper part of the upper unit. Upper unit cherts include various amounts of siliceous aggregates resembling tripoli, sometimes referred to as cotton rock. Dolomoldic chert is recovered as residues from dolomitic beds.

Hiestand (1938, p. 1,594) in reporting on insoluble residue zones of the "Mississippi lime" of south-central Kansas stated that his zone B corresponds closely with the Keokuk-Burlington Formations of Missouri. My study area overlaps part of Hiestand's study area. Zone B3 (the lowest B subzone) contained much smoky to pearl-gray, translucent to glassy chert, and commonly pyrite. The chert in residues is "gnarly," containing fossil tracings and replaced crinoid stem fragments. In southern Kansas, glauconite is conspicuous near the contact with the underlying zone C (Fern Glen). Hiestand compared this glauconite with the green material which seems to be common at the top of the Chattanooga Shale in Oklahoma.

Hiestand reported zone B2 as transitional in residue characteristic between the zones B3 and B1. Chert in zone B2 is translucent and either vitreous or non-vitreous. The contact with the overlying zone B1 is sharply defined in many places and marked by glauconite and mineralization, particularly by sulfides.

The Burlington Limestone is extremely difficult to distinguish from the Keokuk Limestone in western Kansas. Chert in cores, samples, and residues was observed as not dissimilar; and few sections possess similar sequences of strata. Where no distinction was possible, the interval of the Keokuk-Burlington Limestone has been marked as Osagian in the stratigraphic cross-sections presented (Pls. 3-7). A large and sudden increase in chert, usually light colored, cream to gray, blocky, opaque to subopaque usually with crinoid stems and molds, and sometimes with oolites marks the upper boundary of these Osagian strata. Glauconite is usually present and disseminated throughout Osagian rocks. Quartz is common and a more or less characteristic constituent in the Burlington.

Core and residue data.--There is no chert in the Burlington Limestone of the Sinclair Oil and Gas No. 1 Circle well (Pl. 12) in Barber County. The typical semicrinoidal limestone with shale laminations, however, is well developed. There is little evidence here of abrasion of the surfaces of the crinoid ossicles. Other lithologic features of the Burlington Limestone are presented in the peel-prints, core descriptions, and residue identifications on Plate 12.

Osagian conodonts are included in the residues; distribution is given in Appendix A. These conodonts include Bactrognathus hamata, Gnathodus antetexanus, G. semiglaber, G. texanus, Polygnathus communis, and Pseudopolygnathus (Pl. 1, Figs. 5 and 6).

The Burlington Limestone in the Sinclair-Prairie No. 1 Alice Gentry well (Pl. 10) also in Barber County contains the type and quantity of chert characteristic of the Burlington. Peel-prints of Burlington Limestone cores, pertinent observations on lithology, and data on residues are given in the captions of Plate 10.

Conodonts (Appendix A) recovered as insoluble residues from the Burlington Limestone of the Gentry core include specimens of Gnathodus antetexanus, G. cuneiformis, G. semiglaber, G. texanus, Metalonchodina, and Polygnathus?. This fauna indicates an age of medial Osagian. Conodonts of early Osagian age were recovered low in the core (Pl. 10, Appendix A).

The Burlington Limestone in the Sinclair-Prairie No. 1 Exchange Bank well (Pl. 11) in Comanche County is of the "Cowley" lithologic type, composed of dolomitic, gray-green, siliceous argillaceous shale containing scattered blebs of dark-blue opaque chert. Residues described in the plate caption contain no conodonts.

Biostratigraphic Zones

The Burlington Limestone in the type section contains all of the Bactrognathus-Taphrognathus Assemblage Zone and the upper part of the Bactrognathus-Polygnathus communis Assemblage Zone. The latter zone is shared with the Fern Glen Formation (Fig. 6). Collinson and others (1962) defined the top boundary of the upper zone by the less abundant occurrence of Gnathodus texanus. The lower limit is marked by the highest occurrence of Polygnathus communis. Conodonts from the upper zone have more similarities with younger conodont assemblage zones than with older conodont zones.

Conodont specimens recovered as residues from the Sinclair Oil and Gas No. 1 Circle core (Pl. 12) include elements of both assemblage zones, but preferred

assignment is to the upper part of the lower zone (Bactrognathus-Polygnathus communis) because of the presence of Bactrognathus, Pseudopolygnathus, and Polygnathus communis. The upper zone (Bactrognathus-Taphrognathus) is judged present in the Sinclair-Prairie No. 1 Alice Gentry core (Pl. 10) although no specimens of Taphrognathus were identified.

Results of work underway on the Fern Glen Formation and Burlington Limestone in southwestern Missouri by Thompson (letter, Feb. 10, 1966) should add materially to knowledge of distribution of conodont microfauna useful for establishing biostratigraphic assemblage zones.

Distribution, Thickness, and Stratigraphic Relations

The difficulty in differentiating the Burlington Limestone from the Keokuk Limestone has been discussed. The Burlington Limestone probably is not of widespread distribution in western Kansas. Identification of the unit has been restricted to an area south and southwest of the Central Kansas Uplift, where it seemingly thins toward the north.

In A-A' (Pl. 3) east-west across southwestern Kansas, the Burlington Limestone is identified in Meade County in well 6 (Stanolind No. 1 Rickers). Eastward along the line of this cross-section Burlington is identified as far as well 13 (Sinclair Oil and Gas No. 1 Circle).

The Burlington Limestone is identified above the Fern Glen Formation in Clark County in well 9 (Alma Oil Co. No. 1 Watkins) in cross-section A-A' (Pl. 3). To the north from well 9, along cross-section B'-E (Pl. 4) the Burlington Limestone is recognized above Fern Glen rocks as far north as well 52 in Ford County (the Sinclair-Prairie No. 1 Young well). These designations are in agreement with

intervals from wells logged by Lee (1953) in this area.

In cross-section C-C' (Pl. 6) from Dundy County, Nebraska, into Sherman County in northwestern Kansas, Burlington Limestone is carried to the Kansas border as seen in well 30 (No. 1 Glasco). Data on well 29 in Dundy County, Nebraska, are adapted from Carlson (1963, fig. 12), and the extension of Carlson's lower Keokuk-Burlington Formation southward to Kansas is arbitrary.

Sample examination failed to indicate strata elsewhere in western Kansas which could be assigned with reasonable certainty to the Burlington Limestone. Several cores were available from the Keokuk Limestone in western Kansas. In all places in the stratigraphic cross-sections (except Pl. 12, Sinclair Oil and Gas No. 1 Circle), designation of the Keokuk indicates only that the upper portion of the Osagian rocks in that particular locality was identified as part of the Keokuk Limestone. No lower limit of the Keokuk is indicated. Burlington Limestone probably is not present in many of these localities.

The Burlington is conformable upon the Fern Glen Formation in south-central Kansas and probably overlaps it northward in western Kansas. It is disconformable below the Keokuk with which it has great lithologic affinity. In north-central Kansas the variable position of the contact on which Lee (1956) separates the lithologies of the lower and upper units supports his conclusions that the upper unit lies disconformably on the lower. As an undifferentiated unit the Keokuk-Burlington overlaps older Mississippian Kinderhookian rocks to the north in western Kansas (Pl. 4). The distribution of the undivided unit essentially outlines pre-Pennsylvanian structural features of Kansas (Fig. 1, and Pl. 2D).

Keokuk Limestone

Outcrops.--The Keokuk Limestone was named by Owen (1852). Hall (1857) expanded the Keokuk to include the "Archimedes" Limestone and 40 feet (12m) of overlying calcareous shales.

The Keokuk in the type region in Iowa overlies the Burlington conformably and is overlain conformably by the Warsaw Formation.

The Keokuk Limestone crops out in an area of less than 2 townships in Cherokee County, southeastern Kansas.

Subsurface character.--Lee (1940, p. 58) reported two types of chert in sample cuttings from the Keokuk-Burlington. One type that is typical of the upper part of the undivided Keokuk-Burlington is represented in the Ballard Mine well in Cherokee County (sec. 10, T. 35 S., R. 24 E.) as reported by Mary Hundhausen (in Lee, 1940). The well is near the margin of the small outcrop area of Mississippian rocks in southeastern Kansas. It is only 15 miles (24km) north of a locality in Oklahoma (sec. 31, T. 27 N., R. 24 E.) where Laudon (1939) reported Keokuk to be directly over Reeds Spring. It seems probable that in the area of the Ballard Mine well the beds reported by Miss Hundhausen as undivided Keokuk-Burlington are Keokuk (Lee, 1940).

The Keokuk Limestone thins in the subsurface west of Cherokee County. Farther west in southern Kansas, Lee interpreted the Keokuk Limestone as having been eroded before deposition of Meramecian rocks (Cowley Formation). Lee reported the general absence of Keokuk in western Kansas and (Lee, 1953) mapped a limited distribution southwest of the Central Kansas Uplift.

Hiestand (1938, p. 1,592, fig. 3) equated his B1 insoluble residue zone in south-central Kansas with the Keokuk Limestone. Residues from the zone consist of aggregates of soft, porous, spongy, tripolitic to kaolinitic material. Vitreous chert

is common and contains delicate tracings which are fragments of bryozoans, crinoids, or other fossils. Pale to bright green glauconitic material is generally conspicuous in residues. Subzones in the B1 zone contain oolitic beds not unlike the Short Creek Oolite in Missouri and Oklahoma of Fowler and others (1935). The Short Creek is lenticular in its occurrence, but it could well appear at the same horizon as it does in northeastern Oklahoma.

The upper unit of the Keokuk-Burlington sequence of Lee (1956) in the Salina Basin may be the lithologic equivalent to the Keokuk Limestone elsewhere. In the Salina Basin the chert in the upper part is white, rough and pitted, and breaks to subangular fragments. Microfossiliferous chert similar to that of the Warsaw occurs in some areas in the middle or upper part of the zone but is distinguished from Warsaw chert because micro-organisms are replaced by vitreous or translucent chalcedony. Chert in the upper unit includes siliceous aggregates resembling tripoli. Insoluble residues of dolomitic beds contain dolomoldic chert. On the southern margin of the Salina Basin, the upper part of the Keokuk-Burlington sequence can be differentiated from the lower part by an oolitic bed at or near the base of the upper part, which is thought to be equivalent to the Short Creek Oolite of southwestern Missouri and adjacent parts of Kansas and Oklahoma. Lee (1956, p.82) mapped an unconformity below the upper unit of the Keokuk-Burlington in the Salina Basin. This is strong evidence to separate the Keokuk from the Burlington.

The upper Keokuk-Burlington Formation (unit 5) of Carlson (1963) in southwestern Nebraska is preserved only as erosional remnants on crests of pre-Pennsylvanian topographic highs. It is a light medium-gray, dense to finely crystalline limestone containing light-gray, mottled, fossiliferous blocky chert. Carlson identified upper Keokuk-Burlington unconformably on lower Keokuk-Burlington which is overlain

disconformably by beds of Pennsylvanian age. I logged as Keokuk all of Carlson's upper Keokuk-Burlington and most of the lower Keokuk-Burlington in northwestern Kansas.

Keokuk in Western Kansas

The Keokuk Limestone is characterized by a large amount of white and blue-black chert. Stratigraphic variations in chert and carbonate content are common. The chert content is generally greater than 50 percent by volume and weight, and the Keokuk should be called a chert rather than a limestone. Keokuk chert is pitted, porous, calcareous, and tripolitic and is usually limited to the upper part of the unit. Locally, tripolitic chert is logged also in the lower part of the Keokuk (Pl. 12; Lee, 1953, well 8; Olson No. 1 Fowler, sec. 20, T. 27 S., R. 22 W., Ford County).

Data available from rock cores, from mineral residues, and from sample examination indicate that the Keokuk Limestone is widespread in western Kansas, more so than the underlying Burlington Limestone.

Where mapped as the Keokuk-Burlington undifferentiated sequence, the unit is thickest in Stevens, Seward, Meade, and Clark Counties in southwestern Kansas (Fig. 3). Locally it is more than 350 feet (106m) thick (Pl. 3). Along this west to east cross-section Osagian rocks are less than 150 feet (45m) thick in well 1 in Morton County. They thicken to more than 350 feet (106m) in well 9 in Clark County, but they cannot be recognized or are absent in well 12 in Barber County on the southern end of the Pratt Anticline where they seemingly were removed by pre-Pennsylvanian erosion.

Core and residue data.--Lithology typical of the Keokuk Limestone is presented in Plates 9, and 12-15. The Gnathodus texanus-Taphrognathus Assemblage Zone of Collinson and others (1962) and Rexroad and Collinson (1965) was present in all these cores.

A bed of calcarenite (Pl. 12, Sinclair Oil and Gas No. 1 Circle) overlies the Burlington Limestone in Barber County in an area where the "Cowley" facies locally is not developed. The poorly-sorted calcarenite yielded chert-dominated residues typical of the Keokuk (described in caption of Pl. 12). A conodont fauna from the calcarenite and the overlying cherty shale includes Gnathodus texanus and Taphrognathus varians (Appendix A).

To the northwest of Barber County on the flank of the Hugoton Embayment the No. 2 Fralick "A" core in Kiowa County (Pl. 13) and No. 1 Teeter "A" core in Gove County (Pl. 14) exhibit the lithology encountered elsewhere in the Keokuk chert. Chalky chert occurs as halos around granular and ordinary blue-black brecciated chert. Dark-gray shale partings separate the chalky chert and limestone. Microfossiliferous chert, non-microfossiliferous chert, silicified fossil fragments, pyrite, glauconite, anhydrite, and sphalerite are typical of Keokuk residues (described in plate captions). Anhydrite in the Teeter "A" core (Pl. 14) fills fractures which transect fossiliferous chert and limestone. Gnathodus texanus and Taphrognathus varians dominate the conodont faunas (Appendix A) from the Fralick "A" and Teeter "A" Keokuk Limestone cores.

In Logan County in northwestern Kansas, the upper part of the Keokuk Limestone contains gray to brown, fine-grained dolomite with chalcedonic microfossiliferous chert and gray semicrinoidal limestone. The core yielded abundant Gnathodus texanus and Taphrognathus varians (Appendix A).

In Scott County in the Hugoton Embayment, the lower part of the Keokuk in the No. 1-A Mark well (Pl. 15) is fine-grained, dolomitic, cherty limestone that contained typical Keokuk residues, but the weight percent was low. Less than 200 grams of core yielded three Gnathodus texanus and two Taphrognathus varians (Appendix A).

Biostratigraphic Zone

In the type section of Mississippian rocks, Collinson and others (1962) referred the Gnathodus texanus-Taphrognathus Assemblage Zone to the Keokuk Limestone (Fig. 7). The upper limit is marked by the earliest occurrence of Apatognathus?, and by the earliest occurrence of abundant Taphrognathus varians. The lower limit of the zone is marked by the lowermost occurrence of abundant Gnathodus texanus. This is a zone of relatively few species but great abundance of G. texanus. A study of conodonts from the Keokuk, Warsaw, and Salem Formations of Illinois by Rexroad and Collinson (1965) showed general similarity between the Keokuk fauna and the Warsaw-Salem fauna in terms of species; but proportions of species in the two were distinct. G. texanus dominated their Keokuk collection, constituting 78 percent of the fauna; Taphrognathus constituted only 7 percent.

The species, proportions, and numbers of conodonts in the collections from Keokuk Limestone in Kansas (Appendix A) compared with the species, proportions, and numbers of conodonts established by Rexroad and Collinson (1965) for Illinois are strikingly similar. The Gnathodus texanus-Taphrognathus Assemblage Zone is widespread in western Kansas Keokuk Limestone. The zone occurs in some instances directly above the Gilmore City Limestone.

Distribution, Thickness, and Stratigraphic Relations

The Keokuk Limestone is widespread in western Kansas. The thickness ranges from zero on the flanks of the Central Kansas Uplift, where it occurs unconformably over the Gilmore City Limestone, to more than 300 feet (91m), where undivided from the Burlington, in Clark County adjacent to the Oklahoma Panhandle.

In western Kansas as elsewhere, the lower boundary of the Keokuk Limestone is difficult to discern. The Keokuk is mapped as unconformable on either Burlington or pre-Osagian rocks in much of western Kansas. The Keokuk overlaps onto older rocks northward. A similar unconformable relationship between the Keokuk and the Burlington also has been indicated for the Salina Basin by Lee (1956).

Where Keokuk rocks or Keokuk-Burlington rocks occur beneath the Pennsylvanian unconformity, the top of Osagian rocks is marked by a widespread deposit of "Chat" (Pl. 2D). Where it is obvious from sample examinations and core descriptions that the chert has not been transported, the interval of rock has been included with Osagian rocks (isopachous map, Interval B, Pl. 2B). Abundance of tripolitic or chalky chert is interpreted as weathered chert and used by some investigators as evidence of a buried surface which was exposed at the close of Osagian time (Clair, 1948; Beebe, 1959, p. 195).

Residue Analysis

Subdivision of Mississippian rocks of Osagian age of Kansas has been made by a number of authors (Lee, 1940, 1949, 1953, 1956; Hiestand, 1938; Clair, 1948) all on the character and content of insoluble residues composed mostly of cherts. The highly variable occurrence and distribution of various types of cherts demonstrated in cores from western Kansas Osagian rocks severely tests the reliability of

using cherts in regional lithostratigraphic correlation. Ireland (1958) reported that long-distance correlations are not reliable because of local secondary changes as well as lateral facies changes. Only correlation from well to well over short distances will show the lateral changes.

Insoluble mineral and rock residue suites from Osagian rocks of Kansas share similarities with inter-regional Osagian rocks. This suggests similar conditions of deposition or similar diagenesis. Chert composes a large percentage (often more than 50 percent by weight) of the residues of Keokuk and Keokuk-Burlington undivided sequence in Kansas. Bluish-white semi-translucent chert in the Keokuk is coated with cotton rock or is chalky and porous. The occurrence of chalky and tripolitic chert, however, is not limited to the upper surfaces or portions of the Osagian rocks, which occur below the unconformity with Pennsylvanian rocks. It exists also in the lower portions of the Keokuk (Pl. 12) and in the top part of the Burlington Limestone. The highly variable distribution of chert also was observed in sample examination. There is general absence of detrital heavy minerals in the residues from Kansas Osagian rocks.

The residues studied from the Fern Glen and Burlington rock cores in Barber County may be atypical because of changes due to local development of "Cowley" facies, local chertification, or diagenesis. Abundance of marcasite and microfossiliferous chert, which make up less than 20 percent of the original weight of the core sample, characterizes the Fern Glen rocks in the Gentry core (Pl. 10). Burlington Limestone residues from the Sinclair Oil No. 1 Circle core (Pl. 12), characterized by their low weight (less than 20 percent), are composed of green and gray shale, evenly distributed pyrite, and silicified fossil fragments, and anhedral quartz. These characteristics do not accord with those revealed in sample examination of other wells

or with Hiestand's (1938) residue study in south-central Kansas or Lee's (1956) study in the Salina Basin.

Keokuk chert is dominated by ordinary to granular and chalcedonic to chalky types. Pyrite occurs throughout Keokuk cores. Anhedral to subhedral quartz in association with concentrations of glauconite, sphalerite, and galena mark the lower portion of the Keokuk.

The occurrence and distribution of conodonts in the residues of Kansas Osagian rocks is important not only as indicative of useful biostratigraphic zones but also as a lithic feature. The yield of conodonts and other phosphatic, siliceous, and chitinous microfossils from Osagian rocks is high considering that generally less than half the rock is soluble in acid. Past investigators have experienced difficulty in subdividing cherty Osagian rocks. The possibility of recovery of microfossils from cherty carbonates by acid residue techniques should provide impetus for additional research.

Environment of Deposition

Much indirect evidence on the environment of deposition of Osagian rocks in Kansas has been presented in the previous sections. Similar conditions of deposition were prevalent in the north-central interior of the Unites States from Indiana to western Colorado and Montana and from Oklahoma into Canada. Osagian and Meramecian rocks are sheet-like carbonate beds with a relatively high degree of lithologic similarity at outcrops. Moore (1957, p. 124) summarized the conditions as follows:

> In Mississippian time, as in many other parts of the Paleozoic era, very large epicontinental seas spread over the North American and other continental platforms and because these seas were bordered only

> locally by land sufficiently elevated to furnish clastic detritus, the waters were predominantly clear and probably moderately warm. Benthonic invertebrates and other marine organisms that secreted hard parts of calcium carbonate were widespread and their populations were prodigious. Relatively uniform, widely distributed limestone formations were made.

To this can be added that in western Kansas fluctuations of the level of the epicontinental seas resulted in some local and periodic re-working of calcareous materials on the sea floor. This is indicated by the presence of some calcarenites disseminated and intercalated with semicrinoidal and crinoidal limestones and coquinites. Wave action may have contributed to the development of calcarenite where fossil skeletal material accumulated on shelf or bank areas.

The conditions of deposition for early Osagian rocks in southwestern Kansas are similar to those recorded in equivalent rocks present in the Ozarks. Moore (1957, p. 104) reported shaly and reddish limestones in places in the upper layers in the Compton-Pierson of the Ozarks area. Alternating reddish and greenish colored semicrinoidal limestones also make up rocks of early Osagian age south of the Central Kansas Uplift. The red color is due to iron oxide coating of the carbonate sediments. The color of the limestones probably reflects sea level fluctuations resulting in alternating times of oxidization and reduction. Also uplift of the southern end of the Central Kansas Uplift area at this time is a probability.

Moore (1957, p. 106-107) found a somewhat local distribution of Kinderhookian and overlying Reeds Spring beds in the Ozark area. A local distribution of these formations also occurs in Kansas. Preservation of noncorroded crinoid ossicles in semicrinoidal reddish and greenish beds with faintly laminated texture in limestone of the Kansas Fern Glen reflect conditions of deposition similar to

those reported by Moore (1957, p. 109) for the Reeds Spring and St. Joe of the Ozarks. This seemingly is an environment which allowed periodic settling to the sea floor of fine and coarse debris that remained there without much disturbance after accumulation. The resultant texture does not appear to be a result of compaction. The lack of abrasion of crinoid ossicles and other fossil remains attests to quiet bottom conditions without much translation of sediments by bottom currents. There are few oolitic limestone beds in the Osagian rocks. Limestone in Osagian strata above the Fern Glen in Kansas was precipitated by organic agencies, mainly invertebrate animals.

Although the quantity of clay-size particles decanted in processing insoluble residues was not recorded during my study, the stratigraphic distribution of shale partings and shale as matrix material was observed in many Osagian cores in Kansas. Particles caught on the 100-mesh screen were included in tallied residue weights. Additional investigation of the clay fraction of Mississippian cores could yield information on environments of deposition during the Mississippian.

The presence of glauconite in sedimentary rocks has been widely used as a criterion for recognizing shallow marine environments (Cloud, 1955). Glauconite is widespread throughout Osagian rocks. Glauconite is resistant to alteration in nonoxidizing environment, and its transfer from place of origin by currents could well explain its dissemination or concentration in many Mississippian formations. The high concentration of glauconite recorded in residues from the lower portion of the Keokuk Limestone is a usable stratigraphic marker as well as possibly marking the unconformity, where it exists, between Burlington and Keokuk rocks.

There is little evidence of transgression of lower Osagian rocks. Possibly, the spreading of epicontinental seas onto continental areas was from several directions,

or the evidence of transgression is clouded because terrigenous clastic source material was not generally available to the transgressive seas for incorporation into basal clastic beds.

Diagenesis.--Secondary features developed in Osagian rocks certainly include dolomite crystals admixed with grains of evenly distributed calcite, seemingly unaltered.

Stylolites are secondary features recorded throughout Osagian cores but are common in semicrinoidal and crinoidal limestone giving a record of post-depositional solution.

Silicification and dolomitization of carbonate fossil fragments attest to the secondary nature of these features. Incompletely silicified crinoid ossicles and other skeletal fossil materials were reported in Kansas Osagian rocks residues especially from chert. Crinoid columnals or ossicles, originally precipitated by the animal as calcite crystals (Moore et al., 1952, p. 575) are the most abundant fossil observed totally encompassed or enclosed by chert. Partial silicification of ossicles probably indicates the inability of the replacing mechanism to handle large crystals of calcite. Perhaps silicification of the outer surfaces of ossicles slowed the reaction or prevented deeper penetration.

In the Osagian rocks of southeastern Iowa, Harris and Parker (1964) reported fossil fragments diagenetically silicified, enclosed in chert. Branson (1952, p. 20), in a petrographic study of exposed Osagian rocks in Craig County, Oklahoma, reported tiny calcite remains of fragments of echinoderm plates or ossicles that show incomplete silicification.

Secondary sulfide minerals (sphalerite, pyrite, marcasite, and galena) occur in Osagian rocks. That some anhydrite is secondary is well established by its occurrence in fractures which transect fossiliferous chert and limestone, but the

relation of other anhydrite to the associated secondary sulfide mineral is not clear in Osagian rocks.

Chert

The widespread occurrence of chert in Mississippian rocks in western Kansas, especially in the Osagian, has been reported and described by formation in each section on lithology. The Osagian rocks should be described as cherts because the chert content usually exceeds 50 percent by weight and probably by volume. Discussion of the environment of deposition of western Kansas Osagian rocks would be incomplete without evaluation of evidence presented by the occurrence of chert. Study of the origin of chert was not a goal of my investigation, but the environment of deposition is pertinent to my study. My study revealed no new evidence on the origin of chert but includes much evidence that has been used by advocates of both primary and secondary origin of chert.

Although many theories have been forwarded to explain the sequence and nature of chert deposition, probably no one explanation fits all occurrences and each locality must be studied in the light of its own evidence. Chert probably formed in any one locality by more than one process operating at different times during deposition of the rock sequence.

The chalky chert (cotton rock) in Osagian rock cores occurs as a rim or aureole around the chert; it ranges in thickness from an almost imperceptibly thin coating to several millimeters. Cotton rock aureoles observed in the Fralick, Circle, Gentry, and Teeter well cores (Pls. 10, 12, 13, and 14) are depicted in photographs and peel-prints. Concentrations of pyrite crystals in the interface between cotton rock and limestone may be noted. Silicified fossil fragments are

seen to project from the chert into the limestone (Pl. 14). Thin projections of limestone fill fractures and openings in the chert (Pl. 14). A stylolite preserved in chert is depicted on Plate 14. In residues, molds of calcareous fossils are found on the surfaces of chert fragments and also within them. Some of the molds are lined with a crust of white silica. Also, some chert cores exhibit vugs lined with calcite, amorphous white silica, drusy quartz, and subhedral quartz crystals.

A relationship between occurrence of chert and shale partings can be seen on Plate 14. Chert occurrence seemingly is localized and related to thin or thick discontinuous wavy bands and partings of gray, black to green shale. Where chert is well distributed in nearly tabular layers, it engulfs the shale partings, which appear as thin, dark stringers of color in the chert.

Shale partings are widespread in Osagian rocks in western Kansas. These are dark gray to green and carbonaceous. The partings consist of clay- and silt-size particles. Although no distribution pattern was determined, carbonaceous material is a common constituent of the acid residues, rimming the solution buckets and floating on top of the spent acetic acid used in residue determination.

Many descriptions of thick sections of nonfossiliferous, granular, and chalcedonic chert in Osagian rocks in Kansas are in my report. Detailed thin section study of the chert was not attempted, but this procedure and trace element analysis of chert and carbonate beds in association with chert could reveal pertinent data relative to the origin of chert and therein the environment of deposition.

Stratigraphic Relations and Discussion

Lower Surface

Osagian rocks consist of Fern Glen, Burlington, Keokuk, and Keokuk-Burlington undivided (Pl. 3). The westward limit of the Burlington is unknown. The Osagian in extreme southwestern Kansas is probably entirely Keokuk. The Keokuk overlies the Burlington which in turn overlies the Fern Glen in Barber and Comanche Counties. From Barber to Meade County the Fern Glen lies unconformably on Chattanooga and Viola Limestone. Westward from Meade County, the Keokuk probably overlaps the Burlington and Fern Glen, resting unconformably on Kinderhookian Gilmore City Limestone at the Colorado-Kansas line in Morton County.

The Osagian rocks from east to west probably consist entirely of the Keokuk Limestone lying disconformably on the Gilmore City of the Kinderhookian (Pl. 5).

Although undifferentiated Keokuk-Burlington was identified in Dundy County, Nebraska, by Carlson (1963), as presented on Plate 6, the rocks in Kansas are probably entirely Keokuk Limestone lying disconformably upon Gilmore City Limestone of Kinderhookian age (Pl. 7). From Clark County to Trego County, the oldest Osagian rocks (Fern Glen) lie unconformably on Viola Limestone (Pl. 4). Northward, the Fern Glen overlies the Gilmore City, but it is overlapped northward by younger Osagian rocks, probably entirely Keokuk.

Lee (1956) in his report on the Salina Basin illustrated a similar northward overlap of younger Osagian units across an unconformity onto late Kinderhookian units in eastern Kansas (Fig. 14A, 14B). In the Salina Basin, rocks of early Kinderhookian age are absent (Fig. 12); they are also absent in western Kansas. Lee interpreted that at the end of Kinderhookian time Kansas was raised above sea level, and during a period of relative stability the Kinderhookian formations were

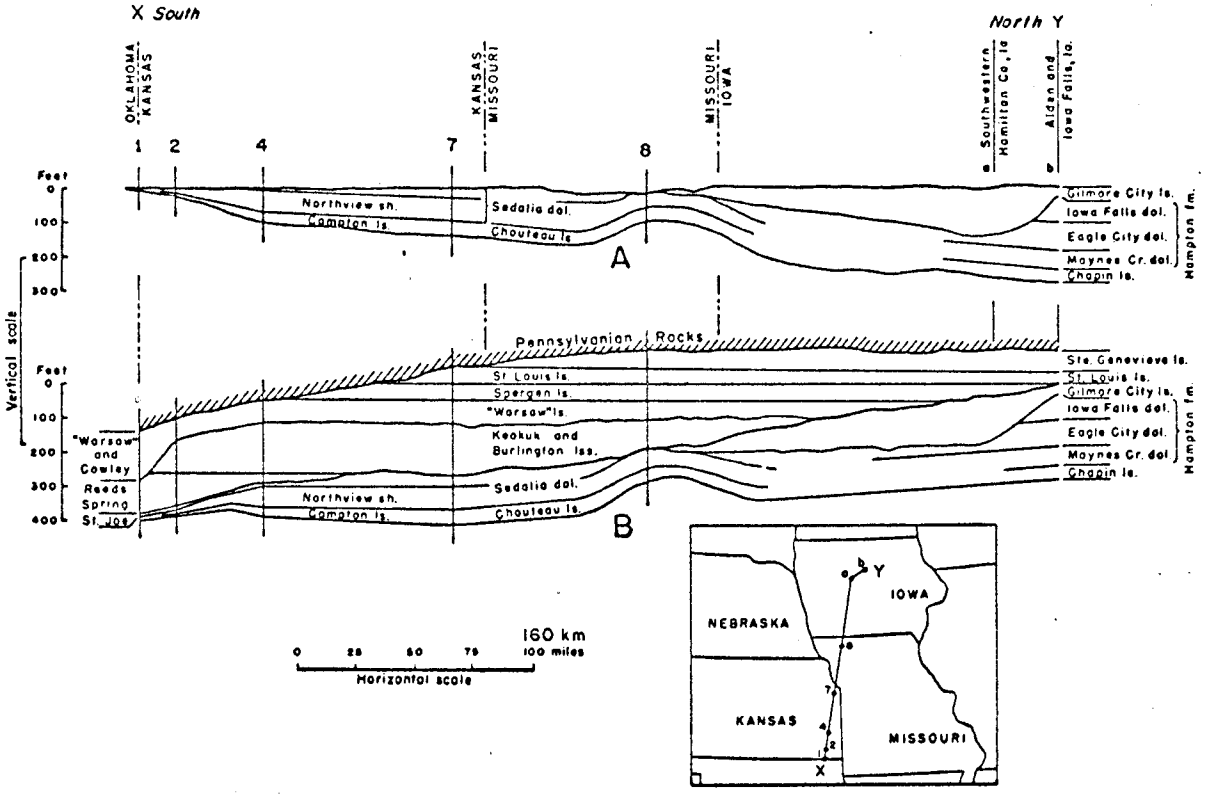


Figure 14.-- Diagrammatic cross sections from southeastern Kansas to central Iowa, showing northerly thickening of Kinderhookian rocks and northerly thinning and overlap of younger Mississippian strata (from Lee, 1956)

beveled (Fig. 14A). Lee reported (1956) that with the advent of Osagian time this surface seemingly was tilted southward because earliest Osagian rocks wedge out northward (Fig. 13). Probably only the Keokuk-Burlington unit extended into the area of the Central Kansas Uplift. Along with tilting of Kansas toward the south in Osagian time, warpings were probably initiated during the deposition of Burlington Limestone (Hiestand, 1938, p. 1,597) which elevated some areas that had been depressed in pre-Mississippian time and depressed other areas that had been elevated in pre-Mississippian time.

Upper Surface

Plates 2D, and 3-7 show the relationships of the upper surface of the Osagian rocks to younger Mississippian and to Pennsylvanian rocks. Where the Meramecian Warsaw Limestone and Pennsylvanian rocks occur above the Osagian rocks, there is some evidence of disconformable relationship. A residuum of weathered chert known as the "Chat" is developed here.

It is at the boundary of the Osagian and the Meramecian rocks that Lee (1940, 1953, 1956) placed the development of the Cowley Formation, which he believed was deposited in a basin eroded from Osagian and older rocks in a large area in south-central Kansas in pre-Meramecian time. Lee reported (1956, p. 83) that Meramecian time in the Salina Basin in north-central Kansas was preceded by elevation above sea-level. As a result, Keokuk and earlier Mississippian rocks were eroded there. The relations of the early Meramecian deposits to the Keokuk in the Salina Basin reveal a dissected surface at the base of the Meramecian (Lee, 1956).

Spreng (1961) pointed out that the problem of the location of the unconformity between the Osagian and Meramecian revolves around the placement of the surface either above or below the Warsaw Limestone. Spreng also reported (p. 151) that the sequence of beds in southwestern Missouri lends support for minimizing the significance of the Osagian-Meramecian break between the Keokuk and Warsaw Formations. Spreng did not recognize unconformities as existing between the Burlington and the continuous sequence that ends with the St. Louis Limestone.

Harris and Parker (1964) included the Warsaw of southeastern Iowa in the Osagian (Table 2), and Moore (1948, 1957) included Warsaw Limestone in the Osagian of the Ozark area.

Lee's (1956) Warsaw of the Salina Basin in Kansas was judged by Moore in an editorial note (Lee, 1956, p. 83) to be wholly younger than the type Warsaw on the basis of Osagian faunal characteristics of the type Warsaw and on field studies by Laudon, and he changed Lee's Warsaw to "Warsaw."

Moore (1948) was convinced of the wide areal extent of the unconformity between the Osagian and the Meramecian in the United States. He classified surface Mississippian deposits and the fossils in the United States and equivalents in Europe as the Waverlyan Series, including the Kinderhookian and Osagian, and the Tennesseean, including the Meramecian and Chesteran. These correspond to the European Tournaisan and the Visean plus the lower part of the lower Namurian (Fig. 7). Moore (1948) reported extinction of camerate crinoids at the Osagian-Meramecian boundary. In the Tennesseean, occurrence of abundant pentremitid blastoids and common appearance of the compound coral Lithostrotium was cited as characteristic of the fauna (Moore, 1948). Talarocrinous and Pterotocrinous, distinctive crinoid genera, characterize higher Mississippian (Chesteran) strata in the central Mississippi

River Valley; whereas these genera are entirely unknown in older rocks.

The changes in form of the entire endothyroid group of Foraminifera which appear above the Osagian-Meramecian unconformity was cited by Zeller (1950) as indicating prominence of a regional stratigraphic break. The appearance of Endothyra and Plectogyra in rocks of the same age is most important. Endothyra is common especially in oolitic limestone beds such as the Salem Limestone and Ste. Genevieve Limestone of the Meramecian Stage and has been found in many western Kansas wells. Mississippian Endothyra are distributed from the Kinderhookian into Chesteran and the genus is known from Devonian to Triassic (Moore and others, 1952).

Rexroad and Collinson (1965), studying conodonts and their distribution in the Keokuk, Warsaw, and Salem formations of Illinois, reported that differences in abundance of conodont species seem to indicate biostratigraphic zones which embrace the Keokuk and the Warsaw-Salem and part of the St. Louis. They reported general similarity of species present in the Keokuk fauna and the Warsaw-Salem faunas, but the proportions of species in the two faunas are quite different. The Illinois Geological Survey, which published the report by Rexroad and Collinson, does not recognize the Meramecian Stage or Osagian Stage, and includes the Keokuk, Warsaw, and Salem of the type locality in the Valmeyeran.

MERAMECIAN STAGE

General Statement

Because of difficulty in differentiating subdivisions in western Kansas, Lee (1940) collectively termed the Salem, St. Louis, and Ste. Genevieve Limestones as the Watchorn Formation. He did not identify the Watchorn in south-central Kansas, where he mapped the Cowley Formation. Later, Lee (1949, 1953) recognized subdivisions of the Watchorn in a limited area of south-central and southwestern Kansas. The availability of data from many more wells than Lee had to work with makes possible the subdivisions used in my report. The Meramecian in Kansas (Fig. 2, Table 3), and as used herein, includes in ascending order the Warsaw, Salem, St. Louis, and Ste. Genevieve Limestones.

The thickness of Meramecian rocks ranges from zero in places along the outline of the Central Kansas Uplift to a known thickness of more than 850 feet (259m) in the Hugoton Embayment (Pl. 2C, Pl. 3). Surface formation names were extended into the subsurface of Kansas by Lee (1940). Moore and others (1951, p. 108) reported that Meramecian rocks probably originally extended throughout Kansas but were eroded from post-Mississippian highs in early Pennsylvanian time. Possible regression of the Meramecian sea in late Meramecian time provided a framework in which some upper Meramecian rocks were eroded before the deposition of Chesteran rocks. Carbonate lithology dominates the Meramecian strata, but quartz sand is common and small quantities of chert are present.

In extreme southwestern Kansas, Meramecian rocks unconformably underlie Chesteran rocks (Pl. 2D). Elsewhere in western Kansas, Meramecian rocks unconformably underlie Pennsylvanian rocks. The Meramecian rocks unconformably overlie Osagian rocks. Maher and Collins (1949) observed that onlap of Meramecian

rocks toward the west, north, and east in western Kansas probably resulted in the lack of deposition of the Warsaw Limestone in the northern part of the Hugoton Embayment, and the absence of Warsaw, Salem, and most of the St. Louis strata in the southeastern part of Colorado. Evidence of thinning of formations toward the margins of the embayment was observed in my study, but overlap of Meramecian formations was not verified in western Kansas.

Warsaw Limestone

The position of the boundary between the Osagian Stage and the Meramecian Stage has long been a point of dispute. Spreng (1961, p. 66) reported that some workers regarded the Warsaw in the outcrop areas as the lowest formation in the Meramecian Stage because its clastic (quartz sand and silt) character differed from the calcareous composition of the Keokuk and also because its fauna contained many new species not present in the Keokuk. The Warsaw has been placed by other geologists as uppermost Osagian because its fauna resembles the Keokuk fauna in many respects, and the boundary between the two formations is obscure in many places. Spreng, however, regarded the Warsaw as the basal formation in the Meramecian and considered it in conformable relationship with underlying Osagian rocks. Moore and others (1951) placed the Warsaw in the Meramecian in Kansas. The pre-Pennsylvanian section of that report was prepared by Lee and follows earlier work by Lee (1940, 1949). Lee (1956) placed the Warsaw in the Meramecian (Table 3) on the grounds of an identified unconformity at the base of the Warsaw in the subsurface, and because there was no evidence for an unconformity with overlying rocks. In the type area in the upper Mississippi River Valley, the Osagian and Meramecian are not recognized and the rocks between the Kinderhookian and Chesteran are designated the Valmeyeran Stage, which includes the Warsaw.

There is general similarity of conodont faunas from late Osagian rocks (Keokuk) and early Meramecian rocks (Warsaw-Salem) in Kansas and in the type area, but the proportion of species in the two is quite different. Conodont faunas from Kansas Warsaw Limestone have greater affinity with Meramecian faunas than with Osagian faunas. My report follows usage of the Kansas Geological Survey and places the Warsaw in the Meramecian.

Outcrops.--The Warsaw Limestone was named by Hall (1857) from outcrops near Warsaw, Illinois. Scattered exposures of the Warsaw occur throughout Missouri. In southwestern Missouri, it has been subdivided into numerous letter-designated units (Fowler and others, 1935).

Cowley Formation--"Cowley" facies.--In the southern tier of Kansas counties, from Cherokee on the east to Barber on the west, Lee (1940, p. 66) reported that a concentration of glauconite occurs progressively lower stratigraphically westward in pre-Meramecian rocks. He stated that the glauconite is overlain by thick deposits of gray and dark colored silty and cherty dolomitic limestone beds which are stratigraphically below the base of the Warsaw. These rocks, together with a glauconitic zone at the base, Lee designated as the Cowley Formation. Lee mapped the Cowley Formation as cutting out in different areas Keokuk, Burlington, Reeds Spring, and St. Joe Limestones (see Lee, 1940, cross-section F-F', pl. 7). Lee mapped the Cowley as resting in places on the Northview Shale, Compton Limestone, Chattanooga Shale, and even on pre-Chattanooga rocks. The Cowley is not present in Missouri (Lee, 1940, p. 68), but the J-bed of the Warsaw in the Tri-state Mining District is an eastward continuation of the transgressing basal deposit of the Cowley. Lee (1953, p. 14) reported tracing the Cowley Formation as far west as Meade County

where the glauconite is absent at the base.

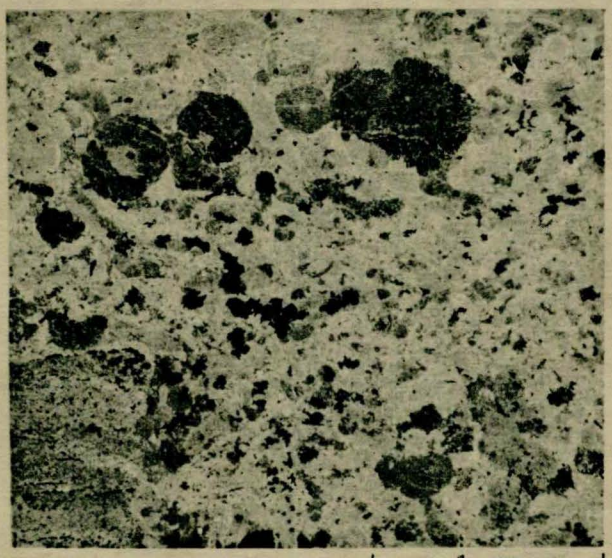
Lee (1940) recognized no break between the Cowley and the Warsaw in western Kansas. In a cross-section from Meade to Smith County, Kansas, Lee (1953) showed the Warsaw as conformable over the Cowley Formation. The Cowley Formation as reported by Lee (1940, 1949, 1953, 1956) is characterized by "discontinuity of sedimentation," and its most distinctive rocks are silty and siliceous dolomite, limestone, and dolomitic siltstone. In some areas large quantities of gray and dark-colored opaque fossiliferous chert are present (Lee, 1940, p. 15).

These variations in sedimentary sequence have led some geologists to conclude that the Cowley is a facies of the Keokuk-Burlington-Fern Glen Limestones and the Chattanooga Shale. I concur on the basis of evidence revealed in the course of my investigation. A possible explanation of the discontinuity of sedimentation typical of the Cowley, suggested from sample and core examinations, is that selective and partial chertification locally of rocks from this interval has occurred. Also cable tools tend to pulverize drill cuttings and perhaps chert so macerated tends to become silt-sized particles.

In a footnote Lee (1940, p. 109) described cores from the Kessler and Thier, Inc., No. 1 Wolfje (also well 15, Pls. 3 and 16) in Harper County as lithologically and stratigraphically from the Cowley Formation (Pl. 16). Residues from the Wolfje core included specimens of Cavusgnathus, indicative of late Meramecian age, mixed with Gnathodus texanus. These conodonts and others are listed and the distribution given in Appendix A. Cavusgnathus first appear in the Apatognathus? gemina-Cavusgnathus Assemblage Zone of the type area. Collinson and others (1962) referred this zone to the upper part of the St. Louis Limestone (Fig. 6). Gnathodus texanus does not range above the Taphrognathus varians-Apatognathus Assemblage

A, 4430' (X2)

B, 4436'



C, 4440' (X3)

Plate 16.--Illustrations prepared from polished core slabs of St. Louis Limestone from the Kessler and Thier No. 1 Wolfje, sec. 17, T. 33 S., R. 6 W., Harper County. Lee (1940, p. 109) described the core interval from 4,425-4,439 feet in this borehole as lithologically and stratigraphically from the Cowley Formation. A mixed conodont fauna from residues indicates late Meramecian age.
(A) Peel-print of calcarenite, fine-grained containing pieces of blue-white microfossiliferous chert and semicrinoidal limestone.
(B) Photograph of shale, calcareous, silty, wavy-bedded containing pieces of chalky and chalcedonic chert.
(C) Peel-print of limestone, semicrinoidal and pieces of blue-white microfossiliferous chert in a groundmass of crystalline calcite.

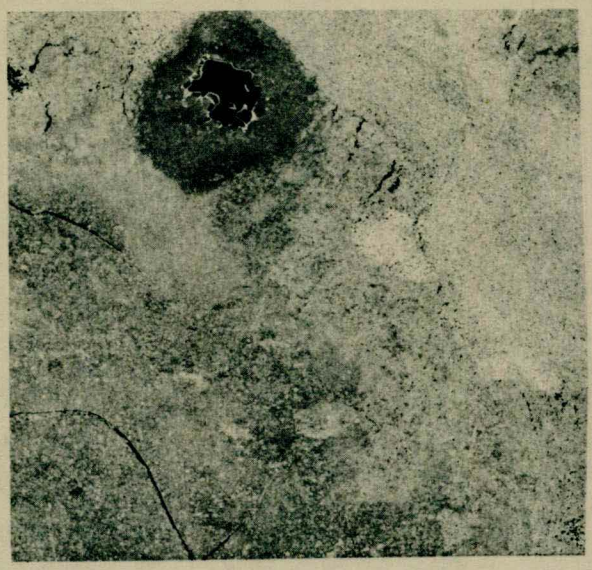
Zone of the type area. Thompson (1965) correlated the biostratigraphic zone represented by the mixed fauna from the Wolfje core with the A.? gemina-C. Assemblage Zone. The rocks of the Wolfje core are no older than late Meramecian.

Obviously, assignment in my study of this rock interval in the Wolfje core to the St. Louis Limestone implies its former continuity with the St. Louis Limestone elsewhere in southwestern Kansas, and demands relegation of the Cowley Formation to "Cowley" facies in the immediate area. Future reference in my study will use "Cowley" (in quotes) when referring to lithologic intervals formerly assigned to the Cowley Formation. The "Cowley" facies is shown on Plate 3. Also evident is a similarity of the "kicks" on the electric logs and other mechanical logs, which form a converging pattern downhole in the same intervals as the "Cowley." The designation of "Cowley" as a local facies of Osagian and Meramecian rocks (Fern Glen Limestone into the St. Louis Limestone) is made in this cross-section.

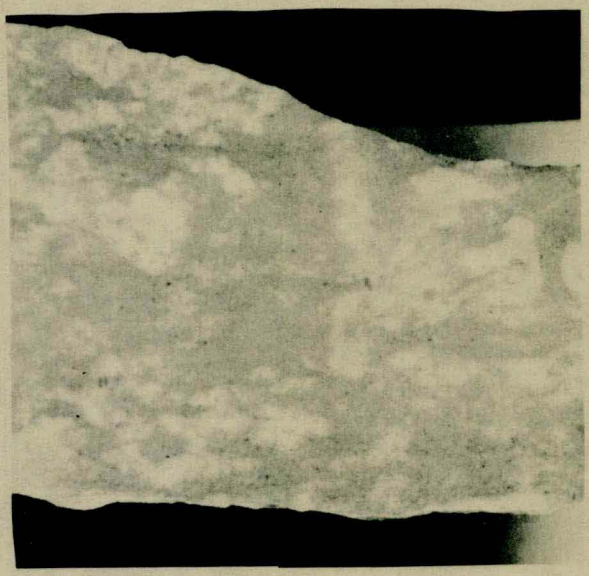
Subsurface character.--The Warsaw Limestone is described from drill-cuttings in western Kansas outside of the area of the "Cowley" facies as semigranular to coarsely crystalline limestone interlaminated with sugary dolomite. It contains varying amounts of gray mottled, opaque, microfossiliferous chert. Geodal and drusy quartz are local constituents. The residues from the dolomite beds are spongy masses of spicules in some cases. Molds of fossils are present. Pyrite and glauconite are disseminated throughout the formation, and glauconite is locally concentrated near the base.

Core and residue data.--The "Cowley" facies of the Warsaw Limestone in Barber County in the Sinclair Oil and Gas No. 1 Helmley well (Pl. 17) is cherty limestone and chalky calcareous chert that is stylolitic with obvious laminations. The conodont

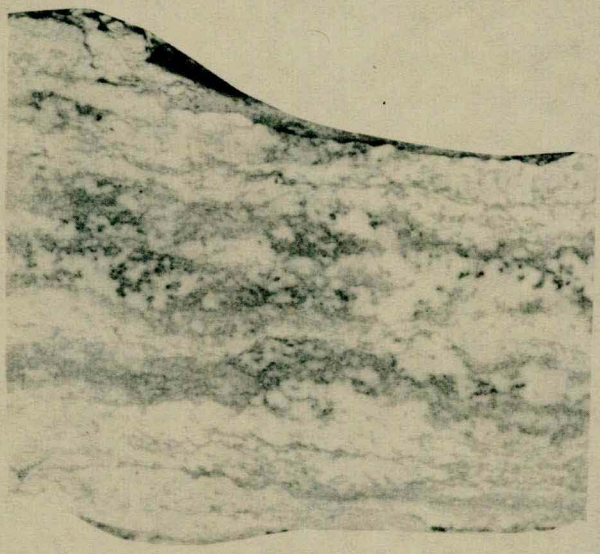
A, 4737' (X2.7) 1 cm



B, 4742'



C, 4764'



D, 4790' (X3.8) 1 cm

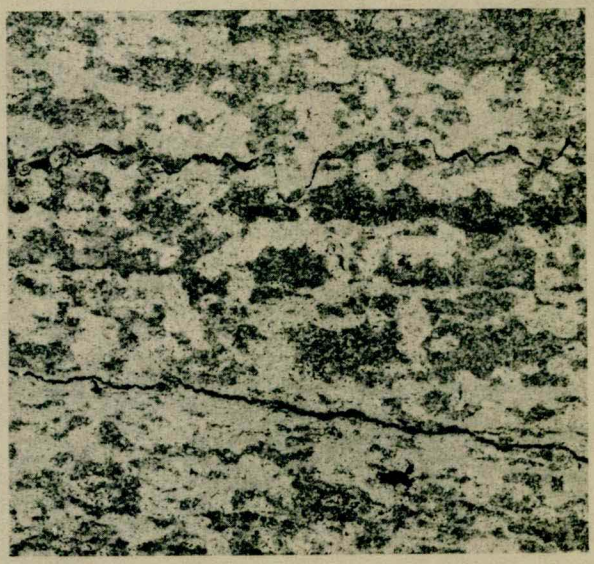


Plate 17.--Illustrations prepared from polished core slabs of Warsaw Limestone from the Sinclair Oil and Gas No. 1 Helmley borehole, sec. 3, T. 35 S., R. 10 W., Barber County. Conodont fauna from residues indicates early Meramecian age. (A) Peel-print and (B) photograph of limestone, fine-grained, stylolitic, with randomly disseminated chert, chalky and ordinary. Vertical fractures are filled with pyrite. Residues less than 40 percent by weight.
(C) Photograph and (D) peel-print of chert, chalky, calcareous, stylolitic. Note laminations of chert and limestone. Residues are from 70-85 percent.

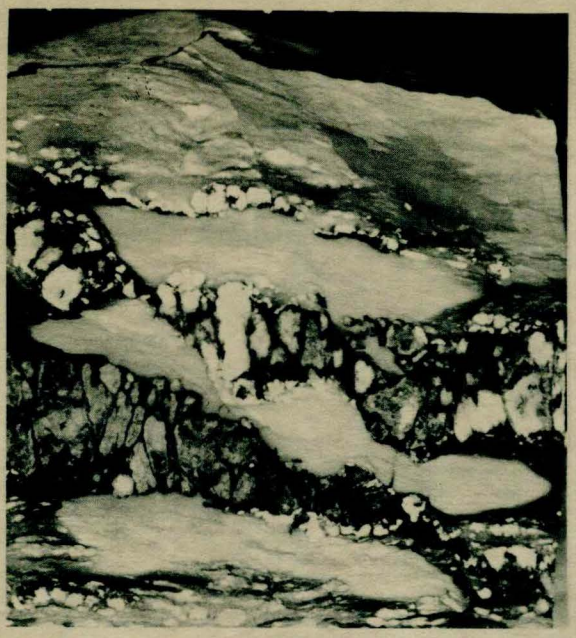
fauna recovered in the residues from the Helmley well core (Appendix A) is dominated by Gnathodus texanus and Taphrognathus varians.

The Warsaw Limestone is recognized in cores from Kiowa County (Pl. 13), from Hodgeman County (Pl. 18), and from Scott County and Ness County (Pl. 15). In Kiowa and Hodgeman Counties, the Warsaw Limestone cores are from directly below Pennsylvanian rocks and are made up of conglomeratic, sandy, dolomitic shale, with chunks of chert. Post-depositional and post-chert fracturing and faulting or slump is exhibited in the Warsaw Limestone in Hodgeman County. Mineral and rock residues are summarized in the caption of Plate 18. Conodonts listed in Appendix A include Apatognathus? n. sp. A, which resembles descriptions of Rexroad and Collinson (1965, p. 5 and 8, and pl. 1, figs. 1, 2). Absence of Gnathodus texanus from the fauna is noteworthy, but assignment to the Taphrognathus varians-Apatognathus? Assemblage Zone is warranted by the other conodonts present. In Ness County, where Salem Limestone is present, the Warsaw Limestone contains large fragments of finely crystalline limestone breccia with interspersed green silty clayey shale. Fowler and Robbie (1961) defined this lithology as quasi-breccia. Thompson and Goebel (1963) applied the term to the Warsaw Limestone in the Mid-Continent Petroleum Corp. No. 1 Collins core (Table 1).

The Warsaw Limestone of Scott County (Pl. 15) consists of calcarenite as well as cherty limestone. Residues contain typical Warsaw glauconite.

Conodont faunas (Appendix A) were recovered as residues from all Warsaw Limestone cores. These (Table 1) include, in addition to the cores discussed, the Mobil Oil Co. No. 1 Winans in Lane County, the Mobil Oil Co. No. 1 Elsasser Heirs in Ness County, and the Sinclair Oil and Gas No. 1 Colburn "A" in Barber County. Taxonomic descriptions and assignment of the Kansas faunas to the

A, 4454'



B, 4454' (X2.3) 1 cm

C, 4458' (X2.8) 1 cm

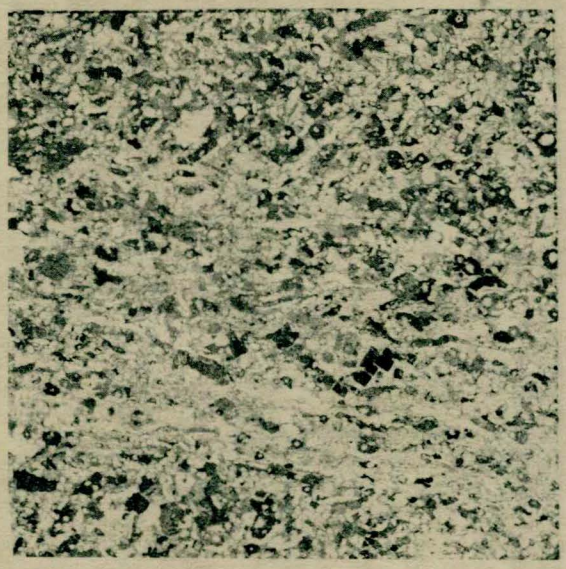


Plate 18.--Illustrations prepared from polished core slabs of Warsaw Limestone from Mobil Oil Co. No. 1 E. Salmans, sec. 3, T. 22 S., R. 22 W., Hodgeman County. Conodont fauna from residues indicates early Meramecian age. Residues from 4,454-4,458 feet, nearly 70 percent by weight consist of shale, chert, and a trace of pyrite; below 4,458 feet, residues less than 15 percent, consist of shale, pyrite, drusy quartz, and a trace of glauconite.
(A) Photograph and (B) peel-print of shale, gray, calcareous containing lenses of altered blue-black chert which is surrounded by chalky chert. Clear crystalline calcite fills voids in the chert. Note fractured lenses representing faulting or slump.
(C) Calcarenite, medium-grained.

Taphrognathus varians-Apatognathus? Assemblage Zone of the type area (Collinson and others, 1962) was made by Thompson (1965).

Biostratigraphic Zone

Collinson and others (1962) referred the Taphrognathus varians-Apatognathus? Assemblage Zone in the type locality to the Warsaw Limestone, Salem Formation, and part of the St. Louis Formation. The Gnathodus texanus-Taphrognathus Assemblage Zone was referred by them to the Keokuk (Fig. 7). A subsequent statistical study by Rexroad and Collinson (1965) of the occurrence of specimens related significant differences in abundance of conodont specimens, and indicated that the units can be subdivided. That study showed general similarity of conodont faunas in the Keokuk and the Warsaw-Salem, but the proportion of the species in the two is reported as quite different. Gnathodus texanus (Roundy) dominated Rexroad's and Collinson's Keokuk collection, making up 78 percent of the fauna; and Taphrognathus constituted only 7 percent of the fauna. In the Warsaw (Rexroad and Collinson, 1965) Gnathodus represented 44 percent of the specimens and Taphrognathus 20 percent of the specimens.

The distribution and abundance of conodonts from cores described in the lithology section of the Warsaw Limestone in my study is given in Appendix A. A surprising similarity of proportion of numbers of specimens from Kansas Warsaw Limestone cores to the proportions established in the type region is noted.

Thickness, Distribution, and Stratigraphic Relations

The thickness of the Warsaw Limestone in a number of wells is presented on Plates 3 to 7. The Warsaw thins toward the Central Kansas Uplift area and thickens

southward toward the Panhandle area of Oklahoma. It is more than 250 feet (76m) thick in its maximum development in Meade County, Kansas.

The Warsaw and upper Osagian rocks probably extended over the Central Kansas Uplift but were removed by pre-Chesteran or early Pennsylvanian erosion. Overlap of Warsaw by younger Meramecian formations toward positive areas flanking the Hugoton Embayment in Kansas and Colorado, as reported by Maher and Collins (1949), could not be verified within the study area in western Kansas. Overlap toward the north (Fig. 14) of Warsaw by Salem Limestone and St. Louis Limestone from northeastern Kansas into Iowa was illustrated by Lee (1956). Similar overlapping probably occurred in north-central and western Kansas.

Concentrations of glauconite in the lower part of the Warsaw in western Kansas mark a disconformity above the Keokuk. The Warsaw seemingly is conformable below the Salem. An inlier of Osagian rocks in Meramecian rocks (Pl. 2D) points to an area where Meramecian rocks were removed from locally positive areas by erosion in early Pennsylvanian time and possibly in pre-Chesteran time. Local thinning of Meramecian rocks (Pl. 2C) also may indicate positive areas.

Salem Limestone

Outcrops. --The Salem Limestone was named by Cummings (1901). Thick and nearly complete exposures of the Salem Limestone occur in southeastern and east-central Missouri. Early reference to the Salem Limestone as the Spergen Limestone is common in the literature (Table 2), but adoption of Salem in Missouri and Kansas is in accord with present usage of the U. S. Geological Survey and the Illinois and Indiana Geological Surveys. The Salem is conformable above the Warsaw in outcrops.

Subsurface character in Kansas.--Lee (1943, p. 75) mapped the Salem from Missouri into northeastern Kansas and subsequently (Lee and others, 1948) into the Salina Basin. In the latter area, Lee noted that the Salem had a less widespread distribution than the Warsaw. Most of the Salem is preserved in the structural basins and synclinal areas as a noncherty, yellowish granular limestone interstratified in the upper part with noncherty saccharoidal dolomite. Specimens of Endothyra were observed; silt and "spongy" masses of sponge spicules were recovered in the residues. Remnants of the Salem in the Salina Basin normally overlie the Warsaw, but where the Warsaw is absent they overlap upon the Keokuk-Burlington (Lee, 1956, p. 85).

In southwestern Kansas the Salem consists mainly of semigranular and granular limestone, in part dolomitic. This helps to distinguish it from the overlying St. Louis Limestone. Microfossiliferous chert similar to that found in the underlying Warsaw Limestone occurs in some Salem beds, but the proportion of chert in samples from the Salem is distinctly less than in the Warsaw. Specimens of Endothyra occur sparsely to abundantly in cuttings from Salem Limestone and also occur in the St. Louis Limestone. Lee (1953) described the limestone in the Salem as containing algae-coated grains and reported the lack of oolites in the cuttings from the Salem of a small area of western Kansas.

In cores and well records, the Salem Limestone in western Kansas was found to consist of coarsely crystalline, oolitic limestone with fragmental fossils and saccharoidal dolomite, dolomitic limestones, and chert. The distinctive salmon-pink, semi-opaque, and dark chert commonly found by Lee (1956) in the Salem in the subsurface of east-central Kansas was found only sparingly in samples from wells of western Kansas. Where the Salem Limestone is oolitic in western Kansas, it is difficult to distinguish from the overlying oolitic facies of St. Louis Limestone.

The limestone of the Salem is lighter in color than the overlying St. Louis Limestone, and the chert is light-colored, granular, and fossiliferous. Some drusy quartzose chert and geodal quartz is present.

Maher and Collins (1949) reported on the lithologic characteristics of the undifferentiated Spergen-Warsaw in a series of sample log cross-sections of the Hugoton Embayment. They noticed a facies change to the south and east from a shoreward area to a basinal area. The shoreward facies consisted for the most part of gray to buff, finely granular, silty, slightly cherty dolomite and also buff to gray, finely to coarsely crystalline glauconitic, oolitic, and cherty limestone. Some of the dolomitic beds had a distinctive dark buff color and resinous luster and some of the gritty limestones had a peculiar black mottling; quartzose chert occurs near the base in some wells. The basinward facies of Maher and Collins (1949) undifferentiated unit consists primarily of buff, coarsely oolitic, finely to coarsely crystalline, cherty limestone, and a white- to cream-colored, finely to coarsely crystalline dolomitic limestone. Distinction of these facies was not apparent in the wells studied in my investigation.

In stratigraphic cross-sections (Pls. 3-7) in my report, the Salem is differentiated from the Warsaw on the basis of smaller proportions and different kind of chert, generally abundant Endothyra, sparse glauconite, local oolitic lenses, and dolomitic limestone and saccharoidal dolomite.

Core and residue data. --The lithology of Salem Limestone is known from cores from Comanche County (Pl. 11), Ford County (Mull-Mobil Oil Co. No. 1 Matkin, Table 1), from Scott County (Pl. 15), from Logan County (Pl. 19), and from Lane County (Trigg et al. No. 1 Nimocks, Table 1). In Comanche County, the Salem consists of

semicrinoidal limestone with thin oolitic beds. The Salem in Ford County is calcarenite containing quartz sand and glauconite. In Scott County, in the deeper part of the Hugoton Embayment, the Salem consists of calcarenite, fossiliferous limestone, and dolomite with sparse chert. Part of the Salem in Logan County is dolomite with calcite-filled fossil-casts. Crystalline limestone makes up part of the Salem in Lane County.

Mineral and rock residues which are a small part of the original rock are described in the captions of the plates in which the lithologies of the Salem Limestone are exhibited. Taphrognathus varians dominates the conodont fauna in the residues from the cores (Appendix A); specimens of Apatognathus? n. sp. A (after Rexroad and Collinson, 1965) are also present.

Biostratigraphic Zone

The Salem Limestone (Figs. 6, 7) falls within the Taphrognathus varians-Apatognathus? Assemblage Zone (Collinson and others, 1962). Rexroad and Collinson (1965) suggested the possibility of subdividing the zone according to the abundance of species but additional study is needed. Pilot work on the Matkin, 1-A Mark, and Watchorn cores (Thompson and Goebel, 1963) indicated assignment to this zone. Thompson (1965) assigned the conodont faunas in the Salem cores from the Exchange Bank, Matkin, 1-A Mark, and Watchorn wells to this assemblage zone. Characteristics of the zone were discussed under the biostratigraphic zone section of the Warsaw Limestone.

Thickness, Distribution, and Stratigraphic Relations

The Salem unconformably underlies the Pennsylvanian in places. The subcrop distribution of the Salem Limestone is given on Plate 2D. The Salem increases in

thickness southward from zero along the outline of the Pennsylvanian subcrop pattern to more than 200 feet (61m) in the Hugoton Embayment (Pl. 3-5, and 7). The thinness of the Salem is attributed in great part to exposure and erosion in late Mississippian and early Pennsylvanian time. The Salem is present and conformable beneath the St. Louis throughout southwestern Kansas, generally thickening basinward into the Oklahoma Panhandle area. The Salem also is conformable above the Warsaw.

The Salem is mapped beneath the St. Louis in southeastern Barber County and western Harper County (Pl. 2D). This is the first report of Salem in the Sedgwick Basin. Warsaw, Salem, and St. Louis equivalents are probably widespread in the southern portion of the Sedgwick Basin but have not been recognized because of the "Cowley" facies and because either the chert residuum of the "Mississippi Chat" or chertified rocks conceal them.

St. Louis Limestone

Outcrops. --The St. Louis Limestone was named by Engelmann (1847) for exposures at St. Louis, Missouri. In the type area, the formation is a gray, lithographic to finely crystalline limestone. Spreng (1961) reported that limestone breccia is common in the lower part but is not confined there. Lithostrotium proliferum and Lithostrotionella castelnaui are compound corals that are diagnostic of the formation.

Subsurface character. --Lee (1943, p. 76) described the St. Louis Limestone in the Forest City Basin in northeastern Kansas as a lithographic to sublithographic limestone interstratified with semigranular limestone that has oolitic beds in some localities. The preservation there of part of a once widespread formation is attributed to its protection from erosion in a post-Mississippian synclinal basin.

Westward, on the basis of the absence of lithographic limestone in the interval above the Salem Limestone in wells in the Salina Basin, Lee (1956, p. 85) assigned the total thickness of post-Warsaw rocks to the Salem, even though the total thickness in one well (Auto Ordnance-Darby No. 1 Gawith, sec. 27, T. 11 S., R. 5 W.) was double the average thickness of the Salem in the Basin. Lee (1940) included the St. Louis of western Kansas in the Watchorn Formation and did not identify St. Louis or Watchorn in south-central or southeastern Kansas. St. Louis Limestone is differentiated from the Salem and Ste. Genevieve in my study (Fig. 2).

The St. Louis Limestone in western Kansas is thought to be conformable with Meramecian rocks above and below it. The beds are characteristically composed of noncherty lithographic and sublithographic limestone but also include remarkably widespread oolitic limestone and calcarenite. Semigranular limestone containing traces of translucent chert is found in some wells. In the deeper part of the Hugoton Embayment the St. Louis contains coarsely crystalline limestone and dolomitic limestone. The upper part of the St. Louis is arenaceous and light colored; sand grains generally are larger than in the overlying Ste. Genevieve Limestone. Chert, which occurs sparingly in the upper part in some wells, is light colored, smooth, and sub-opaque. The dolomite in the lower part is saccharoidal in texture; a few embedded sand grains were observed, and fewer oolitic beds are present. This portion of the St. Louis tends to be darker colored (tan to brown) than the upper portion.

In a limited area study in southwestern Kansas, Lee (1953) observed that the absence of silty limestones differentiated the St. Louis from the Ste. Genevieve. Clair (1948, p. 5) described the ooliths in the coarsely oolitic, dense St. Louis Limestone in western Kansas as very large and perfectly round. Clair observed an abundance of large free ooliths where the matrix was coarsely crystalline. Where

the St. Louis is a finely oolitic limestone, he reported that the ooliths are nearly the same color as the matrix and spherical. He distinguished the Ste. Genevieve from the St. Louis on the basis of very tiny, elliptical ooliths always darker than the containing matrix. These observations of Lee (1953) and Clair (1948) were not clearly substantiated by me during my investigation.

Hundhausen (in Lee, 1940, p. 83), using hydrochloric acid residues, subdivided rocks of Meramecian age encountered in the Spangler well in Scott County (sec. 23, T. 20 S., R. 33 W.) into Warsaw, Spergen, and St. Louis. Girty (1940, p. 84) referred to the Spangler well as containing "...fossils definitely identified... as St. Louis although no limits were set"--fossils indicative of age equivalents of late Meramecian time. The residues were reported by Lee as being very small in quantity and consisting mainly of gray translucent silica enclosing gray, opaque fossil fragments.

The St. Louis Limestone is a prime target for exploratory drilling by the petroleum industry in western Kansas. The largest oil field in the Hugoton Embayment, the Pleasant Prairie located in Haskell and Finney Counties, produces from oolitic limestone beds of the St. Louis Limestone. Also, the deepest producing zone in Kansas is in the St. Louis Limestone (well 3, Pl. 3) at greater than 6,700 feet (2,042m) depth. Detailed subsurface mapping by oil company geologists has outlined the extent of the oil and gas producing zones in known St. Louis Limestone fields (Kansas Geological Society, 1959, Vol. II, and 1965, Vol. IV) which, in most instances, have permeable, oolitic reservoir rocks. Subdivision into oolitic zones (by letter-designation), and lateral-mapping by use of characteristics of cuttings in adjacent wells correlated by use of mechanical logs have been proved possible by Roby (1959). The occurrence of hydrocarbons in commercial quantities

in the oolitic beds of St. Louis Limestone, where the overlying rock is the sandy, oolitic Ste. Genevieve Limestone, presents an unsolved puzzle for advocates of a Pennsylvanian source rock as well as for advocates of lateral migration of hydrocarbons.

Core and residue data. --The lithology of the St. Louis Limestone is variable but well known from cores and drill cuttings. In Scott County, the St. Louis Limestone contains: beds of oolitic, stylolitic, arenaceous limestone; and calcarenite (Pl. 15). Shale partings occur throughout the St. Louis Limestone. Generally, the characteristics of the St. Louis in Scott County are common to the formation in western Kansas. Beds of limestone breccia, limestone conglomerate, and chert breccia have developed locally in the St. Louis (Pls. 15, 19) providing evidence of intra-formational erosion in the Hugoton Embayment. Corallites (Lithostrotium proliferum) similar to those reported in the type area of the St. Louis are preserved in Scott County (Pl. 15).

Thin section examination of limestone (Pls. 19-22) from the St. Louis revealed fragments of echinoderms, brachiopods, bryozoans, and foraminifers as skeletal elements of the calcarenites. Endothyra is common in the underlying Salem Limestone; specimens also are found in the St. Louis Limestone.

Beds of anhydrite were logged in the St. Louis Limestone of Stevens and Hamilton Counties. This occurrence was verified from core chips of the Mobil No. 1 Cunningham Est. (Table 1) and No. 1 Alden Foster (sec. 5, T. 34 S., R. 36 W.).

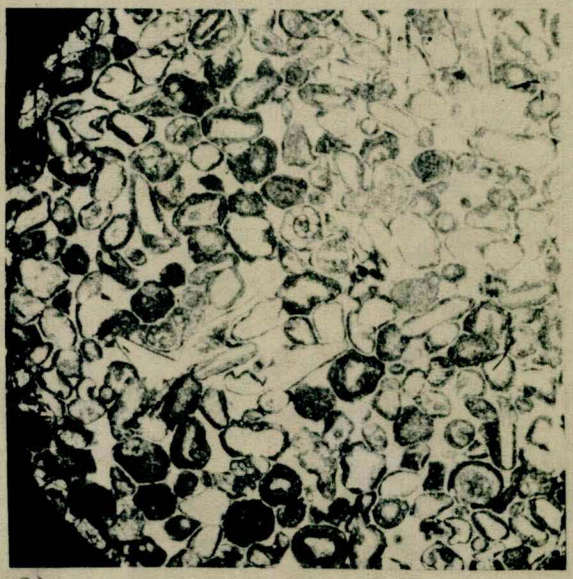
The St. Louis contains more interbedded shale in Comanche County than farther west. To the east, in Barber and Harper Counties, the "Cowley" facies of the St. Louis is developed (Pl. 16, and Sinclair No. 1 Colburn "A", Table 1). To the north in Gove County, the St. Louis contains quasi-brecciated, fossiliferous

A, 5138-5149'

B, 5025-5037'

C, 5147-5162'

D, 5147-5162'

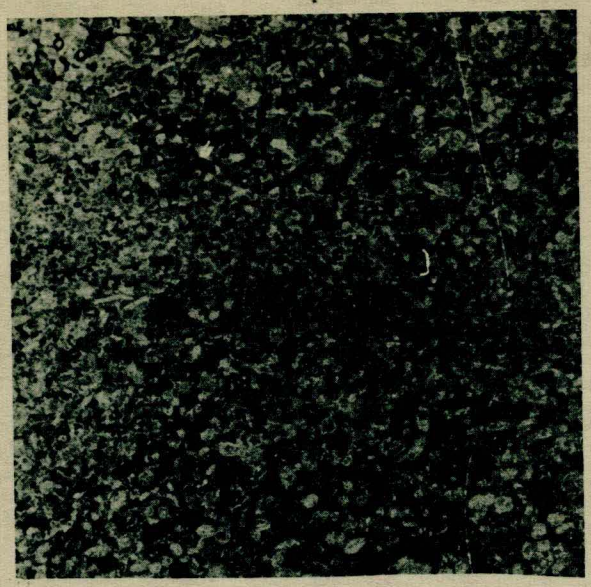


(X15.6)

0.1 cm

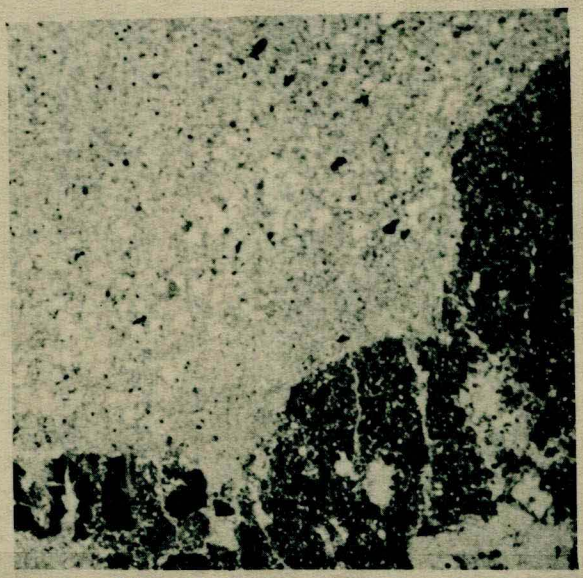
Plate 20.--Photomicrographs of core slabs of St. Louis Limestone from the McKnab Lindsay Kuhn-Devlin lease in sec. 19, T. 26 S., R. 34 W., Finney County. (A) Well No. 7, calcarenite, oolitic, in which the skeletal grains comprise pieces of echinoderms, foraminifers (note Endothyra), bryozoans, and brachiopods in calcite spar. Ooliths exhibit overgrowths reflecting shape of nuclei. Evidence of pressure solution displayed by concavo-convex relationships of grains and ooliths.
(B) Well No. 8, calcarenite, coarse-grained in groundmass of coarse-grained spar. Skeletal elements recognized same as in A, but fewer foraminifers.
(C) Well No. 5, calcarenite, oolitic, closely packed in sparry calcite. Note tangential concavo-convex contacts of grains, and note also the stringer of coarse-grained skeletal elements in coarse-grained calcite spar.
(D) Also, Well No. 5, a deeper calcarenite, oolitic in a microspar groundmass. Note overgrowths of skeletal elements which serve as nuclei for ooliths. Foraminifera recognized as Endothyra.

A, 5613' (X6.9) 0.5 cm



B, 5632' (X7.0) 0.5 cm

C, 5701' (X5.0) 0.5 cm



D, 5706' (X5.3) 0.5 cm

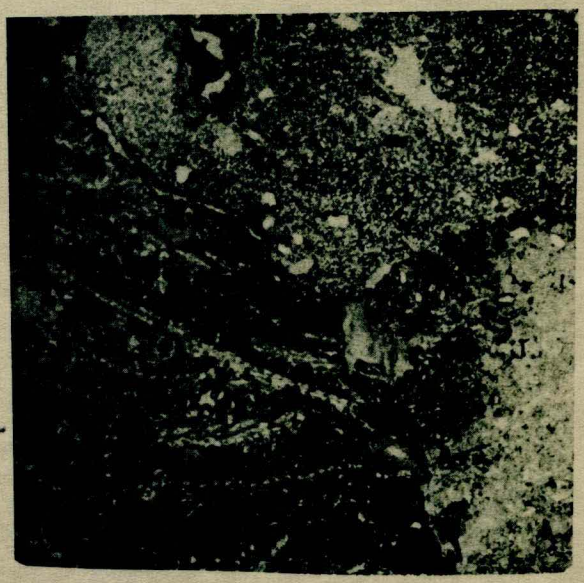
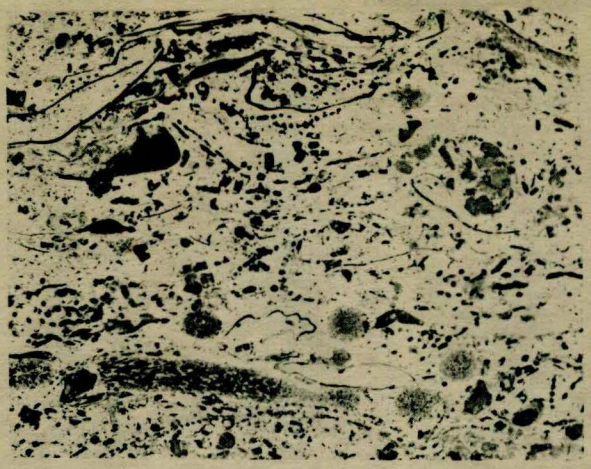


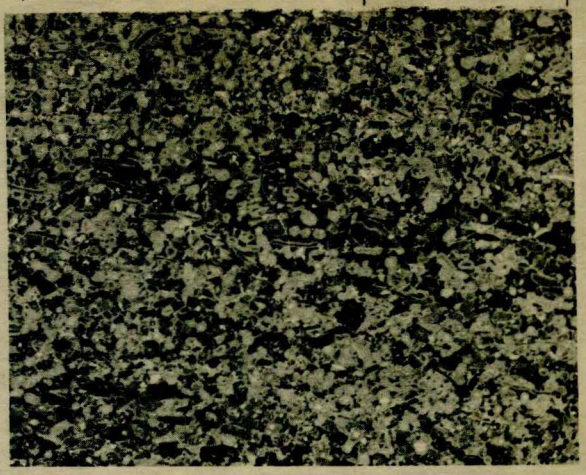
Plate 21.--Photomicrographs of thin sections of Ste. Genevieve Limestone and St. Louis Limestone from Cities Service No. 1 Kells "B", sec. 5, T. 28 S., R. 34 W., Haskell County.
(A) Ste. Genevieve Limestone, a calcarenite, fine- to medium-grained; grains mostly skeletal comprised of echinoderms, brachiopods, and bryozoan pieces in groundmass of calcite spar (25 percent).
(B) St. Louis Limestone, a calcarenite, medium- to coarse-grained; skeletal elements mostly echinoderm debris, with minor elements comprised of pieces of bryozoans, gastropods, foraminifers, and brachiopods. Coarse spar groundmass optically continuous with adjacent echinoderm ossicles.
(C) St. Louis Limestone, a sandstone, fine- to coarse-grained quartz (40 percent), and clastic carbonate (10 percent) in groundmass of microspar and clay; sandstone overlies a saccharoidal dolomite, altered from a calcarenite.
(D) St. Louis Limestone, a dolomite, saccharoidal, overlying an oolitic calcarenite. The contact is stylolitic. Ooliths are fine to medium sand size and echinoderms are main skeletal components in a groundmass of lime mud and spar.

Plate 22.--(see opposite page) Illustrations prepared from core slabs and core chips from Helmerich and Payne No. 1 Eubank, sec. 28, T. 28 S., R. 34 W., Haskell County.
(A) Peel-print from the Ste. Genevieve Limestone of a coquinite, composed of stacked layers of bryozoans, (mostly lacy fronds of fenestrate forms), and invertebrate shells.
(B) Peel-print from Ste. Genevieve Limestone of a calcarenite, oolitic (75 percent grains comprised of ooliths and skeletal debris). Rounded grains in groundmass of mud and coarse spar.
(C) Photomicrograph from Ste. Genevieve Limestone of a calcarenite, oolitic, (60 percent grains), comprised of skeletal pieces of echinoderms, brachiopods, bryozoans, foraminifers, and gastropods. Irregularly ellipsoidal to spherical shaped ooliths display concentric structures and are fine to coarse sand size.
(D) Photomicrograph from St. Louis Limestone of a limestone, oolitic (80 percent ooliths, 15 percent skeletal, 5 percent quartz). Ooliths are fine to coarse sand size, mostly spherical and display overgrowths.
(E) Photomicrograph from St. Louis Limestone of a limestone, oolitic in a groundmass of spar (50 percent); no free skeletal grains, but pieces of skeletal elements make up nuclei of ooliths. Note spar stringer transecting ooliths in upper left quadrant.
(F) Photomicrograph from St. Louis Limestone of a micrite, quasi-brecciated; the mud blebs are separated by silty, calcareous spar.

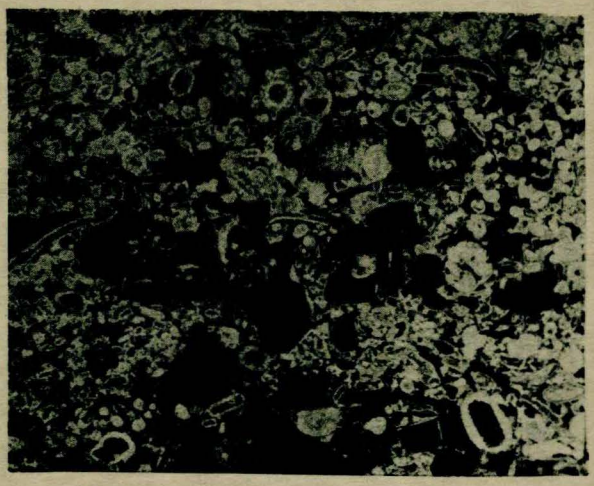
A, 5446' (X2.5) 1 cm



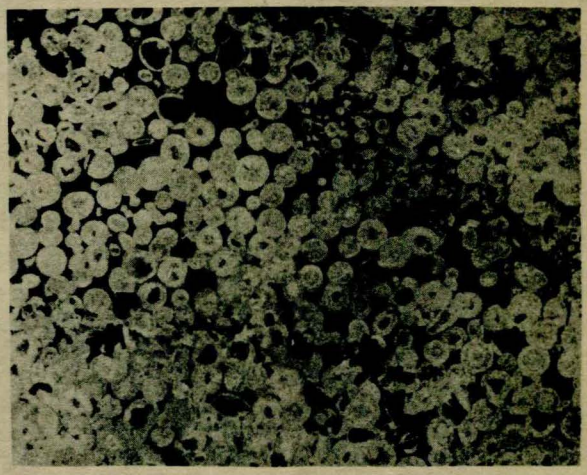
B, 5449' (X2.7) 1 cm



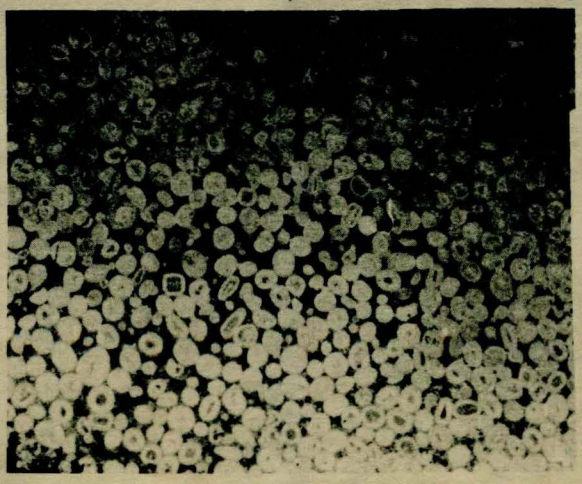
C, 5457' (X7.0) 0.5 cm



D, 5469' (X7.0) 0.5 cm



E, 5514' (X7.2) 0.5 cm



F, 5642' (X6.8) 0.5 cm

Plate 22.

and sparsely cherty limestone (Hockersmith, Table 1). Other cores studied from the St. Louis Limestone are listed in Table 1.

Mineral and rock residues from cores from the St. Louis Limestone generally constituted less than 5 percent and consist of shale, silicified fossil fragments, chert, pyrite, sphalerite, and conodonts. Some residues contained a few fine quartz sand grains. Residue descriptions are given in the plate captions (Pls. 15, 19) and in Appendix B.

Conodonts recovered as residues include Apatognathus? gemina, A.? porcata, Cavusgnathus convexa, C. regularis, C. unicornis, Cladognathodus, Magnilaterella robusta. The occurrence and distribution of conodonts by core is given in Appendix A.

Biostratigraphic Zones

Collinson and others (1962) proposed two conodont biostratigraphic assemblage zones including all or part of the St. Louis Limestone of the type locality. The Taphrognathus varians-Apatognathus? Assemblage Zone includes the lower part of the St. Louis Formation and the underlying Salem and Warsaw of the Mississippi River Valley area. This zone is defined by the earliest occurrence of Apatognathus? and common occurrence of Taphrognathus varians. The upper limit of this zone is marked by the last regular occurrence of Taphrognathus and the earliest occurrence of abundant Taphrognathus.

In the type area, that portion of the St. Louis Limestone which occurs above the base of the main breccia bed but below the base of the Ste. Genevieve Limestone coincides with Apatognathus? gemina-Cavusgnathus Assemblage Zone. Apatognathus? are common in this zone and the upper limit is delineated by the latest occurrences of Spathognathodus scitulus. The lower limit almost coincides with the earliest

common occurrence of S. scitulus and does coincide with the earliest occurrence of common Cavusgnathus or with the latest regular occurrence of Taphrognathus. Transitional forms of both Taphrognathus and Cavusgnathus were found respectively above and below the lower boundary (Rexroad and Collinson, 1963). A faunal break occurs at the top of the zone and more than one-third of the species in the zone do not continue into the overlying zone.

Cores of St. Louis Limestone which contained conodonts were reported by Thompson and Goebel (1963) and are listed in Table 1. Also, the conodont faunas from St. Louis Limestone from the Watchorn, the 1-A Mark, the Kells "B", the Colburn "A", and the Exchange Bank cores, were described by Thompson (1965) who correlated the Kansas faunas with conodont faunas of the biostratigraphic zones of the type area. Conodonts from the Cunningham Est. core are correlated by me with conodont biostratigraphic zones of the type area. In addition to these western Kansas cores, Thompson (1965) described conodonts from St. Louis Limestone cores from wells in Greenwood and Woodson Counties in eastern Kansas. These are important evidence in correlation of subsurface biostratigraphic zones in Kansas.

Thickness, Distribution, and Stratigraphic Relations

The St. Louis Limestone in western Kansas thickens from zero below the Pennsylvanian rocks (see Pl. 2D) to more than 250 feet (76m) thick in the deeper parts of the Hugoton Embayment (Pls. 3 and 7) where it averages about 200 feet (61m) in thickness.

The St. Louis Limestone is conformable above the Salem and below the Ste. Genevieve except locally where the Ste. Genevieve was removed and it is overlain by Chesteran rocks. Where early Pennsylvanian erosion has removed younger

Meramecian rocks, the St. Louis is unconformable beneath the Pennsylvanian rocks (Pl. 2D). The St. Louis Limestone probably covered most of Kansas at one time. Lee (1956, p. 83) mapped St. Louis in the Forest City Basin in northeastern Kansas and stated that although neither the St. Louis nor the Ste. Genevieve have been recognized in the Salina Basin, they were probably deposited but removed by pre-Pennsylvanian erosion.

Where Mississippian rocks have been preserved beneath the Pennsylvanian "basal conglomerate" and local chertification has inhibited the identification of late Meramecian rocks, widespread presence of the "Mississippi Chat" occurs, especially in south-central Kansas. Difficulty in differentiating Mississippian formations in this area has led to widespread use of the term "Mississippi Lime" by geologists concerned with exploratory drilling. Reworked chert deposited on the eroded surface of Mississippian Limestone is difficult to differentiate from residual chert. Locally, this residual chert exceeds 50 feet (15m) in thickness. Local chertification of Meramecian rocks forming "Cowley" type cherts also confuses identification of units.

Ste. Genevieve Limestone

Outcrops. --The Ste. Genevieve Limestone was named by Shumard (1860). It is typically developed in Ste. Genevieve and St. Louis Counties in east-central Missouri (Spreng, 1961, p. 70). A locally developed basal conglomerate marks a disconformity above the St. Louis Limestone. Pre-Chesteran erosion is present at the top of the Ste. Genevieve.

Subsurface character. --Lee (1943, p. 77) described the Ste. Genevieve in northeastern Kansas as gray to white, finely granular to "mealy," oolitic limestone that

contains 10 to 20 percent broken, angular, fine-grain quartz sand. He believed the Ste. Genevieve was conformable on the St. Louis in northeastern Kansas. The Ste. Genevieve is absent in the Salina Basin in north-central Kansas (Lee, 1956).

The Ste. Genevieve in western Kansas is a silty and sandy, light-colored limestone, with interbedded fine-textured oolitic limestone (Pls. 3-5, and 7). Some medium- and coarse-grained oolites occur in the lower part of the Ste. Genevieve; beds of Ste. Genevieve strata cannot be positively identified if they overlie the finely oolitic limestone of the St. Louis. The shape of ooliths which Clair (1948) used as a criterion was not found useful in distinguishing the Ste. Genevieve from the St. Louis. The criterion of a larger percentage of sand (up to 30 percent) in the limestones of the Ste. Genevieve is useful in some areas. Minor quantities of pink chert occur locally. Megafossil fragments are scarce in drill cuttings.

Maher and Collins (1949) included a white to cream, slightly glauconitic, fine-grained sandstone in the upper part of the formation in the southeastern half of the embayment (Hugoton). In Cimarron County, Oklahoma, they reported red-stained sandstone beds equivalent to their Ste. Genevieve sandstone beds and reasoned they were so stained as a result of ground water action at the time the Chesteran strata were eroded from the Keyes Dome.

Core and residue data.--Cores in Logan County from the Ste. Genevieve Limestone include siltstone and calcarenite in wavy-bedded shale (Pl. 19). Well-rounded sand grains are present in the matrix. Cores from Scott County (Pl. 15), Haskell County (Pls. 21, 22), and Kearny County (Table 1) contain similar rocks.

Residues range from more than 65 percent insoluble to less than 1 percent and consist of shale, silt, quartz sand, pyrite, and chert. These are described in

the plate captions (Pls. 15, 19). Residues include the conodonts, Cavusgnathus characta, C. convexa, C. regularis, and C. unicornis. Occurrence and distribution of specimens are given in Appendix A.

Biostratigraphic Zones

In the type section of the Mississippian rocks in the upper Mississippi Valley, the Gnathodus bilineatus-Cavusgnathus characta Assemblage Zone (Figs. 6 and 7) coincides with the interval extending from the base of the Ste. Genevieve (Meramecian) to the base of the Golconda Group (Chesteran). The highest occurrence of Apatognathus? and Spathognathodus scitulus marks the lower limit of the zone. Occurrence of Gnathodus bilineatus probably coincides with this boundary. The zone is the oldest to contain a fauna with Chesteran aspects (Collinson and others, 1962). The conodonts of the zone have been little studied; but characteristic species include the name-givers and Gnathodus texanus, G. commutatus, Cavusgnathus regularis, C. convexa, C. unicornis, Spathognathodus cristula, and S. campbelli.

Thompson (1965) assigned the conodont faunas from the 1-A Mark, the Watchorn, and the Kells "B" cores (Table 1) to this assemblage zone. Cavusgnathus and Spathognathodus were recovered from the Eubank core (Table 1 and Pl. 22) and indicate age equivalence with conodont zones contained in the Ste. Genevieve Limestone of the type area (Thompson and Goebel, 1963).

Thickness, Distribution, and Stratigraphic Relations

The Ste. Genevieve Limestone in western Kansas exceeds 200 (61m) feet in thickness in the deeper part of the Hugoton Embayment. It thins northward to zero toward the positive areas (Pl. 2D). The Ste. Genevieve Limestone is disconformable

locally beneath Chesteran rocks and is seemingly conformable on St. Louis. Locally in western Kansas it has been removed by pre-Chesteran erosion. Subcrop distribution of Ste. Genevieve is unconformable below Pennsylvanian rocks (Pl. 2D). Ste. Genevieve rocks have not been recognized in the Salina or Sedgwick Basins (Lee, 1956). Ste. Genevieve rocks may at one time have extended throughout Kansas, but more probably a phase of regression took place; and the Ste. Genevieve was more limited in distribution than older Meramecian units.

Residue Analysis

Insoluble residues from Meramecian units of western Kansas share some similarities with those of lateral equivalents. Conodonts recovered as part of the residue are strikingly similar to those found in adjacent areas.

Chert is considerably less common from Meramecian than Osagian rocks. Generally, chert from Meramecian rocks is concentrated in the Warsaw, and the microfossil content is higher than in Osagian chert. Chert content decreases upward in Meramecian rocks and is a minor constituent in the Ste. Genevieve Limestone.

Glauconite content of Meramecian rocks seemingly decreases upward. Glauconite is locally concentrated in the lower part of the Warsaw. Traces of glauconite are not uncommon in many of the residues.

Secondary sulfide mineralization is revealed by the presence of pyrite, sphalerite, and anhydrite. Pyrite is a common residue. Sulfide minerals are less abundant in the residues from Meramecian rocks than from Osagian rocks.

Generally, smaller quantities of clay-size particles from the Meramecian rocks were washed away through the 100-mesh screen during laboratory procedures than the quantities discarded from Osagian cores. This smaller clay content is

obvious from visual inspection of Osagian and Meramecian rock cores. The collection and analyses of clays from Mississippian cores should be a future avenue for geologic research and should yield information on the environment of deposition during the Mississippian.

Insoluble residues from exposed Meramecian rocks have been found useful in identifying laterally equivalent units in some restricted areas (Grohskopf and McCracken, 1949). Lee (1940, 1949, 1953, 1956) used some of the gross residue characteristics in conjunction with sample examination to extend Meramecian units into Kansas. Some of these gross residue and sample characteristics have been found unsatisfactory when applied to western Kansas Meramecian rocks. Color, quantity, and transparency of cherts are thought to be locally controlled and to have little use in mapping, even within a basin. Local and restricted use of these characteristics may be found feasible within one oil field where boreholes are closely spaced.

Recovery of fragments of silicified and partly silicified fossils as residue material is common from Meramecian rocks. Additional study of these fragments and additional study of megafossils in cores is suggested and should yield information on the environment of deposition, diagenesis, and the age of the rocks.

Conodonts recovered as residues in my study prove the value of insoluble residue techniques applied to dominantly carbonate sections of Mississippian rock in Kansas.

Environment of Deposition

Meramecian rocks from the Warsaw Limestone into the St. Louis Limestone in western Kansas were deposited in an environment similar to that in existence during the Osagian and part of the Kinderhookian. Shallow, warm, clear, epicontinental

seas of marine salinity covered most of central and western interior United States most of the time. The source of sediment was mostly organic, including skeletal material of pelagic and benthonic invertebrate animals in great variety. Corals, brachiopods , bryozoans, foraminifers, gastropods, conodonts, and scolecodonts were preserved. Fish and sharks were also present.

Platform or shelf-like conditions typified the environments of deposition. Sands and shales make up only a minor part of the preserved section of rocks below about the upper half of the St. Louis Limestone.

The great variety of lithologies presented in photographs and acetate peel-prints include fine-grained lime mud, pellitoid and oolitic limestone, calcareous dolomite, calcarenite, conglomerate, and brecciated limestone. These reflect changing depositional environments.

The water was probably well agitated at times, and this is attested to by the presence of cross-bedding at different places in the sequence. Chert- and limestone-breccia and conglomerate are evidence of agitated water. Widespread development of oolites and beds of calcarenite may be interpreted as indicating periodic current action sustained over a long period of time in shallow and restricted seas. The lime muds probably indicate protected areas with a low level of current action.

Although fragments, columnals, and ossicles of echinoderms (mostly crinoids) make up a large part of the limestones and dolomites reported, no calices were found.

Down-warping of the Hugoton Embayment, coupled with accumulation of mixed-fossil and oolitic limestone beds, could account for the thickening of shallow water shelf deposits toward the Anadarko Basin. Widespread distribution of calcarenite and oolitic limestone beds suggests conditions similar to those existing during deposition the Gilmore City Limestone of the Kinderhookian. Widespread distribution of

oolitic limestone beds reflects shifting of areas of accumulation or environments of deposition in time and space

Glauconite in thin laminations in some oolitic beds may indicate shallow water. Occurrence of algae in some areas is interpreted to mean that sedimentation was in very shallow water and shoaling was probably a very common occurrence. The presence of bedded anhydrite in the St. Louis Limestone is probably indicative of deposition in a closed or shallowing basin. Anhydrite deposition probably occurred with progressive shallowing of waters and restriction of circulation caused by a drop of sea level or by maintenance of static sea level relative to the building up of shoals.

Diagenetic changes of the Meramecian rocks are shown by the presence of sulfide minerals, dolomitized rocks and fossils, siliceous fossil fragments, and probably by chertified rocks. Molds of calcareous fossils in dolomite attest to the dolomitization of some limestone beds.

Dolomitization locally destroyed much of the original texture of some of the limestone beds and fossils. Relict textures in dolomite indicate that the original rock in some places was fine- to coarse-grained fossiliferous limestone.

Possibly the bedded anhydrite deposition and development of breccia and conglomerate within the St. Louis Limestone reflects a change in regimen of the Meramecian sea in western Kansas. The environment of deposition of Meramecian rocks definitely changes with the development of the Ste. Genevieve Limestone which is characteristically arenaceous. Quartz sand and silt became important constituents of the sediments at this time and increased in importance through Chesteran and into Pennsylvanian time.

It is doubtful that Ste. Genevieve? rocks covered all of western Kansas. Probably the Central Kansas Uplift area and the Las Animas Arch area in Colorado during late Meramecian time began contributing important quantities of terrigenous material to the clastic and detrital content of sediments. And probably at this time, rocks in the area of these up-warpings and areas of provenance included older Mississippian rocks which had a high chert and silicified fossil content.

Stratigraphic Relations and Discussion

Some details of the stratigraphic relationships of the Meramecian rocks have been presented in each section, and from this a general picture evolves of the entire sequence.

The Warsaw Limestone, the lower unit of the Meramecian Stage, overlies Osagian rocks but is less widespread. Physical unconformable relationship of Meramecian and Osagian rocks, which figures so prominently in the literature on the Mississippian of the outcrop areas, cannot be demonstrated from present knowledge of these rocks in western Kansas. The magnitude of faunal breaks and the placement of exposed lithostratigraphic units as lowermost Meramecian or uppermost Osagian constitute an unresolved controversy. In western Kansas, one bit of physical evidence of possible unconformable relationship is the development of chalky and tripolitic cotton rock in the Keokuk or other Osagian rocks. Presence of a zone of glauconite in the lower part of some cores from the Warsaw Limestone may also be indicative of an unconformity (Cloud, 1955). The faunal evidence of a break cited in the literature is presented in the Osagian section on stratigraphic relationships.

Carbonate deposition, with only gradational changes in contacts of lithostratigraphic units apparent, dominated the sedimentation of the Meramecian in

western Kansas until after about half the St. Louis Limestone was deposited. The introduction of quartz sand and increased silt content as part of St. Louis deposition reflects the change in regimen of the seas and a change in the areas of supply of sediments in the source areas, the Central Kansas Uplift and the Las Animas Arch.

Pre-Chesteran erosion removed the Ste. Genevieve Limestone locally in western Kansas. Probably the Ste. Genevieve was not as widespread as older Meramecian rocks. The Chesteran rocks are unconformable locally above St. Louis rocks in extreme southwestern Kansas (Pl. 2D).

Pre-Chesteran and early Pennsylvanian erosion have resulted in the distribution pattern of formations of the Meramecian Stage in western Kansas as displayed in Plate 2D. Generally, the subcrop pattern is formational bands subparallel to the northwest trending axis of the Central Kansas Uplift.

Down-warping of the Hugoton Embayment during deposition of Meramecian carbonate rocks accounts for the thickening of shelf and platform deposits basinward into the Oklahoma Panhandle. Thinning of the Meramecian rocks on the flanks of the Anadarko Basin was reported by Maher and Collins (1949) as occurring at both the top and the bottom of the unit. The thinning at the top, they report, was due to removal by erosion; the thinning at the bottom was due to onlap of the formations toward the west, north, and east, probably resulting in the nondeposition of the Warsaw, Salem, and most of the St. Louis in the southwestern part. This conclusion could not be substantiated in my area of investigation in western Kansas. Part of the thinning of the upper Meramecian rocks may be due to the wedging out on the flanks of early Mississippian topographic highs (Pl. 2C).

The isopachous map of the Meramecian rocks (Pl. 2C) reflects the same regional thickening into the main Anadarko Basin (Hugoton Embayment in Kansas) as

the Osagian rock isopachous map (Pl. 2B). Meramecian rocks range from a thickness of zero along a band subparallel to the Central Kansas Uplift to more than 850 feet (259m) in southern Meade County. A prominent area of thinning is observed in northern Morton and southern Stanton Counties, and an area of flattening and reversal is present northward from Grant and Kearny Counties into Logan County. Meramecian rocks also thicken southeastward and eastward from the Central Kansas Uplift.

Configuration of the total Mississippian isopachous map (Pl. 23A) has gross similarity to that of the isopachous map of interval C (Pl. 2C).

The upper surface of the Meramecian rocks, where not overlaid by Chesteran rocks (Pl. 2D), is part of the unconformable surface which was developed in large part by erosion in early Pennsylvanian time. As in the Osagian rocks, where chert and siliceous materials were a prominent part of the exposed rocks, a residuum of "Mississippi Chat" accumulated as a mantle above Meramecian rocks. Distinction of "Mississippi Chat" residuum from transported sediments is possible in surface exposures, but in rotary or cable tool cuttings from boreholes such identification is not always possible. Accumulations of residual "Chat" in some places above Osagian rocks exceed 50 feet (15m) but are generally of less thickness above recognizable Meramecian units.

Lee (1956) included the "Mississippi Chat" with the Mississippian in constructing isopachous maps, a practice followed in my report. Addition of this material to the Mississippian units tends to flatten the upper surface and gives the appearance of a peneplain (Pl. 23B).

Karst Development

Karst development has been reported on the upper surface of Mississippian rocks in the Midcontinent and Rocky Mountain areas. Foster (1963) reported karst features in Montana. Merrill and Winar (1958) in southwestern Colorado described residual deposits of an ancient soil accumulated by solution of Mississippian and older rocks between Osagian and Pennsylvanian time. Armstrong (1955) reported karst development which he correlated with a part of the Meramecian rocks in northeastern New Mexico. In the Ozark area, surface sinks are reported by Smith and Siebenthal (1907), and Spreng (1961). In Cherokee County in southeastern Kansas, Sauracker (1965) described Mississippian sinkholes.

In the subsurface of Kansas, widespread evidence of solution features in the Mississippian rock surface has been reported (Rich, 1930; Hiestand, 1938, p. 1,598; Lee, 1940; Lee, 1943, p. 78; Shenkel, 1955; Lee, 1956). Karst features in pre-Mississippian rocks in the Central Kansas Uplift area which probably were formed during Late Mississippian--pre-Desmoinesian time have been reported by Ver Wiebe (1941), Walters (1946), and Redman (1947).

In my study area, development of quasi-brecciated limestone and chert breccias may be evidence of karst development. Local occurrence of atypical lithologies in the upper portion of Mississippian formations, especially those in Meramecian and Osagian rocks directly below the Pennsylvanian "basal conglomerate," probably resulted from development of karst solution features. Irregularity of the eroded Mississippian surface was reported by Merriam and Harbaugh (1964) based on the poor fit of a trend-surface analysis. Perhaps the irregular surface resulted from karst development.

The widespread development and variable thickness of residual chert which forms the upper part of the Mississippian is strong evidence for karst development in my study area.

CHESTERAN STAGE

General Statement

Chesteran rocks have been classified into many formations in the upper Mississippi River Valley (Fig. 6) but in Kansas the Chesteran rocks are undivided (Table 3, Fig. 2). In Kansas, Chesteran rocks are of limited distribution, dominantly clastic, but probably all marine.

Outcrop Areas and Extensions into Subsurface

The outcrops of Mississippian rocks (Fig. 1) in southwestern Missouri, northwestern Arkansas, and northeastern Oklahoma include the Chesteran exposures closest to the western Kansas area. In this area there are three formations, the Hindsville, Batesville, and Fayetteville (oldest to youngest) (Table 2). The Chesteran rocks are unconformable on the Keokuk Formation and are overlain unconformably by Pennsylvanian rocks (Spreng, 1961).

In southeastern Kansas, Chesteran rocks (Table 3) 20 feet (6m) in thickness are logged as Batesville Limestone overlying the Warsaw in the Ballard Mine in section 10, T. 35 S., R. 24 E., Cherokee County, Kansas (Lee, 1940, p. 46). Chesteran rocks are absent in south-central Kansas.

Chesteran rocks, all in the subsurface, are mapped in northwestern Oklahoma as interbedded gray and vari-colored, silty, calcareous shales, and fine- to coarse-crystalline, partly oolitic, fossiliferous, and argillaceous limestone (Jordan and Rowland, 1959, p. 134). In the Oklahoma Panhandle, Curtis and Champlin

(1959, p. 95) described Chesteran rocks as buff to gray, coarse crystalline, oolitic, fossiliferous, crinoidal limestone interbedded with gray to brown fissile shale. A detrital zone at the base consists of buff, calcareous, glauconitic, fine- to medium-grained sandstone.

Lithology, Thickness, and Distribution in Southwestern Kansas

Chesteran rocks are present only in subsurface in southeastern and southwestern Kansas. Some sink-fill material in southeastern Kansas could have been deposited during the Chesteran Period. In southwestern Kansas Chesteran rocks are preserved only in the deeper part of the Hugoton Embayment. Chesteran rocks of southwestern Kansas are mapped and identified in sample study on the basis of first appearance of non-micaceous sediments and only rare occurrences of glauconite. Glauconite is not abundant in overlying Pennsylvanian rocks. Chesteran shales are dominantly green; some are pale apple-green. A general absence of dark or black shales is noted in contrast to the dark shales at the outcrops in the Missouri-Oklahoma area. Near the base of the Chesteran rocks, variegated shales and discontinuous sandstones are dominant; lithographic limestones are mapped only in the lower part. Abundant screw-like axes of Archimedes are observed in sample cuttings. On the whole the subsurface beds in western Kansas are dissimilar to the outcrops to the east. The distribution and thickness of Chesteran rocks in southwestern Kansas are shown on Plate 2D. An east-west stratigraphic cross-section (Pl. 3) provides some lithologic details of Chesteran rocks logged in selected wells. Chesteran deposits in southwestern Kansas differ from older Mississippian rocks in the region by being restricted to the southwestern part of the region, and by containing a higher percentage of

clastics. The clastic material is generally of a fine- to very fine-grain size. Older Mississippian rocks, as noted earlier, are dominantly composed of limestones, dolomites, and cherts or cherty limestones and dolomites. These, in all probability, reflect more stable and less turbid conditions of deposition than those which prevailed later during Chesteran time. Shale and sandstone predominate Chesteran lithology and indicate a change in regimen. Also, Chesteran deposits are separated from Meramecian rocks by an unconformity that represents removal of a thick section of older rocks.

Chesteran rocks range in thickness from zero along a semi-arcuate pattern (Pl. 2D) defined by the Pennsylvanian subcrop contact with the Ste. Genevieve Limestone, to more than 300 feet (91m) in southern Meade, Clark, and Comanche Counties. The east-west stratigraphic cross-section from Morton County to Clark County (Pl. 3) and north-south cross-section (Pl. 7) from Gove County to Stevens County depict the range in thickness of Chesteran rocks preserved under the Pennsylvanian unconformity. In Plate 3, Sheet 2, well 2 (No. 2 Going) and well 5 (No. 1 Wheatley) Chesteran rocks are markedly thin relative to their thickness in the other wells in the cross-section. Chesteran rocks are known to exceed 1,250 feet (381m) in thickness farther south in the Anadarko Basin (Beebe, 1959). Maher and Collins (1949) reported that Chesteran strata are very thin over structures in Seward and Meade Counties, Kansas, and are absent on top of the Keyes Dome in Cimarron County, Oklahoma, and in the Stanolind No. 1 Bear well in sec. 17, T. 32 S., R. 40 W., Morton County, Kansas. In their study, some rocks in the Bear well were assigned to the Chesteran on the basis of the presence of green to greenish-gray, soft shale that contained fragments of bryozoans. These rocks are overlain by brown, fine-grained arenaceous limestone and variegated, non-micaceous shale.

Maher and Collins (1949) mapped Chesteran rocks as extending from the Oklahoma Panhandle northeastward to the southern border of Gray County, Kansas, and southwestward into eastern Cimarron County, Oklahoma, and Baca County, Colorado. They reported thicknesses on only 15 wells (1949, sheet 2) and described lithology from only two Kansas wells (Adams and Rickers, wells 10 and 11, also cited by Lee, 1953). They logged a section of sandstone and shale beds in the lower part, beneath oolitic limestone, and a decreasing percentage of shale and sand strata upwards. They did not identify Chesteran fossils but made mention of the presence of fossiliferous and crinoidal limestone beds in Chesteran rocks. Maher and Collins (1949) confirmed the resemblance of Chesteran rocks in the Gulf Oil Corp. No. 1 Ratzlaff well (south of Meade County, Kansas) in sec. 9, T. 3 N., R. 21 E., Beaver County, Oklahoma, to the descriptions of the Chesteran rocks of Arkansas. The maximum thicknesses of Chesteran rocks in the Midcontinent are probably those reported by Harlton (1963, p. 1,561) who assigned 2,200 feet (670m) of Chesteran and 2,000 (609m) additional feet of Springeran rocks to the Upper Mississippian in the fault system of the Wichita Mountains in Oklahoma.

Core and Residue Data

The Anderson Trust core (Table 1) in Stevens County was the only core available for study. Residues consisted mostly of very fine to fine quartz sand and shale. Few conodonts were recovered. The residue percentage ranged from 24 percent near the top of the core to more than 95 percent downhole.

Although the core from the Peters and others No. 1 Gardiner well (sec. 8, T. 34 S., R. 24 W.) was not available for study, a detailed core description (Table 4) on a Kansas Sample Log Company stratigraphic log (by R. A. Carmody,

Table 4.--Core descriptions of Chesteran rocks from the Peters, Writer, Christensen and Siegel No. 1 Gardiner well in sec. 8, T. 34 S., R. 24 W., Clark County, Kansas (from a Kansas Sample Log Service log by R. A. Carmody, 1953).

Core No. 1, 5507-5549 feet

5507-16	sh., blk. w/abt. cal. fauna, cri., shells, bryz. etc.
5516-18	lst., brn. & blk., mot., v. fos. fragm. w/abunt. crin. & ooliths.
5518-21	lst., crm. & lt. brn., v. crin. w/waxy fos. grn. sh. partings.
5521-24	interbedded dk. gray, calc. sh. & v., fos. lst.
5524-25	sh., dk. gray, v. fos., abund. crinoids, bry. etc.
5525-27	lst., crm. & lt. brn., v. fos.
5527-29	lst., dk. gray, v. fos. w/blk. sh. parting.
5529-33	sh., blk., calc. w/dis. dse. lst. & abt. calc. shells,
5533-37	sh., blk., fis., sli. calc. & fos., rare carbonized plant frags.
5537-38	lst., dk. gray to brn., v. fos. w/dis. dk. gray, calc. sh.
5538-39	lst., tan, dse. to nod. w/interbedded blk., fis. sh.
5539-45	lst., lt. buff, dse., nod., w/interbd. grn., waxy sh.
5545-49	sh., blk. w/interbd. brn., crypto-xln., sli. fos. lst,

Core No. 2, 5550-68 1/2 feet - rec. 16 1/2 feet

5550-55	lst., lt. brn., v. fos., fragm. w/abt. crin. shells & blk. sh. partings.
5557-62	lst., lt. brn., v. fos., fragm. w/abt. shells & crin., some ooliths.
5562-63	lst., lt. brn., v. fos., fragm., w/abt. crins. & ooliths & some shells & bry.
5563-65	lst., lt. brn., v. fos. w/dk. grn.-gray sh. partings.
5565-66	lst., lt. brn., v. fos., fragm. w/abt. ooliths, crin., shells, etc.
5566-66 1/2	sh., dk. gray, fos. w/interbedded sli. fos., crypto-xln. lst.
5566 1/2-68 1/2	No. rec.-Prob. sh. & lst. as above.

Core No. 3, 5571-5621 feet

5571-80	lst., lt. brn., v. fos., fragm. & pt. oolitic w/abt. crin. shells & bry.
5580-85	lst., crm. & lt. brn., crypto-xln. to dse. w/abt. dis. & interbd. waxy grn. clay sh.
5585-93	clay sh., dk. gray & grn.-gray w/dis. & interbd. crypto-xln. to dse. lst., pt. arg.
5593-5602	clay sh., blk., pt. v. calc.
5602-07	lst., lt. brn., v. fos., w/abt. crin. & dk. gray to blk. sh. partings.
5607-10	lst., lt. brn., v. fos., fragm. w/abt. crin. ooliths, etc., some blk. sh. partings.
5610-16	clay sh., blk., v. calc. w/strks. v. fos. lst.
5616-21	lst., lt. brown, v. fos., fragm. & pt. ool. w/abt. crin. shells, bryz. etc. & some blk. sh. partings.

1953) of approximately 114 feet (35m) presents pertinent data on the Chesteran rocks in Clark County. Little sandstone is logged and shale exceeds the amount of carbonate rocks present. There are many fossiliferous thin limestone beds throughout the section. The carbonized plant fragments (5,533-5,537 feet depth) in a black fissile shale represent one of the few occurrences of plant fossils observed in my study.

Chesteran Fossils

The insoluble residue portion of the Anderson Trust core included four specimens of Cavusgnathus and Spathognathodus and several abraded specimens of Cavusgnathus and Ligonodina (Appendix A). Specimens from 6,065-6,069 feet depth seemingly were abraded by tumbling action in water. Characteristic tooth-like projections from Cavusgnathus specimens were well-rounded and difficult to discern. Collinson and others (1962, p. 17) listed Cavusgnathus, Gnathodus, and Cladognathodus as genera useful for biostratigraphic zonation of the Chesteran (Pl. 1 and Fig. 7).

Fragments of axes from Archimedes were identified in sample study. Abundance of Archimedes used as a criterion of Chesteran rocks can be misleading because the genus is known to range from early Osagian (in Illinois) into the Permian (Moore and others, 1952, p. 173).

Lee (1940, p. 85) cited Robert Roth "as authority" that Chesteran fossils were identified in the upper 400 feet (121m) of the Mississippian rocks from the Watchorn No. 2 Morrison well in sec. 20, T. 32 S., R. 21 W., Clark County. No record of the fossils or the depths from which they were obtained was available in 1938. Earlier Dille (1932) reported Chesteran fossils from the cuttings of several wells in southwestern Kansas. This was reported indirectly by Dille (in a newspaper, Tulsa Daily World) from his lecture notes. Wells listed by Dille as containing Chesteran

fossils are the Watchorn No. 1 Morrison well (probably No. 2, sec. 20, T. 32 S., R. 21 W., editorial note by Lee, 1940) at 5,395 feet; and from the Woods Oil Company McCrary No. 1 Ransom well, sec. 5, T. 25 S., R. 41 W. (no depth reported). Lee did not include rocks of Chesteran age in the Watchorn Formation. He included the No. 2 Morrison well (No. 7-A) in his cross-section F-F' (pl. 7B, Lee, 1940) which shows no Chesteran rocks. Lee (1953, p. 13) reported Chesteran rocks along a line of a cross-section from Meade to Smith Counties, Kansas, (Stanolind Rickers and Adams, wells 10 and 11). Elias (personal letter to Lee, 1949) examined the fossils from cores from well 11 and reported faunal affinities with fossils contained in the Elvira, Homburg, and New Design Groups (Chesterian of Illinois).

Stratigraphic Relations and Discussion

Lower Boundary

The unconformable relationship of the Chesteran rocks to underlying Meramecian rocks has been observed by many authors and has been substantiated in my investigation.

Beebe (1959) described the sand and detrital zone near the base of the Chesteran rocks in various parts of the Hugoton Embayment as revealing an unconformity between the Chesteran and the underlying Meramecian rocks. In the Eubank oil field in Haskell County, Kansas, Fugitt and Wilkonson (1959) identified Chesteran sandstone as an "unconformity sand---having been deposited in topographic lows remaining from post-Meramecian erosion." Veroda (1959) observed fine-grained sandstone composed of well-sorted quartz sand, without glauconite, in that field. Local thinning and absence of Chesteran rocks in the vicinity of the

Eubank field was reported by Roby (1959). Clair (1948) described the lowermost Chesteran rocks as red, sandy, silty, dolomitic shale or dolomitic sand. McManus (1959a) described the lithic characteristics of the lower Chesteran rocks in the vicinity of the Keyes Dome as very silty, light brownish-red to grayish-red limestone which grades laterally into calcareous siltstone.

Upper Boundary

The boundary between Mississippian and Pennsylvanian rocks in western Kansas is an unconformity which represents the absence of an increasing number of Mississippian beds toward the north (Pl. 2D). The structure map (Pl. 23B) drawn on top of the Mississippian rocks shows the general regional dip of Mississippian rocks into the Anadarko Basin. Unconformable relationship with overlying Pennsylvanian rocks has been reported by Maher and Collins (1949), Lee (1953), McManus (1959b), Beebe (1959), and Veroda (1959).

Where the upper unit of Chesteran rocks underlies Kearny (Pennsylvanian) rocks, the boundary is poorly marked, a condition that arises from the close lithologic similarity of the two units. Upper Chesteran limestones are light gray, cream, light brown, and grayish brown, fine- to medium-crystalline, and commonly crinoidal. The upper section of Chesteran rocks can be differentiated from the Kearny Formation because Kearny rocks are more commonly arenaceous and slightly to profusely glauconitic (McManus, 1959a). Where the truncated lower section of Chesteran rocks of red, purple, and variegated shales underlie the Kearny, this lithic feature and the dominance of sandstone and sandy limestones serve to distinguish the Chesteran rocks from the Kearny Formation.

Maher and Collins (1949, sheet 1) interpreted Mississippian deposition in western Kansas as reaching its northernmost extent in Meramecian time. Subsequently, a gradual retreat of the sea over the low-lying areas occurred. This hypothesis is verified by the erratic and ragged surviving edge of Chesteran rocks in southwestern Kansas (Pl. 2D). The regional break in sedimentation between the Mississippian and Pennsylvanian is more noticeable toward the margins of the depositional basin where erratic thicknesses of Chesteran rocks are identified. The break is strikingly shown by the beveling of Chesteran rocks on top of the Keyes Dome in Cimarron County, Oklahoma, and on other smaller structures of the Hugoton Embayment.

Thinning of the Chesteran rocks toward uplifts and local absence as a result of truncation was reported by Beebe (1959) in areas other than the crest of the Keyes Dome; these areas include the Stratford Dome in Sherman County, the Lips Anticline in Roberts County, and in parts of Hutchinson and Hansford Counties, all in the Panhandle of Texas, and an area in part of Haskell County, Kansas. Beebe interpreted the thinning toward the uplifts as a combination of both onlap and truncation, truncation being assigned the major role. No evidence to support thinning resulting from onlap in Kansas was revealed in my study.

The end of Mississippian time in western Kansas and the beginning of Pennsylvanian deposition in the area marks an important change from relatively stable conditions to tectonically more active conditions in the area. Weaver (1958, p. 302) observed that Chesteran sediments in southwestern Kansas probably came chiefly from the Central Kansas Uplift and other northern areas. Rocks of Springeran age (Mississippian, post-Chesteran) occur only as far north as Ellis County, in northwestern Oklahoma (Boler, 1959, p. 12). These Springeran rocks consist of shale and sandstone that are mineralogically and genetically akin to those of the Chesteran

(Weaver, 1958, p. 303). Weaver stated that areal variation in clay mineralogy is similar in rocks of the two stages. While the montmorillonitic Chesteran-Springeran--type deposition was ending in the western part of the Anadarko Basin, the illitic Morrowan-type deposition was beginning in the eastern part of the basin (Weaver, 1958). During Springeran time, western Kansas was an area of weathering and erosion of rocks.

STRUCTURAL DEVELOPMENT

The isopachous map of total Mississippian rocks in western Kansas (Pl. 23A) by definition indicates areal distribution and shows the principal structural features present at the end of Mississippian time. These structural features are the Central Kansas Uplift, the Cambridge Arch, and the Pratt Anticline. Uplift of much of the western Kansas Mississippian surface occurred before the invasion of Pennsylvanian seas. In consequence the expression of structure by isopachous lines in that area is modified by topographic relief. Karst development on the surface at this time also affected topographic relief.

The pattern of deformation revealed by the isopachous map of total Mississippian rocks (Pl. 23A) is complicated because the top of the Mississippian and the top of underlying rocks are erosional features. The erosional relief is less than the regional structural relief. Thickening of the section to the southeast into the deeper parts of the Sedgwick Basin is evident in the southeastern part of Plate 23A. Thinning of Mississippian rocks over the southern end of the Ellsworth Anticline in Ellsworth County possibly indicates structural movement during the Mississippian. Subsidence of the Hugoton Embayment during deposition of Mississippian rocks is indicated by thickening to the southwest in extreme southwestern Kansas toward the Anadarko Basin. Local changes in thickness reveal many minor structural features on the northeastern flank of the embayment; these features plunge southwestwardly. In extreme western Kansas at the northern end of the embayment the Mississippian rocks thin to the west. This thinning possibly represents uplift of the Las Animas Arch in eastern Colorado. The Keyes Dome in Cimarron County in the Oklahoma Panhandle area is a structural feature that bounds the Hugoton trough on the southwest. It was actively rising during late Mississippian time.

The isopachous map (Pl. 23A) of the total Mississippian reveals many of the same features present on each of the isopachous maps (Pl. 2) of intervals A, B, C, and D. One of these features is the thickening of the section in the northeastern part of Kearny and the northwestern part of Finney County. A general area of thickening and flattening is also obvious in eastern Sherman County. The isopachous map of total Mississippian rocks shows thickening into the Anadarko Basin. Mississippian rocks are more than 1,700 feet (518m) thick in southern Meade County. Isopachous maps of individual intervals were discussed under each of the depositional stages.

Plate 23B shows the structural contours of the top of the Mississippian rocks. The top of the Mississippian has been a favorite reference of petroleum geologists in reporting data, and for that reason it is widely used as a convenient datum in construction of structural contour maps. Merriam (1963, p. 205) listed a large number of published structure contour maps which utilized the Mississippian surface in Kansas.

The structural contour map of the top of the Mississippian (Pl. 23B) indicates some of the same features revealed by the interval isopachous maps; one of these is the flattening of an area northward from Grant and Haskell to Wichita and Scott Counties. The regional dip of the Mississippian to the south is low, approximately 14 feet (4m) per mile (1.6km) toward the southern boundary of Kansas. In northwestern Kansas, the Mississippian rocks are about 1,500 feet (457m) below sea level in an area across Rawlins, Thomas, Sherman, and Wallace Counties. From this area they dip toward the northwest to a distance below sea level of about 1,800 feet (548m) and generally toward the southeast and south to more than 3,800 feet (1,158m) below sea level at the Oklahoma state line.

Sharper details of Mississippian structure are seen on the structure map on top of the St. Louis Limestone (Pl. 23C), especially in areas where the Ste. Genevieve Limestone was preserved. The plate shows a northwesterly trending fault, downthrown to the southwest, in northeastern Morton County. The surface of the Mississippian rocks on the downthrown side dips more steeply toward the south than the surface on the upthrown side, indicating greater displacement to the southeast. In southwestern Haskell County is a northwest trending fault downthrown to the southwest. There is an amphitheater-like configuration of the surface of Mississippian rock dipping into the fault on the southwestern side. Finer details of these and other Mississippian structures are available in geologic oil and gas field studies in the area (Kansas Geological Society, 1965).

Distribution of the oil and gas fields in western Kansas (Pl. 23D) shows geographical alignment which could be structurally controlled. There is a general northwest-southeast and northeast-southwest alignment of the fields along the southern end of the Central Kansas Uplift-Pratt Anticline. Also, there is concentration of gas in the Mississippian rocks in southwestern Kansas in Meade, Seward, and Haskell Counties. Important oil production along the trend north from Grant and Haskell Counties to Scott and Wichita Counties is from the St. Louis Limestone. Oil production in Ness and Hodgeman Counties is primarily from the top or near the top of the Mississippian rocks subadjacent to the Pennsylvanian "basal conglomerate."

Isopachous maps do not establish whether parts of the selected intervals are missing from the top, bottom, or both. Structural cross-sections (Pls. 24 and 25) show whether the loss of units has been from the top or the bottom of the intervals. The control points used for the stratigraphic cross-sections (Pls. 3-7) are the same as those used for the structural cross-sections. Structural cross-sections show the

present attitude of Mississippian rocks. In cross-section A-A' (Pl. 24) from Morton County to Harper County, Chesteran rocks are thin in well 5 as a result of erosion following post-Mississippian uplift. From well 6 through well 10, there probably has been loss of Mississippian rocks at the bottom as well as from the top. On the southern end of the Pratt Anticline (from well 11 through well 15) Upper Ordovician and Devonian-Kinderhookian rocks (Chattanooga Shale) are preserved. The Chattanooga Shale is present over the Pratt Anticline but not to the west.

Cross-section B-B', also on Plate 24, is a structural cross-section from Kit Carson County, Colorado, eastward to Trego County, Kansas. A relatively thick section of Kinderhookian rocks is preserved and Osagian rocks and Meramecian rocks are thinner than farther south. There has been loss of Meramecian rocks at the top in well 24 in Gove County, where an inlier (Pl. 2D) of Osagian rocks shows up through Meramecian rocks, reflecting post-Mississippian structural movement.

In the north-south structural cross-section D-D' (Pl. 25) from Gove County to Stevens County, Kansas, Kinderhookian rocks thicken northward and loss of Mississippian rocks has been mostly from the top.

Cross-section C-C' (Pl. 25) shows general thinning of Meramecian rocks toward Nebraska. The entire Mississippian thins into Nebraska from Kansas. In cross-section B'-E (Pl. 25) from Trego to Clark County (subparallel to the Central Kansas Uplift and Pratt Anticline), there is thinning of Kinderhookian rocks and thickening of Osagian and Meramecian rocks to the south.

The evidence revealed by examination of the structural cross-sections (Pls. 24 and 25) is compatible with the sequence of early Mississippian geologic events known for western Kansas

Kinderhookian rocks thicken northward into a basin in central Iowa (Fig. 14A, Pls. 6 and 7). This reveals that during Kinderhookian time and at its close, central Iowa was subsiding and Kansas was either stationary or was being slightly elevated. At the end of Kinderhookian time the entire region was raised above sea level and during a period of relative stability the formations were beveled, as illustrated in Figure 14A. With the advent of Osagian time the beveled surface seems to have been tilted southward, because early Osagian deposits (St. Joe Limestone) thin northward in southern Kansas (Fig. 13). Later Osagian formations and Meramecian units overlap in succession northward on Kinderhookian limestones (Fig. 14B).

Arching of the Central Kansas Uplift began before deposition of Mississippian rocks, but the movements were definitely minor compared with later developments (Lee, 1953).

SUMMARY AND CONCLUSIONS

The sequence of geologic events revealed during the course of my investigation is similar to that reported for the Mississippian Period in the upper Mississippi River Valley in the type area. Similar conditions of deposition and a strikingly similar sequence of depositional events and preservation of these events mark both areas. Diagenetic changes and alterations of the Mississippian rocks including silicification of fossils, chertification, dolomitization, sulfide mineralization, and reworking of calcareous materials to form younger sediments make the western Kansas rocks different from equivalents in the type region. Most of the alterations and changes characteristic of western Kansas Mississippian rocks also are characteristic of these rocks where buried in the Midcontinent. Post-depositional tectonic activity has altered the structural attitude of the Mississippian rocks.

A summary of the geology of western Kansas Mississippian rocks includes:

1. Transgression of Kinderhookian seas from the north is shown by the lithologic sequence.
2. Part of the study area in western Kansas contained Devonian rocks, had a Devonian source area, or the fossils lived past the Devonian; the evidence of this is reworked Devonian conodonts preserved in Kinderhookian rocks and non-abraded Devonian conodonts preserved in younger Mississippian rocks.
3. Shallow, warm seas prevailed to the end of Kinderhookian time with widespread development of oolitic and crinoidal limestones. The primary sediment source was organic.
4. Southern Kansas was tilted toward the south in early Osagian time, a reversal from Kinderhookian time.

5. Conditions of deposition throughout Osagian time were similar to those of late Kinderhookian time, but few oolitic limestones were preserved, if formed. Osagian rocks were intensively altered by diagenetic changes. Widespread formation of chert in Osagian rocks probably represents the most important of these changes, but silicification of calcareous fossils, dolomitization, and other mineralization also are important changes.
6. Early Osagian rocks give evidence of elevation of the southern end of the Central Kansas Uplift in Osagian time.
7. Early Osagian rocks are limited to southern Kansas, and the Burlington Limestone is probably absent from much of western Kansas.
8. After interruption and widespread formation of tripolitic chert, Meramecian rocks were deposited in an environment of deposition similar to that which prevailed earlier. A zone of glauconite locally marks the indistinct Meramecian sea transgression. Widespread deposition of oolitic limestone and fossil-fragmental limestone beds attest to prevalence of shallow warm seas with little terrigenous detritus, until after about half the St. Louis Limestone was deposited. Chert is abundant only in the older Meramecian rocks. Silicification of fossils and dolomitization is common in Meramecian rocks.
9. Deposits of limestone breccia, chert breccia, and conglomerate in the St. Louis Limestone mark a change in the areas of provenance, for after this time, terrigenous clastics constitute an increasingly larger proportion of the rocks.
10. Shale and sandstone dominate Chesteran deposits.
11. Regression of the Chesteran sea and late Mississippian uplift in the areas of the Central Kansas Uplift-Cambridge Arch and the Las Animas Arch exposed the Mississippian rocks to sub-aerial weathering and erosion.

12. Karst topography developed in early Pennsylvanian time and was widespread in the exposed Mississippian rocks.
13. Cherty Mississippian rocks in positive areas were removed to provide sediments for rocks of late Mississippian and early Pennsylvanian age.
14. Present distribution of Mississippian rocks outlines the positive structural features which define the structural provinces of Kansas today. The features were formed in early Pennsylvanian time.
15. Transgression of Pennsylvanian seas was northward from the Anadarko Basin into the Hugoton Embayment. The pre-Desmoinesian seas reworked Pennsylvanian, Mississippian, and older exposed rocks and formed a widespread conglomerate above exposed pre-Chesteran rocks.

Foremost among the conclusions derived from the study are:

1. Widespread preservation of conodonts in carbonate and non-carbonate rocks provides an important tool for biostratigraphic zonation.
2. The term Cowley Formation should not be used; the "Cowley" facies is locally developed in Osagian and Meramecian rocks in south-central Kansas.
3. Chert has limited use in establishing regional lithologic equivalency except as a gross lithologic feature or in areas of close control. Some Osagian formations are mostly chert, a useful gross lithologic feature.

Additional consideration and investigations should be given to:

1. Clay-mineral content, distribution, and significance and their diagenesis in Mississippian rocks.
2. Significance of trace-elements in chert and host rocks.

3. Overlapping relationships of Mississippian rocks onto Cambrian rocks in southwestern Nebraska and eastern Colorado, which may result in stratigraphic traps for oil.
4. Facies changes into the Anadarko Basin.
5. Origin of hydrocarbons in dominantly carbonate Mississippian rocks.
6. Mineralization of Mississippian beds.
7. A similar study of the pre-Mississippian carbonates (Viola Limestone, Arbuckle Group) in western Kansas. Such study should yield data on the pre-Mississippian structural development of western Kansas and on the distribution of Silurian and Devonian rocks.

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APPENDIX A

Graphs listing types and distribution of conodonts and other microfossils recovered as residues from cores. Filed by legal Township descriptions. Specimens in repository (uncatalogued) at Kansas Geological Survey, University of Kansas, Lawrence, Kansas.

Explanation:

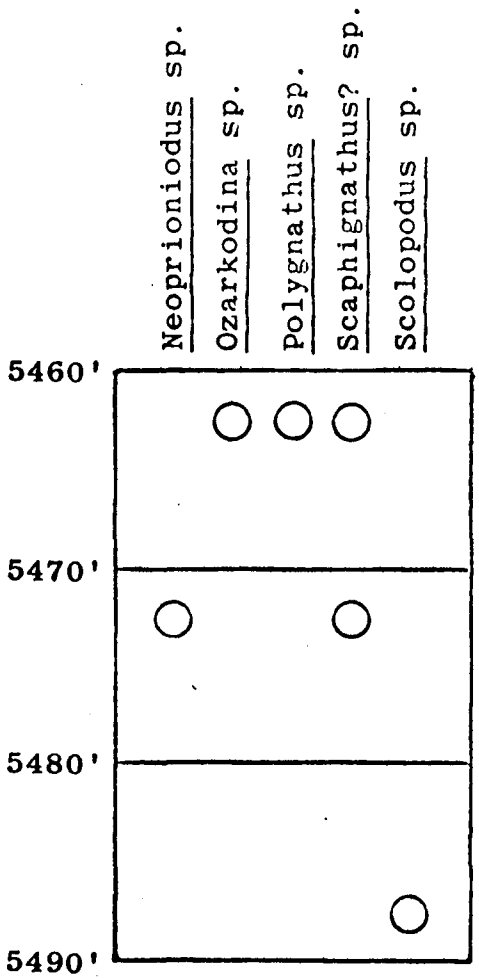
○ < 10 Specimens

◔ 10 - 25 Specimens

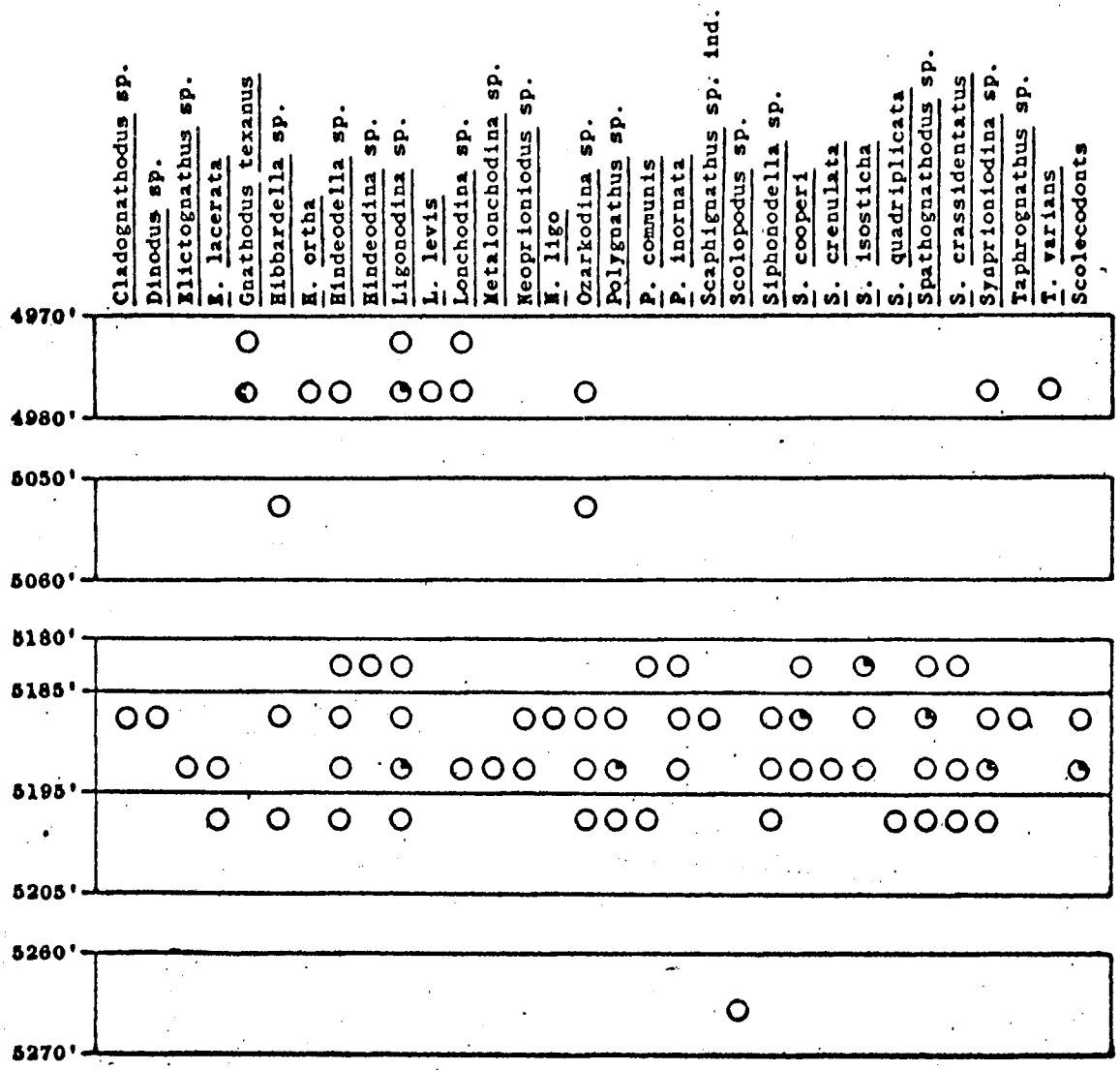
◒ 26 - 50 Specimens

● > 50 Specimens

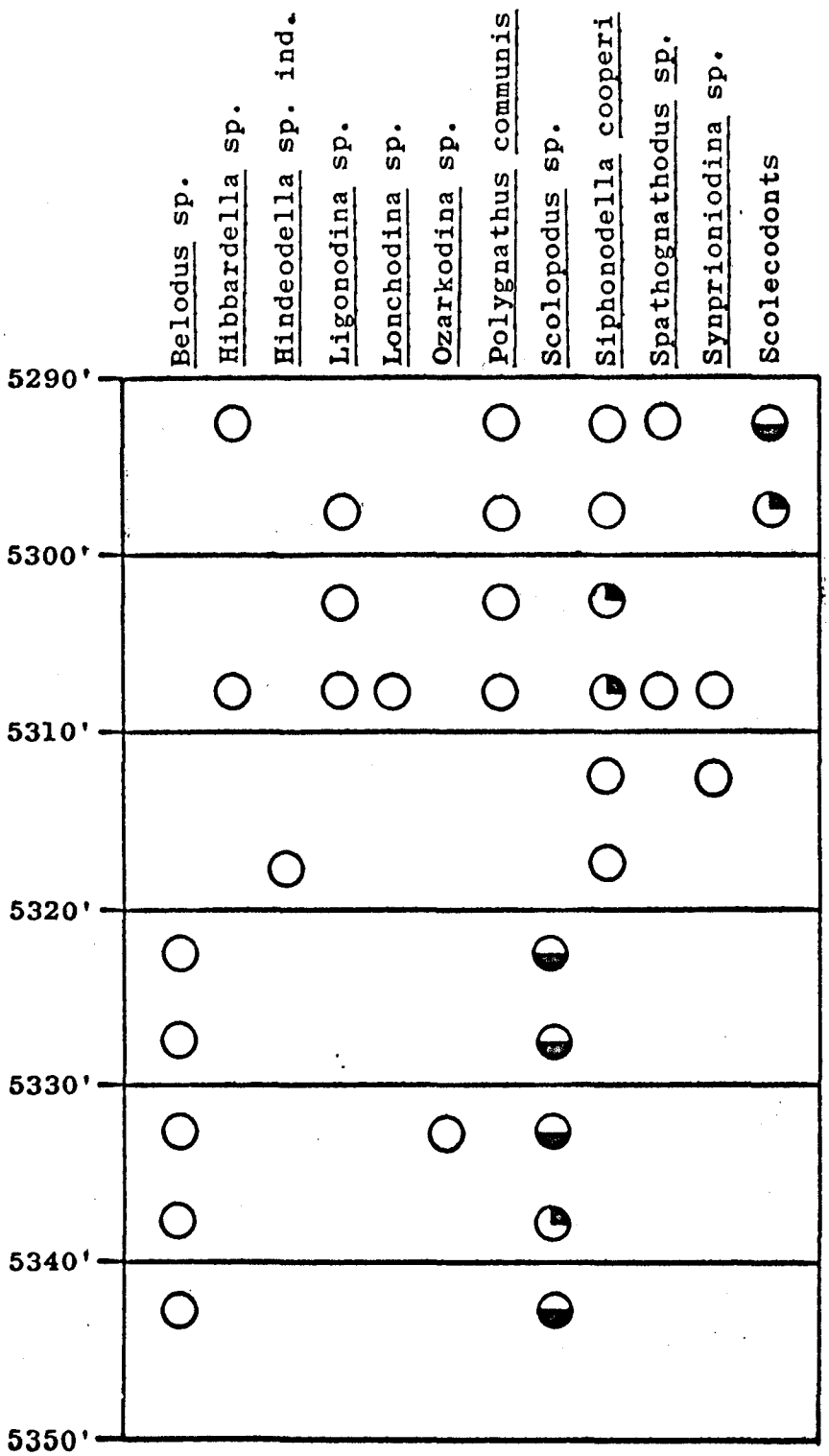
(○) Reworked (abraded)



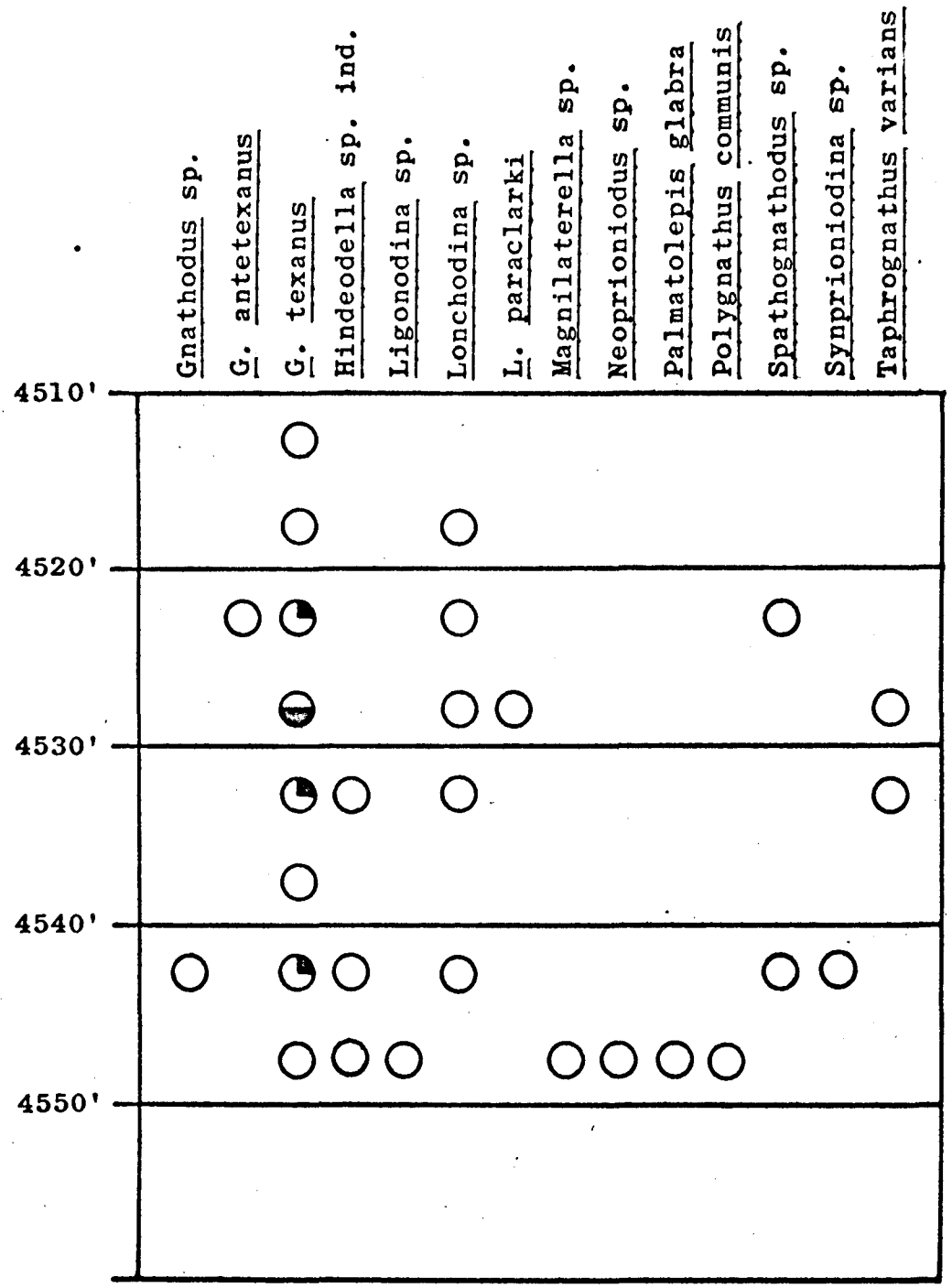
Sinclair-Prairie Oil, No. 1 Mercer,
NEc NW, 28-10S-40W, Sherman Co.



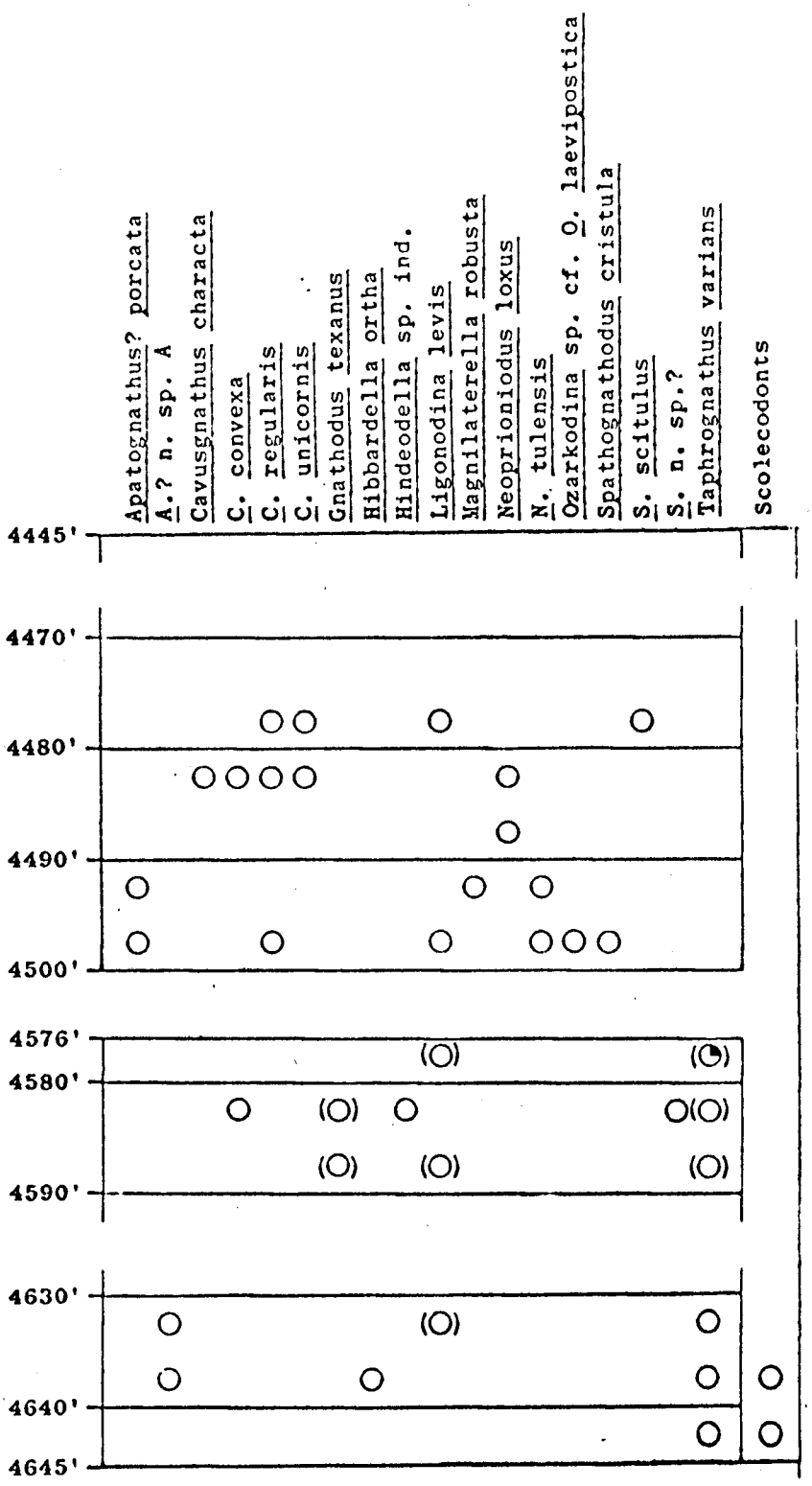
The Texas Co., No. 1 Smith, NE NE SW,
30-11S-36W, Logan Co.



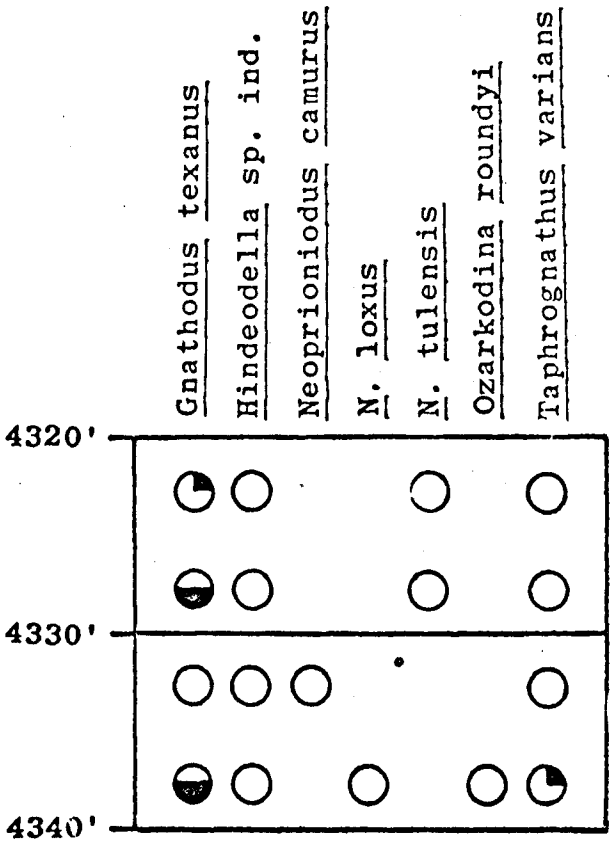
Phillips Oil Co., No. 1 Monument
Prospect, SW SE, 8-12S-34W, Logan Co.



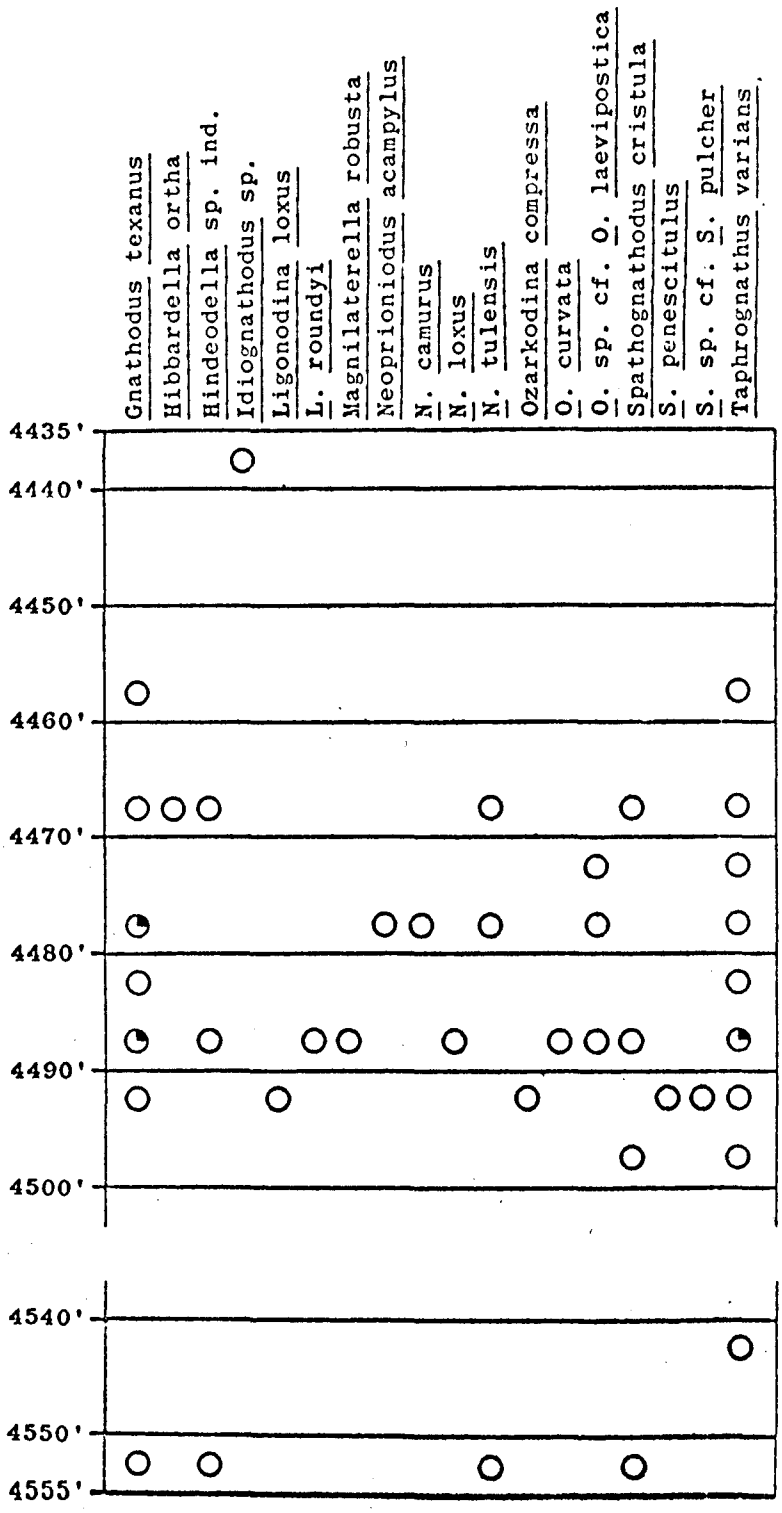
Wycoff, No. 1 Teeter "A",
NE NE NE SE, 26-13S-30W, Gove Co.



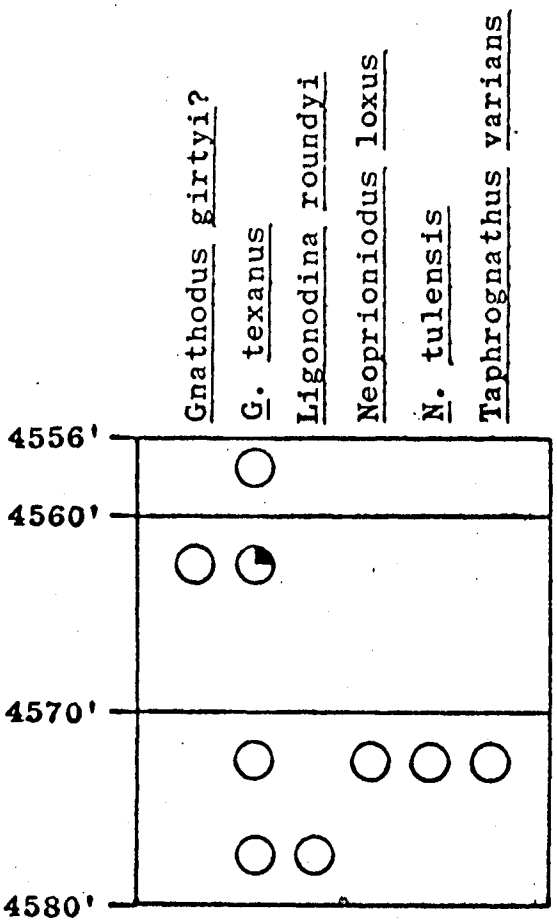
Alma Oil Co., No. 1 Watchorn,
C SW NE, 13-15S-33W, Logan Co.



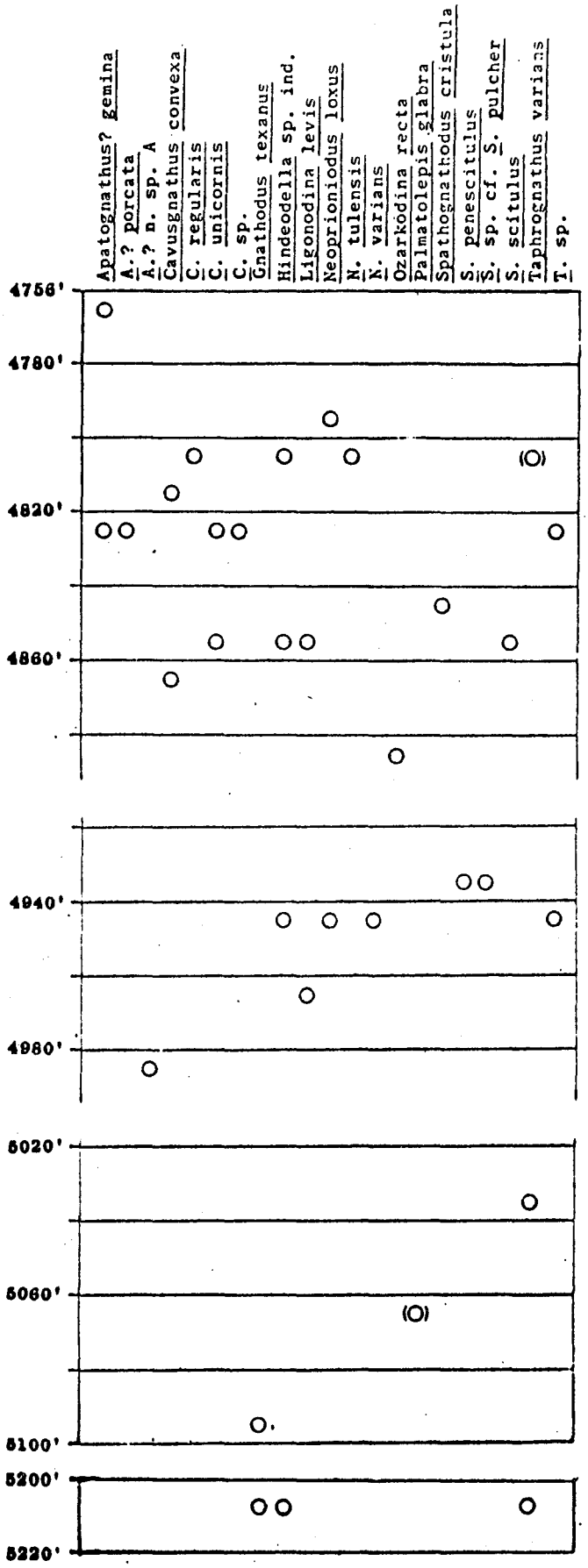
Mobil Oil Co., No. 1 Elsasser Heirs,
C SE SW, 29-18S-22W, Ness Co.



Mid-Continent Petr. Corp.,
No. 1 Collins, NW NW NW,
24-20S-26W, Ness Co.



Mobil Oil Co., No. 1 Winans,
C SE NW, 32-20S-27W, Lane Co.



Atlantic Oil Co., No. 1-A Mark,
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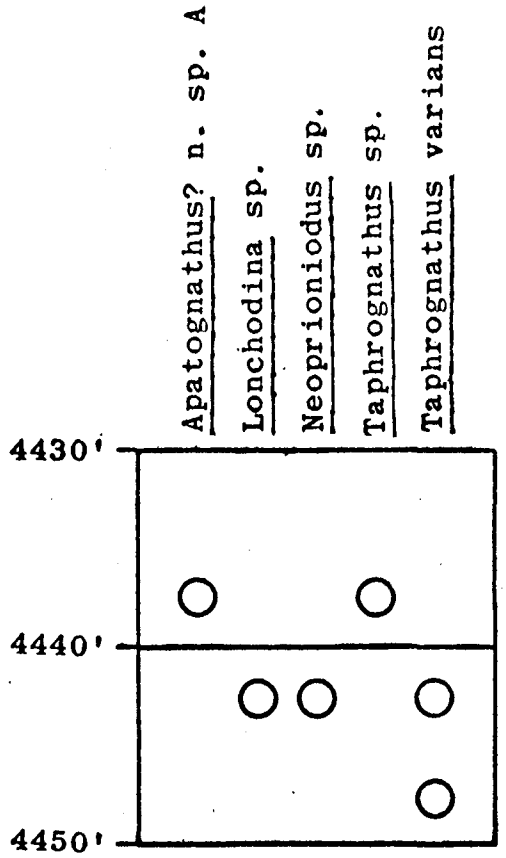
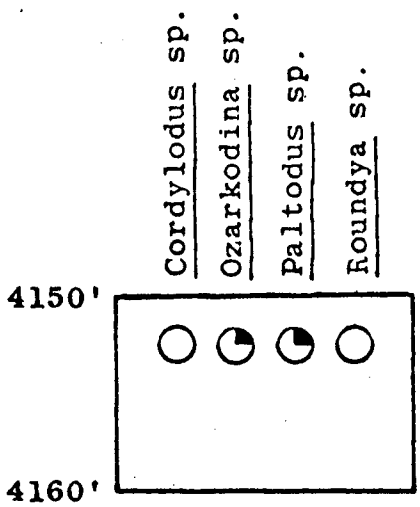
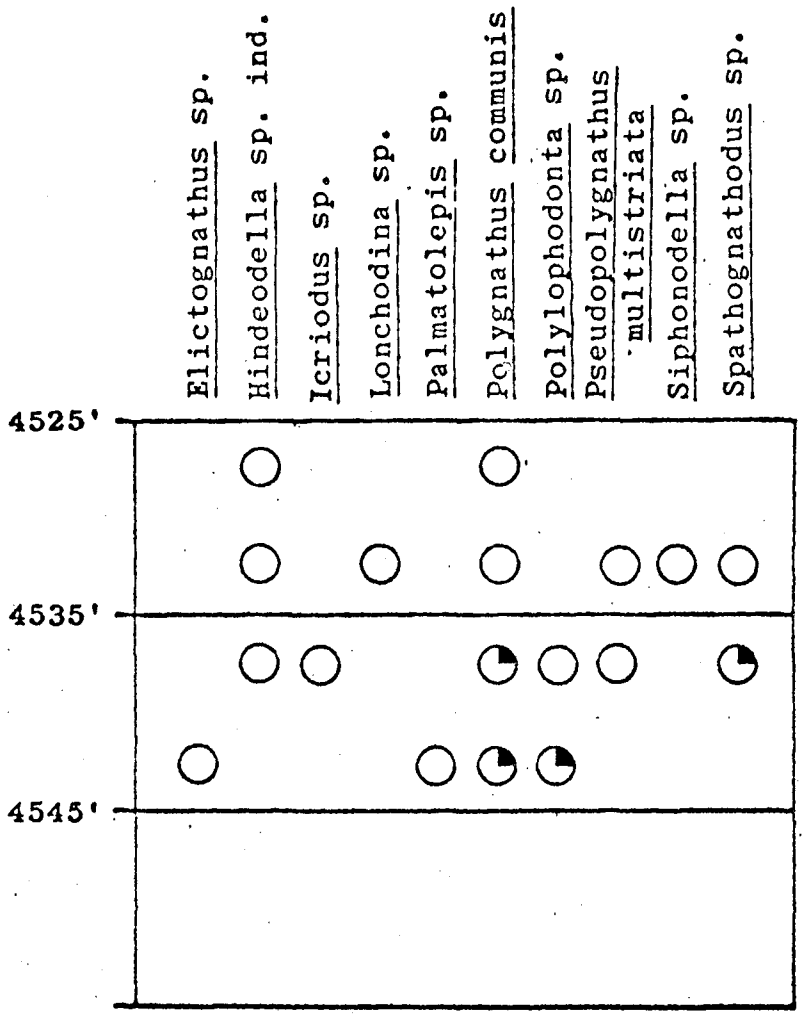


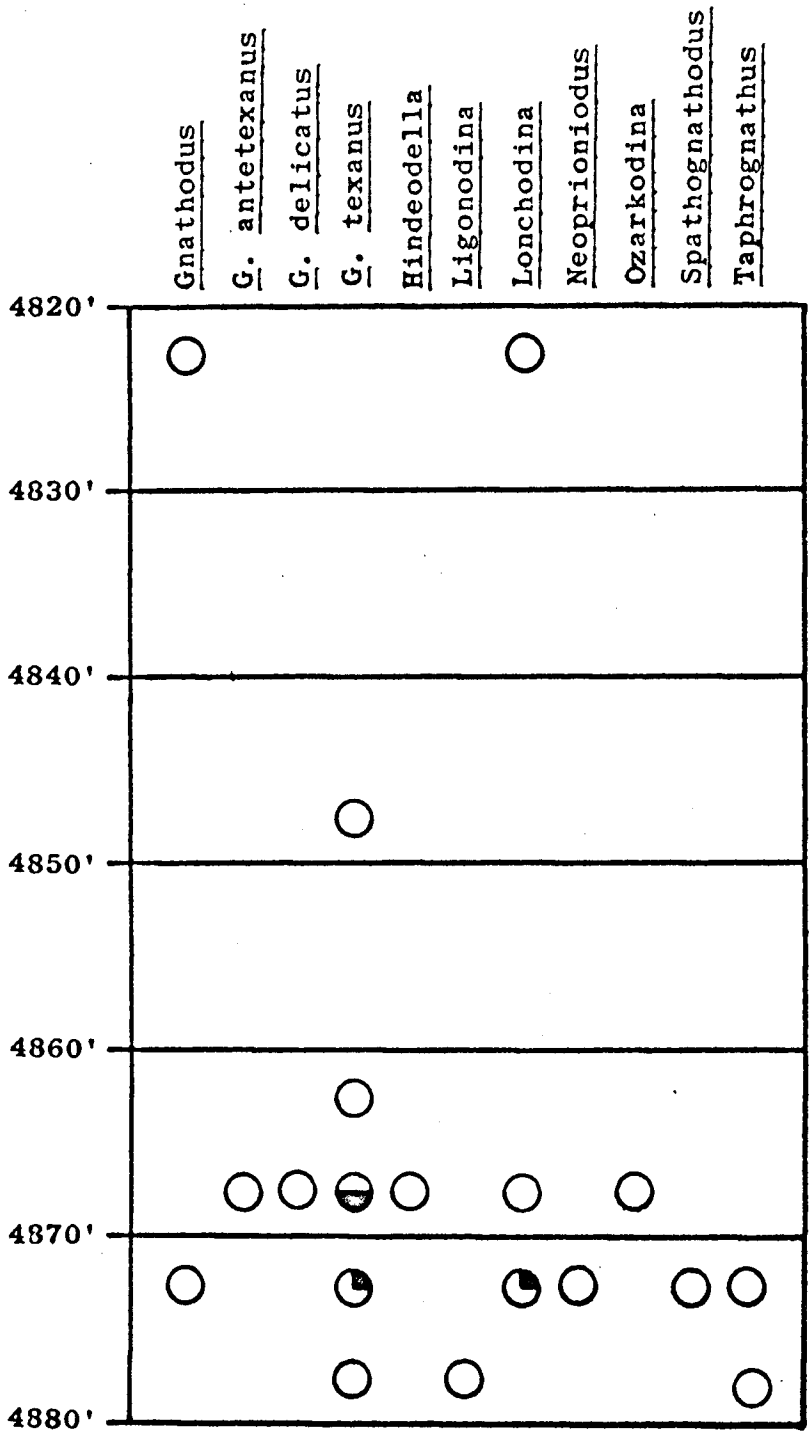
Mobil Oil Co., No. 1 Salmans,
C SE SE, 3-22S-22W, Hodgeman Co.



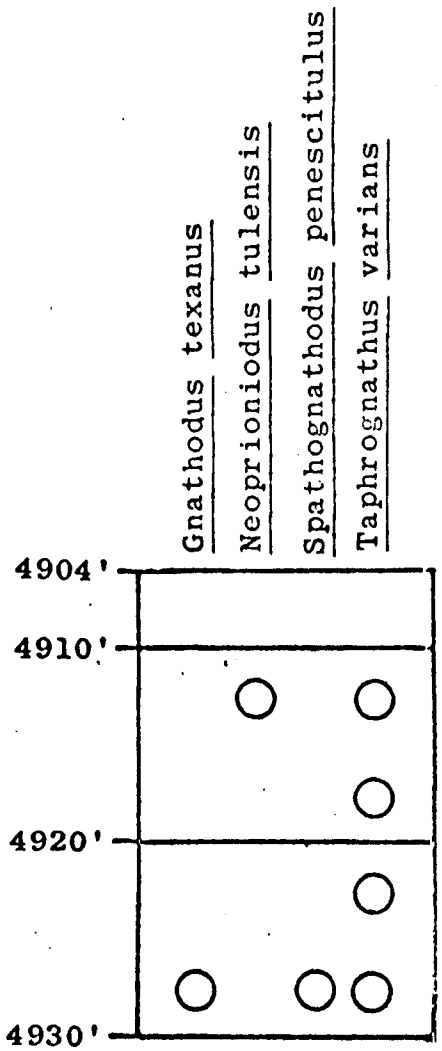
Western Petroleum, No. 1 Brown "A",
SW NE NE, 30-24S-14W, Stafford Co.



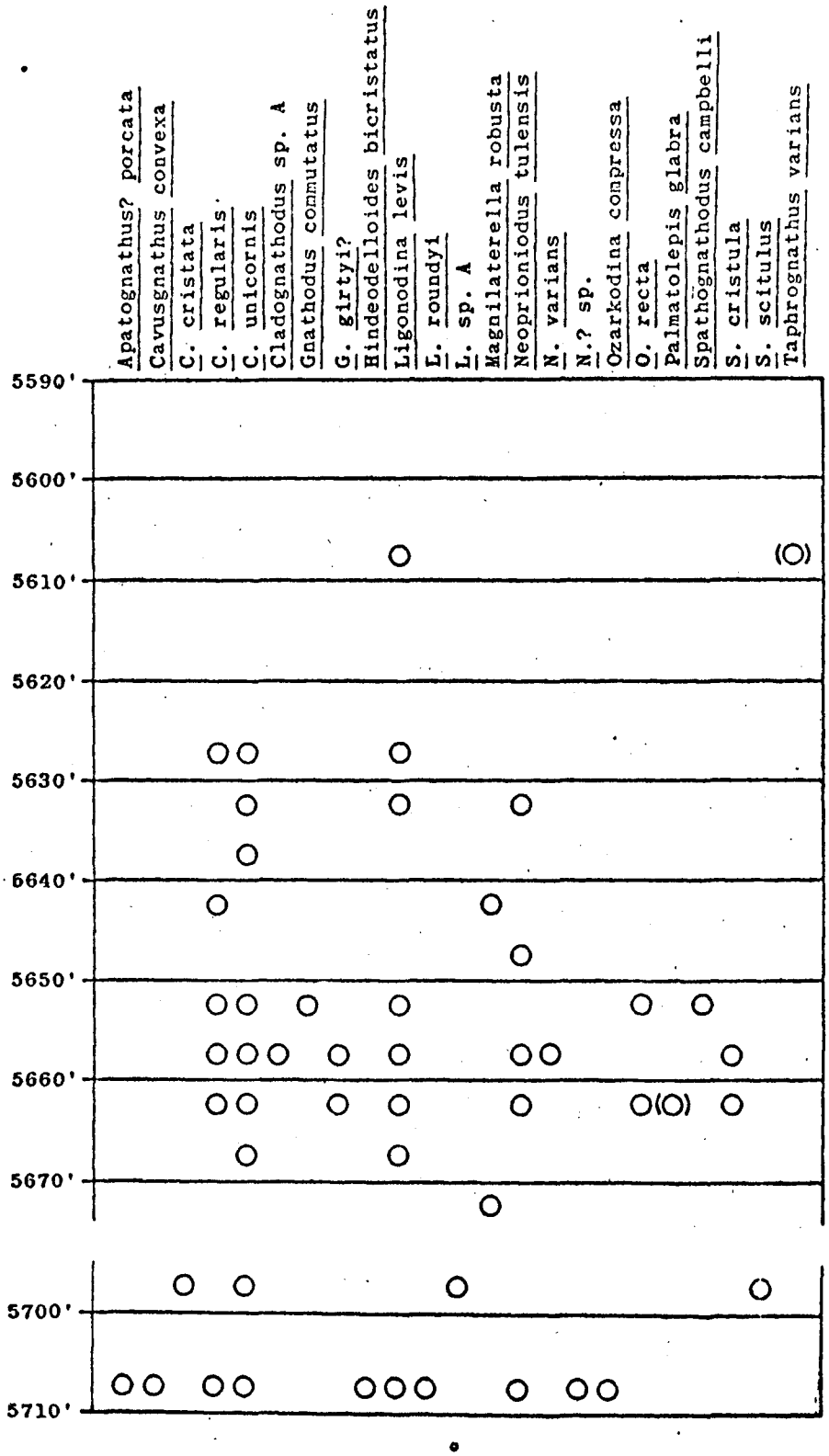
Western Petroleum, No. 1 Hoffman,
C SE NW, 8-25S-17W, Edwards Co.



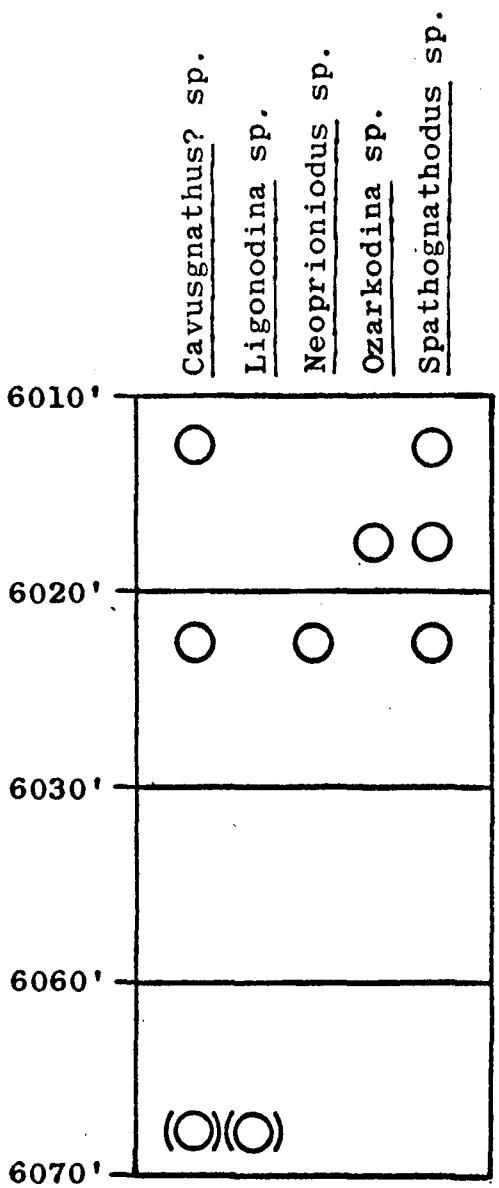
Northern Natural Gas Prod. Co.,
No. 2 Fralick, C NE SW, 14-27S-20W,
Kiowa Co.



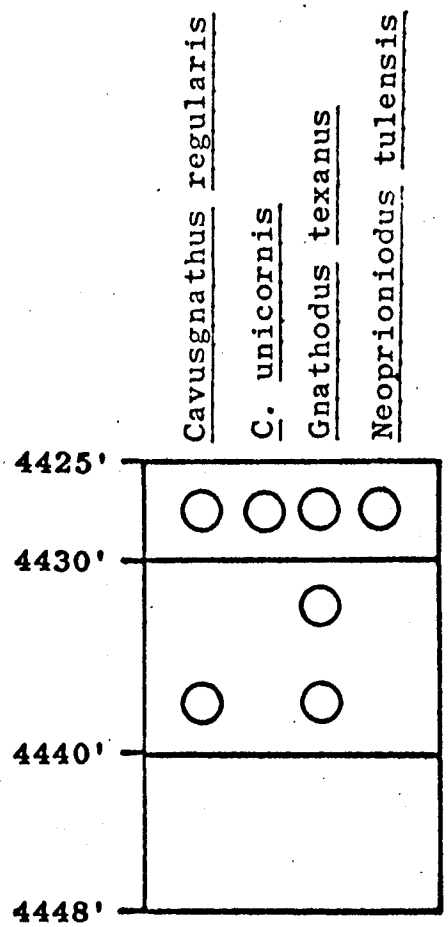
Mull Drilling Co. & Mobil Oil Co.,
No. 1 Matkin, C NE NW, 16-27S-21W,
Ford Co.



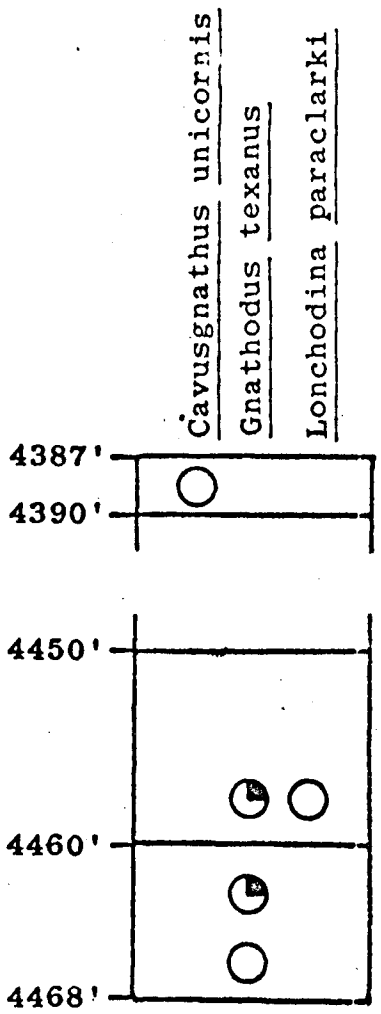
Cities Service Oil Co.,
No. 1 Kells "B", C NW NW,
5-28S-34W, Haskell Co.



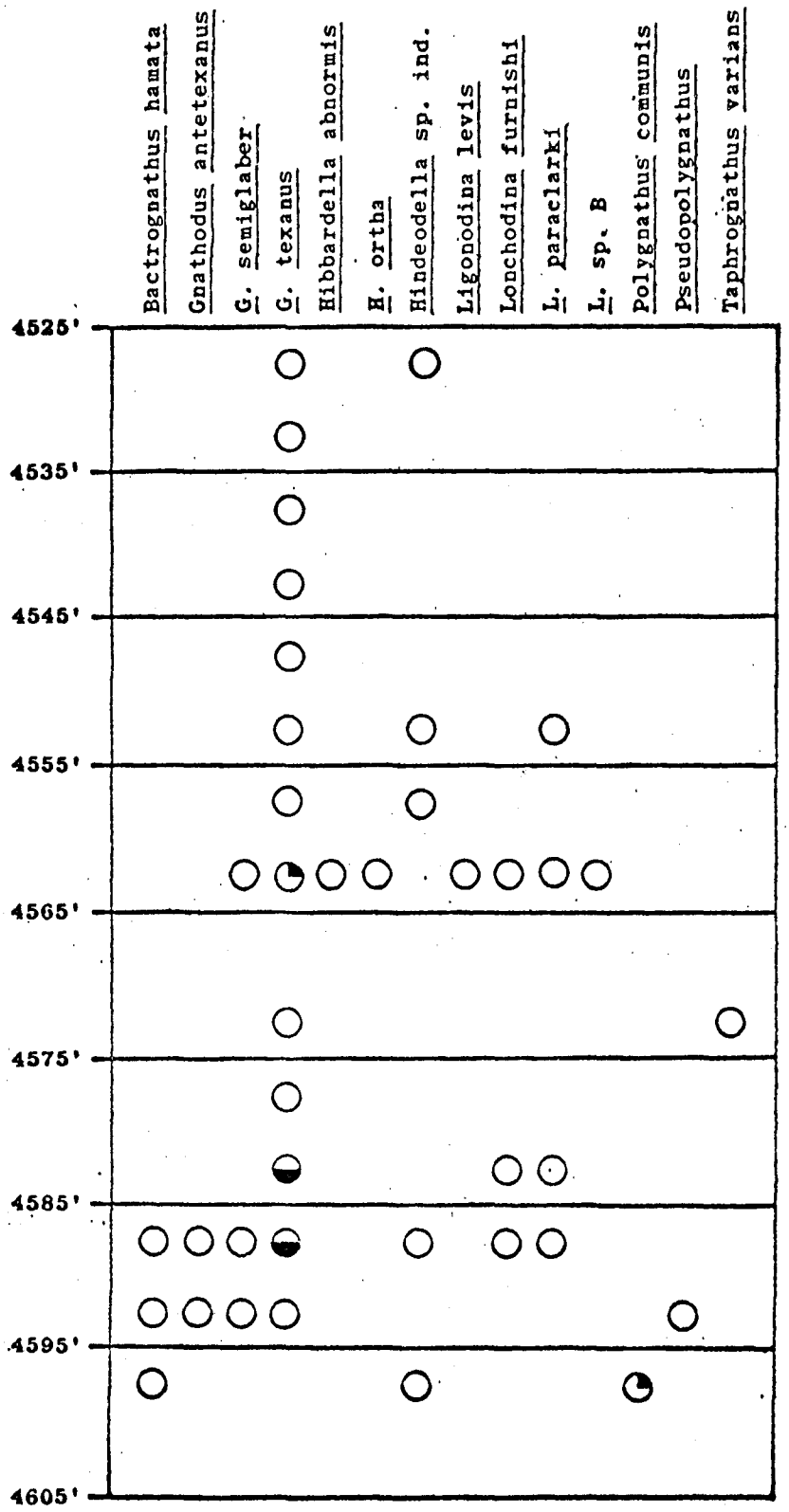
Mobil Oil Co., No. 1 Anderson Trust,
C SW NE, 27-31S-35W, Stevens Co.



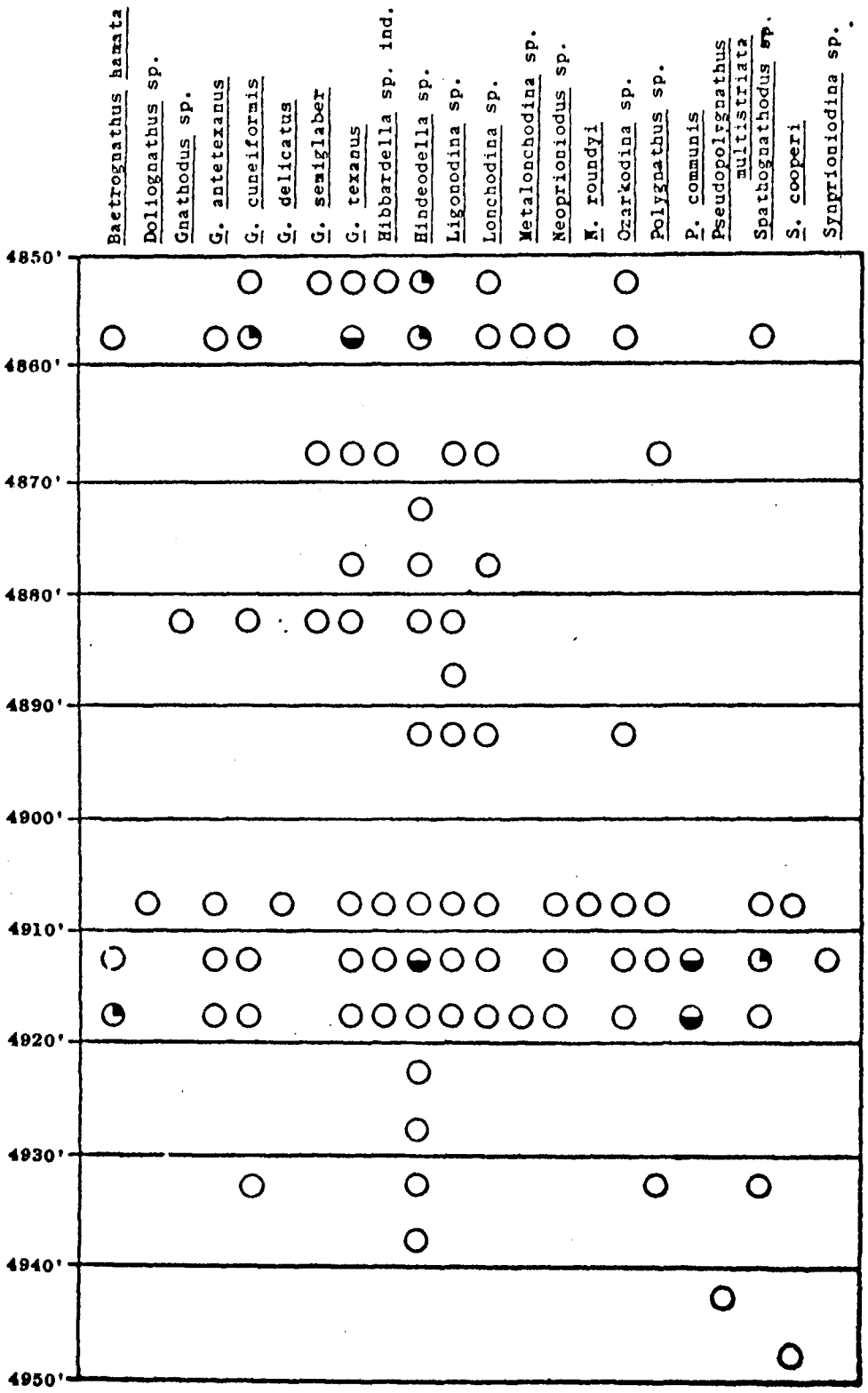
Kessler & Thier Inc., No. 1
Wolfje, C SW SW NE, 17-33S-6W,
Harper Co.



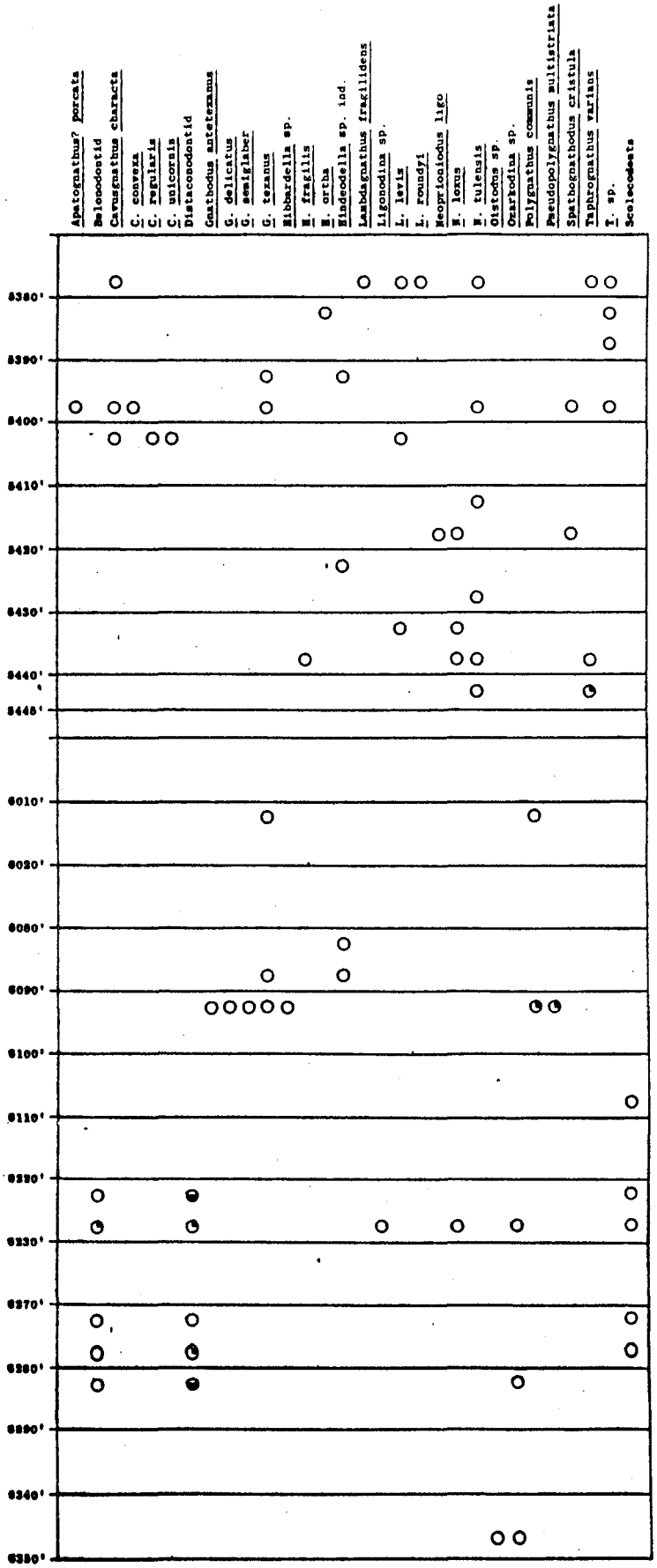
Sinclair Oil and Gas Co.,
No. 1 Colborn "A", NE SW NE,
9-33S-11W, Barber Co.



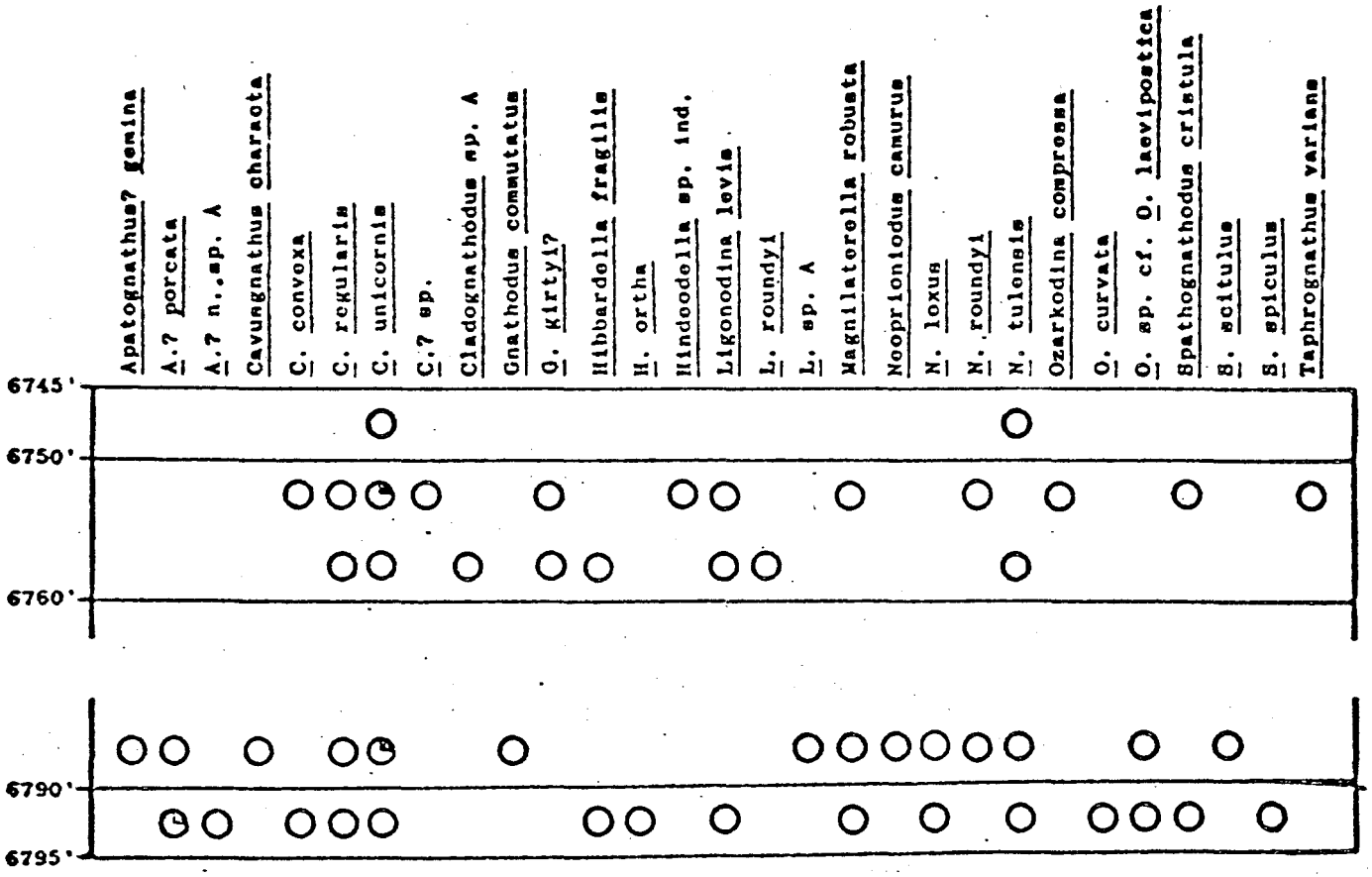
Sinclair Oil & Gas, No. 1 J. A. Circle,
SW SW SW, 14-33S-11W, Barber Co.



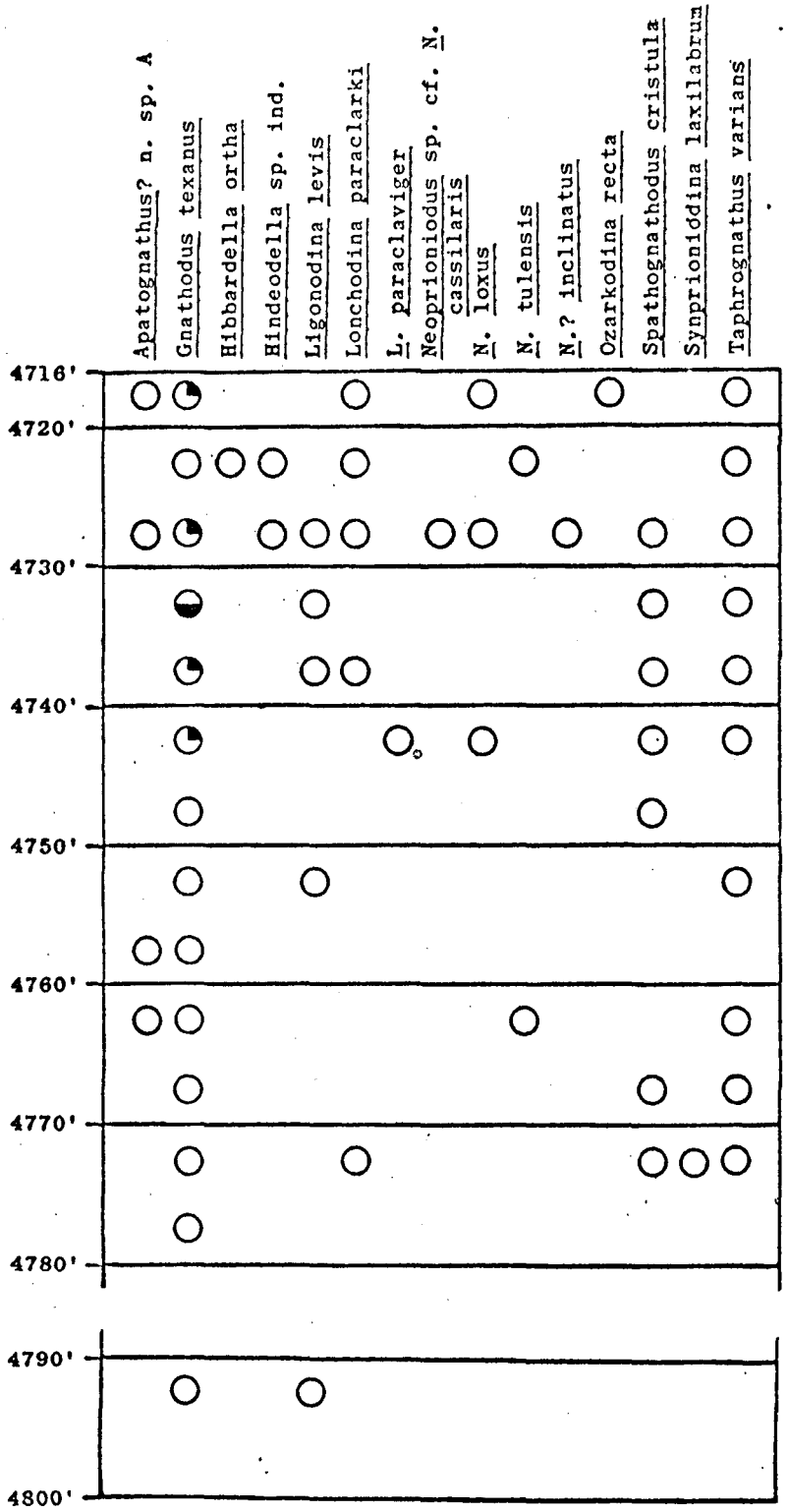
Sinclair-Prairie Oil, No. 1 Gentry,
NEc NE, 1-33S-15W, Barbor Co.



Sinclair-Prairie Oil, No. 1 Exchange Nat. Bank,
SEc SW, 27-33S-19W, Comanche Co.



Mobil Oil Co., No. 1 Cunningham Estate
C SW SE, 13-34S-37W, Stevens Co.



Sinclair Oil and Gas Co.,
No. 1 L. P. Helmley, SW SW SE,
3-35S-10W, Barber Co.

APPENDIX B (in pocket)

Selected mineral and rock residue logs prepared from core study. Residues from cores studied on file at Kansas Geological Survey, The University of Kansas, Lawrence, Kansas.

APPENDIX C

Terminology: Because some geologic terms have different shades of meaning to different people, terms used in this paper are defined below. These definitions are judged as best fitting the features observed. Sources of the terms are indicated.

Calcarenite: Fine- to coarse-grained calcareous sandstone; the grains of the sandstone consist of somewhat abraded rounded crinoid ossicles of various shapes and character, ellipsoidal to spheroidal tests of Foraminifera, and less commonly, fragments of bryozoans and rounded pieces of invertebrate shells. Interstitial material between the grains consists of clear secondary crystalline calcite (from Moore, 1957, p. 115, 119).

Coquinite: Coquina-like limestone formed by compacted layers (laminations) of invertebrate shells of any sort lying one on another with relatively small quantities of admixed foreign materials (from Moore, 1957, p. 117).

Correlation: To correlate in a stratigraphic sense is to show correspondence in character and in stratigraphic position: time correlation of two units is the demonstration of their correspondence in age and stratigraphic position; in mechanical logs, correlation of points in two geographically separated columns is the demonstration of correspondence in log characteristics as well as stratigraphic position; correlation of fossil beds is a demonstration of correspondence of the fossil content and the stratigraphic position; lithologic correlation is a demonstration of correspondence of lithologic character and stratigraphic position (adapted from the International Subcommission on Stratigraphic Terminology, Stratigraphic Classification, and Terminology, 1960, p. 19).

Crinoidal limestone: Composed almost exclusively of the disassociated parts of crinoid skeletons, packed closely together without indication of alignment or any sort of orientation (from Moore, 1957, p. 110).

Fine-grained limestone: A sublithographic limestone; no perceptible grains even with a hand lens; thin section studies under a microscope at higher magnification

permit recognition of particles; well preserved fossil fragments are sparsely distributed at random (from Moore, 1957, p. 113).

Mottled: Residue fragments with two or more colors of different material interspersed and irregularly shaped with either sharp or gradational boundaries; grades into speckled residue (from Ireland, 1958, p. 82).

Oolite: Composed of an aggregation of ooliths (Ireland, 1958, p. 82).

Oolith: Spheroidal bodies generally less than 2.0mm in diameter. The bodies generally contain a central mass or nucleus which is enclosed by a series of radial or concentric layers of the same or different material (adapted from DeFord and Waldschmidt, 1946, p. 1,587; and Ireland, 1947, p. 1,483).

Pellet: Spheroidal to ellipsoidal particles (fine sand to coarse silt size grains) of microcrystalline calcite which display no obvious internal structure (adapted from Folk, 1959, p. 6; and Hatch, Rastall, and Black, 1950).

"Phantom formation": A formation (or bed) missing in the stratigraphic succession of an area, but for which residual faunal evidence is observed (from Branson and Mehl, 1941, p. 208).

Saccharoidal texture: Coarse- to fine-sized crystals--usually dolomite--packed closely (without matrix) like the grains of lump sugar.

Semicrinoidal limestone: Distinguished by a prominence of crinoidal remains but not by their predominance as constituents of the rock. Composed of from 10 to 50 percent of crinoidal detritus, scattered more or less uniformly through the rock, in which the groundmass is of fine- to medium-grained texture and composed of all sorts of unsorted organic detritus (from Moore, 1957, p. 107).

Semigranular texture: Coarsely crystalline grains, principally fossil fragments, in a microcrystalline matrix (from Lee, 1956, p. 20).

Skeletal: Refers to fossils of organisms that secrete hard material around or within organic tissue (adapted from Leighton and Pendexter, 1962, p. 60).

Spar: Clear, transparent, or translucent crystalline particles calcareous 20 microns or larger and

generally forming an interlocking mosaic (modified from Leighton and Pendexter, 1962, p. 60).

Speckled: Disseminated fine spots of color or material different from that of the matrix and having relatively sharp boundaries (from Ireland, 1958, p. 84).

Stratigraphic admixture: A situation wherein conodonts of older sediments have been redeposited along with the conodonts of younger beds (from Branson and Mehl, 1941, p. 206).

Stratigraphic leak: Situation or process whereby microfossils, generally conodonts, are supposed to have descended through crevices or solution channels and lodged in a lower stratum where they may be associated with fossils of greater age (adapted from Branson and Mehl, 1941, p. 206; and the Supplement to the Glossary of Geology and Related Sciences, American Geological Institute, 1960).

APPENDIX B

Selected mineral and rock residue logs prepared from core study. Residues from cores studied on file at Kansas Geological Survey, The University of Kansas, Lawrence, Kansas.

COLORS AND SYMBOLS FOR INSOLUBLE RESIDUES*

Quartz	Green
Chert	
Chalcedonic	Red bars
Ordinary	Red
Porcelaineous	Pink
Granular	Blue
Chalky	Brown
Clastics	
Bentonite	Yellow border green horizontal bars
Clay & Shale	Border actual color
Silt	Yellow border
Sand	Yellow
Anhydrite	Violet
Gypsum	Gray

Black Superscript on Yellow

Coarse sand	♁
Medium sand	○
Fine sand	♀
Very fine sand	♀
Sand rounded frosted	○
Sand rounded polished	⊙
Sand rounded etched	•
Sand subrounded frosted	◬
Sand subrounded polished	◬
Sand subrounded etched	◬
Sand subangular	◬
Sand angular	▲
Sand regenerated	⬭

Black Superscripts

Quartz		Spicular	y
subhedral	Z	Fossiliferous	f
euhedral	⬯	Coquinoidal	q
anhedral	X	Aggregates	A
Vein	V	Chert Breccia	b
Drusy	Z	Pyrimolds	◇
Unmodified	/	Pyrite	+
Lacy	≋	Glauconite	✳
Dolomolds		Flaky	≈
skeletal	◇	Waxy	)
abundant	▱	Laminated	≈
scattered	▱	Nodular	⬭
Dolomorphic	▱	Massive	M
Oolith		Mottled	m
concentric	○	Fibrous	Fi
radiate	⊕	Pseudomorphic	Ps
sandcentered	⊙	Granulated	g
massive	•	Granular	gr
clustered	⁘	Porous	p
free	♂	Fine	f
drusy	Ⓩ	Carbonaceous or Carbon	c
pseudolith	◌		c
Oomolds			
skeletal	⚯		
abundant	⚯		
scattered	○		
Sandy	⁘		
Silty	S		
Banded	✓		

Red Superscripts

Tripolitic	t
Barite	Ba
Chlorite	Ch
Celestite	C
Feldspar	
euhedral	F
detrital	Fd
Hematite	H
Limonite	L
Magnetite	Mg
Marcasite	Ma
Mica	Mi
Biotite	Bi
Muscovite	Mu
Millerite	Ml
Sphalerite	Zn
Sulphur	S
Gilsonite	G
Pyrolusite	Py
Pellets	P
Beekite	B

Chert Color

Light or white --- Pink

Red --- Red

Tan --- Yellow

Brown --- Brown

Black --- Black Ink

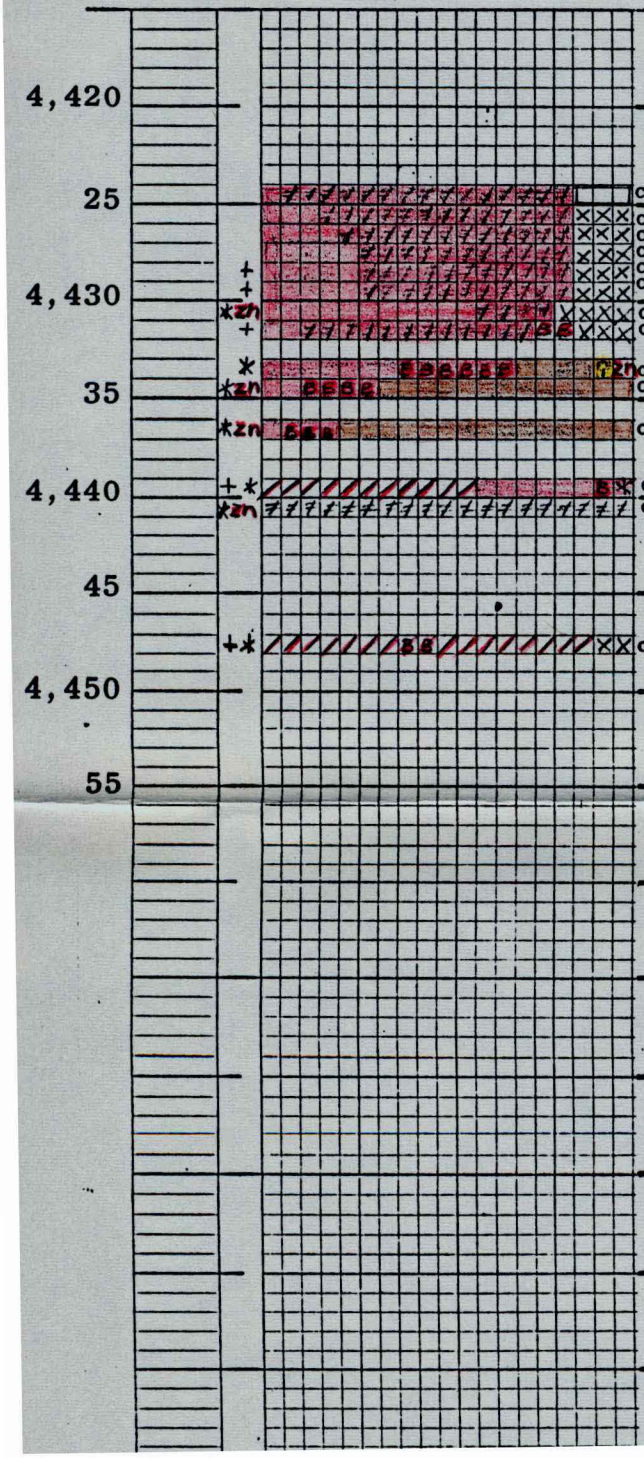
Gray --- Pencil Mark

*(from Ireland, 1947)

STATE
Kansas
COUNTY
Harper
BLOCK
SEC.
17
T. 33 S
R. 6 W
ALTITUDE
1,326
PRODUCTION

COMPANY Kessler & Thier
FARM Wolfje
WELL NO. 1
SURVEY
TOTAL DEPTH 5,078
CONTRACTOR
COMMENCED
COMPLETED
REMARKS

Residue Description

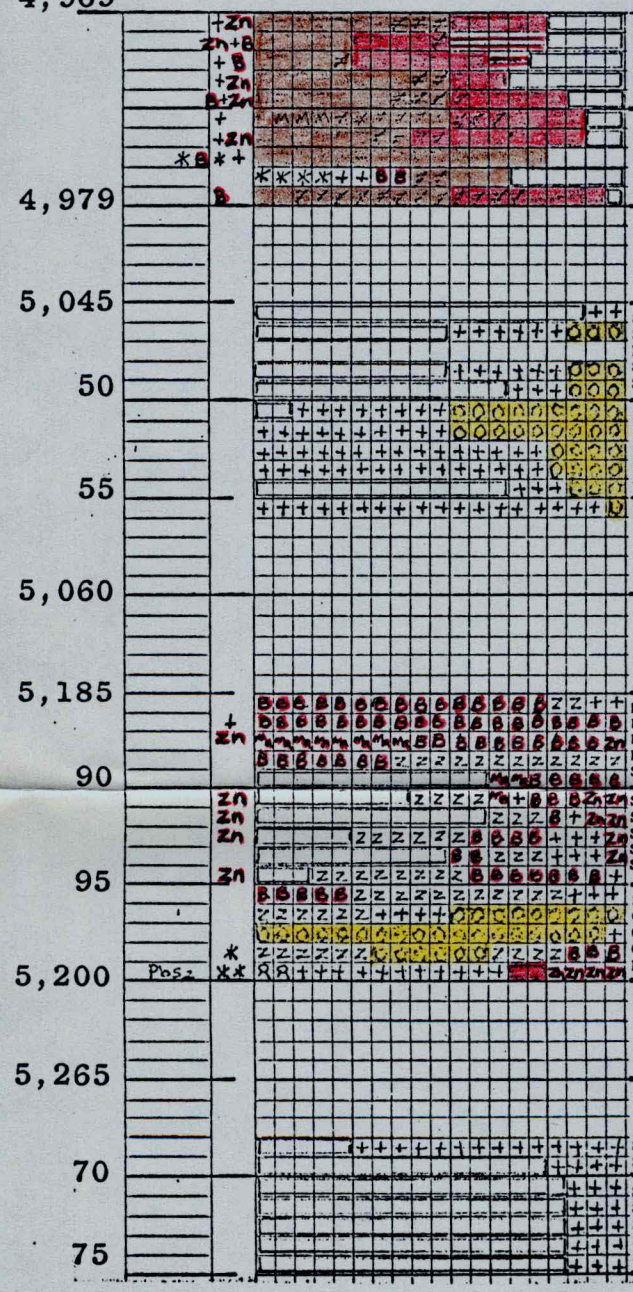


Cht. fossiliferous / spicular / wh. opaque / silt gry.
Cht. fossiliferous bl.-blk.-wh. / qtz. anhedral in masses replacing Brachs & other fossils / ossicl
Cht. fossiliferous bl.-blk.-wh. / qtz. anhedral in masses replacing Brachs & other fossils / ossicl
Cht. fossiliferous bl.-blk.-wh. / qtz. anhedral in masses replacing Brachs & other fossils / ossicl
Cht. fossiliferous bl.-blk.-wh. / qtz. anhedral in masses replacing Brachs & other fossils / ossicl
Cht. blue-wh. semi-translucent blk. coated / qtz. anhedral
Cht. wh. semi-opaque / beekite / ossicles / cht. 80% microfossils
Cht. chalky ord. / cht. replaced ossicles / beekite / qtz. fine sd.
Cht. chalky porous / cht. ord. opaque / beekite / spicules?
Cht. chalky porous / cht. ord. opaque / beekite / spicules?
Cht. milky greasy good show glauconite chalcedonic / cht. blue microfossils + blk. stain
Cht. dull microfossil / porous
Cht. bl. speckled chalcedonic / qtz. anhedral / beekite

STATE: Kansas
COUNTY: Logan
BLOCK:
SEC.: 30
T.: 11 S
R.: 36 W
ALTITUDE: 3,239 ft.
PRODUCTION:

COMPANY: The Texas Co.
FARM: F.L. Smith
WELL NO.: 1
SURVEY:
TOTAL DEPTH: 5,283
CONTRACTOR:
COMMENCED:
COMPLETED:
REMARKS:

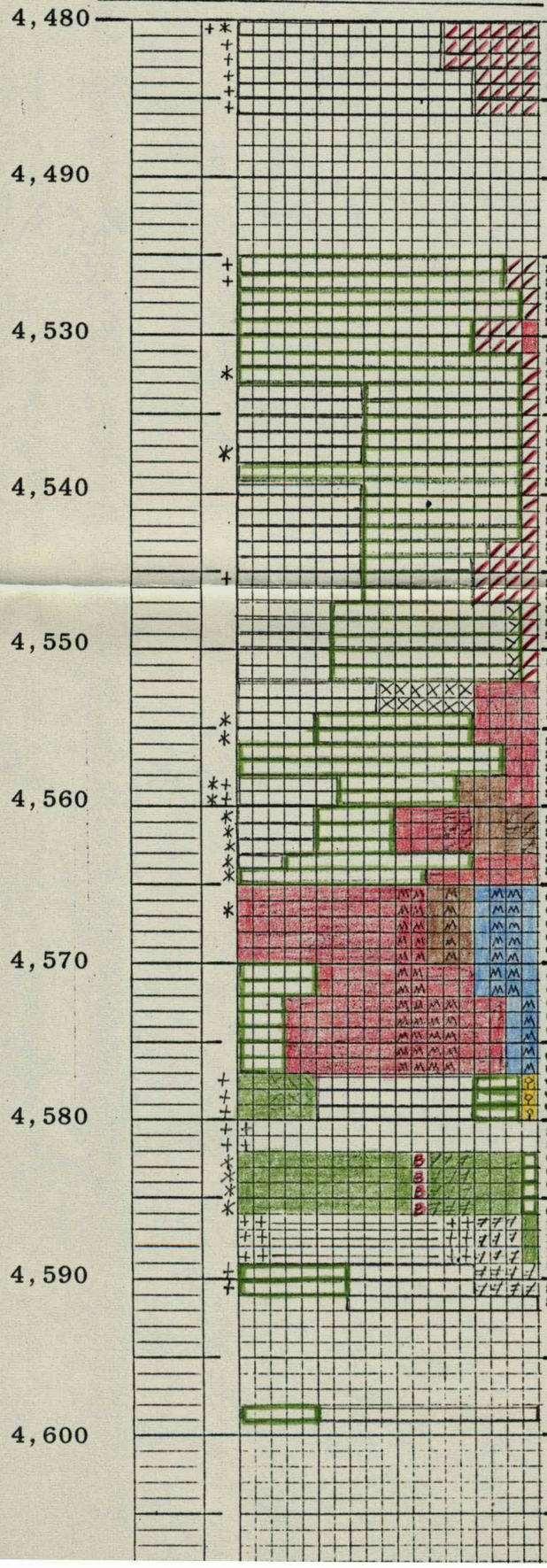
Residue Description



4,969
Cht. gry.-wh. fossiliferous, chalky ord. / sh. gry. silty / pyrite
Cht. gry.-wh. chalky ord. chalc. / sh. gry. silty / pyrite
Cht. gry.-wh. chalky ord. chalc. / sh. gry. silty / crin. columnals of beekite
Cht. gry. chalky / cht. ord. / sh. gry. silty / sphalerite / pyrite
Cht. gry. chalky / cht. ord. / sh. gry. silty / sphalerite / pyrite
Cht. gry.-wh. microfossils / cht. ord. speckled / sh. gry.
Cht. gry. chalky. ord. porc. / sh. gry. silty platy
Cht. gry. chalky-ord. / sh. gry / glauconite / pyrite
Glauconite pyrite beekite cht. chalky gry. sh.
4,979 Cht. chalky dull gry. ord. microfossils / sh. blk. wavy
5,045
Sh. blk. soft organic / pyrite
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
Residue negligible
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
50 Sh. blk. soft organic / pyrite / 15% double-qtz. xls
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
Sh. blk. soft organic / pyrite / 15% double-qtz. xls
55 Sh. soft chocolate brn. / pyrite / 15% double-qtz. xls
Pyrite / qtz. xls double
5,060
5,185
Beekite-replaced "Brach" valves and crinoid columnals
Beekite-replaced "Brach" valves and crinoid columnals star-shaped (oil-stained)
Beekite-replaced "Brach" valves and crinoid columnals / marcasite
Beekite-replaced "Brach" valves and crinoid columnals / qtz. in columnals
90 Sh. blk. tarry / marcasite / beekite replaced fossils
Sh. blk. tarry / marcasite / beekite replaced fossils / qtz. sphalerite
Sh. oil-stained / pyrite / sphalerite / qtz. / silica-replaced fossils
Sh. oil-stained / pyrite / sphalerite / qtz. / silica-replaced fossils
Sh. blk. tarry / silica-replaced fossils / sphalerite / pyrite
95 Sh. blk. tarry / silica-replaced fossils / pyrite, / beekite
Silica-replaced columnals / pyrite / beekite
Qtz. xls-double terminated in clusters / pyrite
Qtz. xls-double terminated in clusters / pyrite
Qtz. fine-sd. size / xls-double terminated in clusters / glauconite
5,200 Pyrite / sphalerite / anhydrite/ galena / glauconite
5,265
Sh. gry. / pyrite
70 Sh. gry. / pyrite
Sh. gry. / pyrite
Sh.
Sh.
Sh.
75 Sh.

STATE
Kansas
COUNTY
Barber
DLOCK
SEC.
14
T. 33 S R. 11 W
ALTITUDE
1,436 ft
PRODUCTION

COMPANY Sinclair Oil & Gas
FARM Circle WELL NO. 1
SURVEY
TOTAL DEPTH 4,660
CONTRACTOR
COMMENCED
COMPLETED
REMARKS



Residue Description

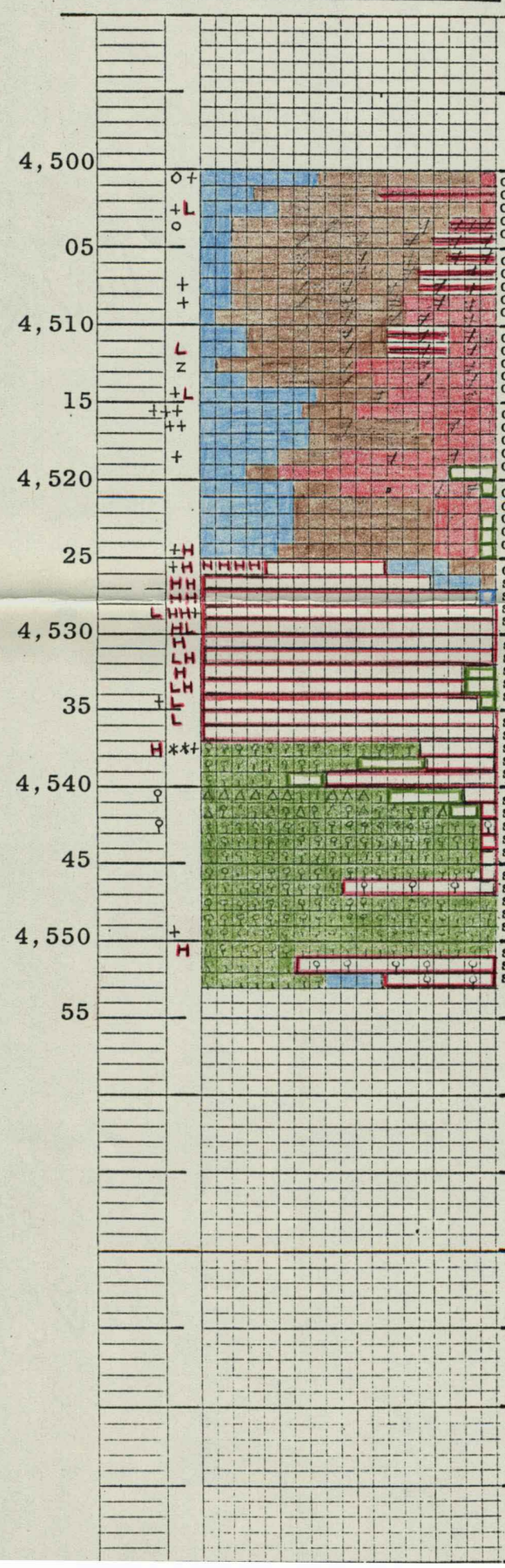
Sh. silty gry. / pyrite speckled / tr. glauconite / cht. blue-blk. chalcedon
Sh. silty gry. / pyrite speckled / tr. glauconite / cht. blue-blk. chalcedon
Sh. silty gry. / pyrite speckled / tr. glauconite / cht. blue-blk. chalcedon
Sh. silty gry. / pyrite speckled / tr. glauconite / cht. blue-blk. chalcedon
Sh. gry.-grn. silty / cht. chalcedonic wh. greasy-semi-translucent
Sh. gry.-grn. silty / cht. chalcedonic wh. greasy-semi-translucent

Sh. grn.-gry. silty / cht. chalcedonic / pyrite
Sh. grn.-gry. silty / cht. chalcedonic / pyrite
Sh. grn.-gry. silty / cht. chalcedonic / pyrite
Sh. grn.-gry. silty / cht. chalcedonic / pyrite
Sh. gry.-grn. silty / cht. wh. chalc. / cht. blue-blk. speckled
Sh. gry.-grn. silty / cht. wh. chalc. / cht. blue-blk. speckled
Sh. gry.-grn. silty / cht. wh. chalc. / cht. blue-blk. speckled
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn.-gry. silty / cht. wh. chalc.
Sh. grn. waxy / cht. wh. chalc.
Sh. grn. waxy / cht. wh. chalc.
Sh. grn. silty / cht. wh. chalc.
Sh. grn. silty / cht. wh. chalc.
Sh. grn. silty / sh. grn. soft / cht. wh. chalcedonic / spic.
Sh. grn. silty / sh. grn. soft / cht. wh. chalcedonic / spic.
Sh. grn. silty / sh. grn. soft / cht. wh. chalcedonic / spic.
Sh. gry. / qtz. anhedral / cht. ord. wht. opaque
Sh. gry. / qtz. anhedral / cht. ord. wht. opaque
Sh. grn. / sh. gry. glauconite / cht. ord. weathered
Sh. grn. / sh. gry. glauconite / cht. ord. weathered
Sh. grn. silty / cht. wht. brn. weathered
Sh. grn. silty / cht. wht. brn. weathered
Sh. gry.-grn. silty / cht. white chalky and ord. / pyrite
Sh. gry.-grn. silty / cht. white chalky and ord. / pyrite
Sh. gry. grn. silty / cht. chalky fossiliferous ord. / glauconite
Sh. gry. grn. silty / cht. chalky fossiliferous ord. / glauconite
Sh. gry. grn. silty / cht. chalky fossiliferous ord. / glauconite
Sh. grn. glauconitic / cht. ord. wh. / scolecodonts + bonelike glauconite
Sh. grn. glauconitic / cht. ord. wh. / scolecodonts + bonelike glauconite
Cht. brn. weathered porous / cht. wht. ord. to buff
Cht. brn. weathered porous / cht. wht. ord. to buff
Cht. buff brn. mottled / cht. granular mottled
Cht. buff brn. mottled / cht. granular mottled
Cht buff brn. mottled / cht. granular mottled
Cht. ord. buff mottled / cht. granular-oil-stained / sh. grn.
Cht. ord. buff mottled / cht. granular / sh. grn.
Cht. ord. buff mottled / cht. granular / sh. grn.
Cht. ord. buff mottled / cht. granular / sh. grn.
Cht. ord. buff mottled / cht. granular / sh. grn.
Cht. buff / cht. / sh. grn.
Cht. buff / cht. / sh. grn.
Qtz. anhedral wh. / sh. gry.-grn. / sand fine / tr. pyrite
Qtz. anhedral wh. / sh. gry.-grn. / sand fine / tr. pyrite
Qtz. anhedral wh. / sh. gry.-grn. / sand fine / tr. pyrite
Sample lost
Sample lost
Qtz. wh. / beekite / sh. grn. glauconitic / forams
Qtz. wh. / beekite / sh. grn. glauconitic / forams
Qtz. wh. / beekite / sh. grn. glauconitic / forams
Qtz. wh. / beekite / sh. grn. glauconitic / forams
Pyrite / wh. bonelike matter / qtz. / conodonts
Pyrite / wh. bonelike matter / qtz. / conodonts
Pyrite / wh. bonelike matter / qtz. / conodonts
Sh. grn. / conodonts / sh. gry.
Sh. grn. / conodonts / sh. gry.
Sh. grn. / conodonts / sh. gry.
Sh. grn. silty / sh. gry. silty / conodonts

STATE: Kansas
COUNTY: Edwards
BLOCK:
SEC.: 8
T. 25 S R. 17 W
ALTITUDE: 2,152
PRODUCTION:

COMPANY: Western Petro. Co.
FARM: Hoffman WELL NO.: 1
SURVEY:
TOTAL DEPTH: 4,705
CONTRACTOR:
COMMENCED:
COMPLETED:
REMARKS:

Residue Description



Cht. gran.-chalky / chalc. / opaque-semi. / sh. grn. waxy / geodal euhedral xls qtz.
Cht. gran.-chalky / chalc. / opaque-semi. / sh. grn. waxy / geodal euhedral xls qtz.
Cht. gran.-chalky / chalc. / opaque-semi. / sh. grn. waxy / geodal euhedral xls qtz.
Cht. chalky-chalc.-wh. milky / microfossils / tripolitic
Cht. chalky-chalc.-wh. milky / microfossils / tripolitic
Cht. chalky-chalc.-wh. milky / microfossils / tripolitic
Cht. chalky-chalc.-wh. milky / microfossils / tripolitic / banding
Cht. chalky-chalc.-wh. milky / microfossils / tripolitic / banding
Cht. chalky-porc. milky smooth microfoss. / trip. / pyrite speckles
Cht. chalky-porc. milky smooth microfoss. / trip. / pyrite speckles
Cht. chalky microfossils-tan in milky cht.
Cht. chalky microfossils-tan in milky cht.
Cht. porc.-chalky-gran. / fossils / wh.-milky / opaque / blocky
Cht. porc.-chalky-gran. / fossils / wh.-milky / opaque / blocky
Cht. porc.-chalky-gran. / fossils / wh.-milky / opaque / blocky
Cht. porc.-chalky / ord. / fossils / cht. speckled / sh. gry. / euhedral +
Cht. gran.-chalky-ord. tan / smooth / pyrite speckled
Cht. gran.-chalky-ord. tan / smooth / pyrite speckled
Cht. gran.-chalky-ord. tan / smooth / pyrite speckled
Cht. gran.-chalky-ord. tan / smooth / pyrite speckled / sh. grn.
Cht. gran.-chalky-ord. wh.-tan / fossils
Cht. gran.-chalky-ord. wh.-tan / fossils
Cht. gran.-chalky-ord. wh.-tan / fossils
Cht. gran.-chalky-ord. wh.-tan / fossils
Cht. gran.-chalky-ord. tan pitted / fossils / sh. gry.-grn.
Cht. gran.-chalky-ord. tan pitted / fossils / sh. red hematitic
Sh. silty chocolate brn. hard siliceous / platy
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Sh. silty chocolate brn. hard siliceous / platy / sh. hematitic
Ss. fine / clustered / glauconite
Ss. fine / clustered / sh. hematitic
Ss. fine / clustered / sh. hematitic
Ss. / subrounded / frosted / sh. grn. / phosphatic ss.
Ss. / subrounded / frosted / sh. grn. / phosphatic ss.
Ss.-subrounded / frosted / med. / ss. fine / conodont ss. / ss. / fine / clustered
Ss.-subrounded / frosted / med. / ss. fine / conodont ss. / ss. / fine / clustered
Ss.-subrounded / frosted / med. / ss. fine / conodont ss. / ss. / fine / clustered
Ss.-subrounded / frosted / med. / ss. fine / conodont ss. / ss. / fine / clustered
Ss.-subrounded / frosted / med. / ss. fine / conodont ss. / ss. / fine / clustered
Ss. fine clustered / clean
Ss. fine clustered / clean
Ss. fine clustered / clean
Ss. / fine / clustered / qtz. cemented
Ss. / fine / clustered / qtz. / cht. gran.
Ss. / fine / clustered / qtz. / cht. gran.

STATE
Kansas
COUNTY
Comanche
BLOCK

COMPANY Sinclair-Prairie
FARM Exchange Bank WELL NO. 1
SURVEY

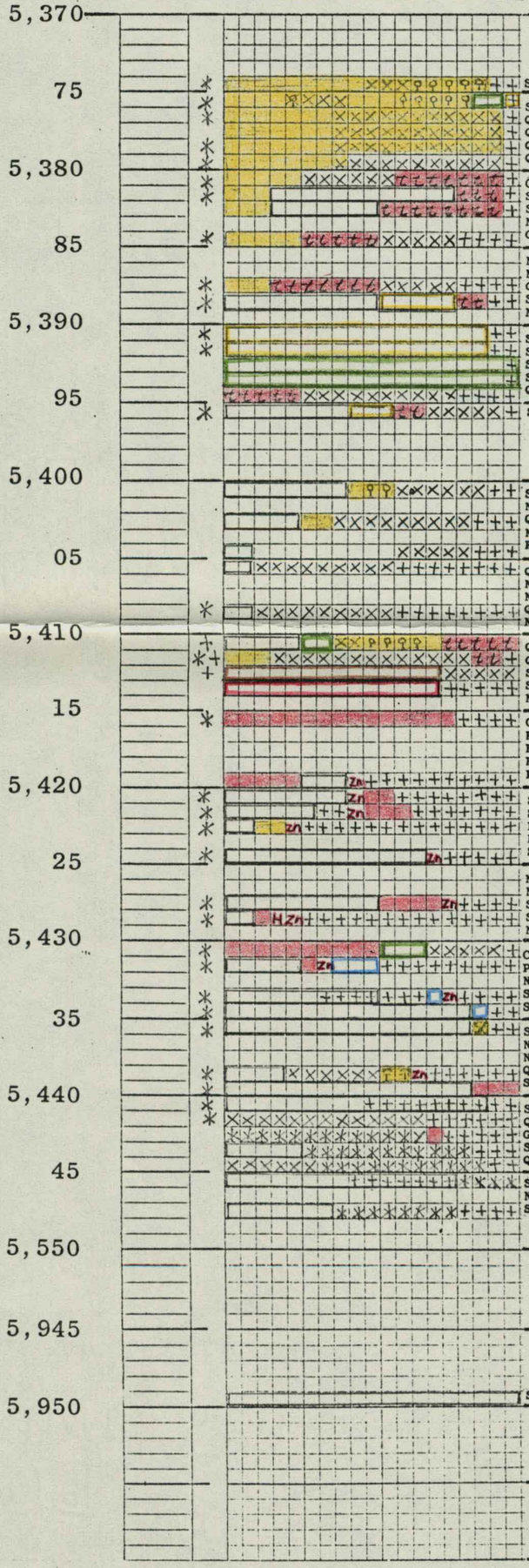
SEC. 27
T. 33 S R. 19 W

6,525
TOTAL DEPTH

CONTRACTOR
COMMENCED
COMPLETED
REMARKS

ALTITUDE
1,935 ft.
PRODUCTION

Residue Description



5,370
Silt / fine sd. / tr. glauconite / much pyrite / qtz. x
75
Silt / fine sd. / tr. glauconite / tr. pyrite / tr. sh. grn.
Qtz. anhedral / tr. pyrite / tr. glauconite
Qtz. anhedral / tr. pyrite / tr. glauconite
Qtz. anhedral / tr. pyrite / tr. glauconite
5,380
Qtz. anhedral / tr. pyrite / tr. glauconite
Cht. chalky / qtz. anhedral / tr. silt / tr. glauconite
Sh. gry. silty / cht. chalky / tr. pyrite
Sh. gry. silty / cht. chalky / tr. pyrite
N.S.
85
Cht. chalky / qtz. anhedral / pyrite / silty sh.
N.S.
N.S.
Cht. chalky / qtz. anhedral / pyrite / sponge? spicules
Sh. gry. / cht. chalky / pyrite in dodecahedrals
5,390
N.S.
Silty sh. gry. / pyrite in dodecahedrals
Silty sh. gry. / pyrite in dodecahedrals
Sh. grn.-gry. / tr. pyrite
Sh. grn.-gry. silty / tr. pyrite
95
Qtz. anhedral / cht. chalky / pyrite clusters / blue-blk. mat.?
Sh. gry. silty / qtz. anhedral / cht. chalky / pyrite
5,400
Sh. gry. silty / qtz. anhedral / pyrite / tr. soft blue flecks?
N.S.
Qtz. anhedral / gry. sh. / Brach shells replaced with silica / pyrite
N.S.
05
Residue mostly undigested calcite in ossicles / pyrite / qtz.
Qtz. anhedral / pyrite
N.S.
N.S.
Qtz. anhedral / pyrite / tr. reddish sphalerite
5,410
N.S.
Qtz. fine sd. and silt / grn. pyritic sh. / chalky cht.
Qtz. anhedral / tr. glauconite / pyrite / sphalerite (yellow)
Sh. brn. / qtz. anhedral
Sh. soft red / pyrite (vivianite?)
15
N.S.
Cht. chalky white / pyrite / tr. reddish sphalerite
Residue negligible
Residue negligible
Residue negligible
5,420
Pyrite / sphalerite / cht. chalky
Sh. gry.-white / pyrite / tr. sphalerite / glauconite (fossil fillings)
Sh. gry. / pyrite and chalcopyrite / sphalerite / glauconite (fossil fillings)
Pyrite / sphalerite / glauconite / chalcopyrite
N.S.
25
Sh. gry. waxy / tr. glauconite / pyrite / sphalerite
N.S.
N.S.
Sh. gry. white / cht. chalky / pyrite / sphalerite
Sh. gry. white / hematite / sphalerite / pyrite / glauconite
5,430
N.S.
Cht. chalky porous puffy / sh. grn. / qtz. anhedral / tr. pyrite
Pyrite / vivianite? / sphalerite / gry.-wh. sh.
N.S.
Sh. gry. silty / pyrite / sh. blue (vivianite?) / sphalerite
35
Sh. gry. silty / pyrite / sh. blue (vivianite?) / tr. sphalerite
Sh. gry. silty / tr. qtz. anhedral / pyrite / blue material?
N.S.
N.S.
Qtz. anhedral / pyrite / sphalerite 6%
Sh. gry. silty / cht. wht. / tr. glauconite / tr. bl. mat.?
5,440
Sh. dark gry. pyritiferous
Qtz. anhedral / pyrite / glauconite / bl. mat.?
Glauconite soft grn. porous / spicules / pyrite
Sh. gry. / glauconite / pyrite
Qtz. anhedral / glauconite / gastropod casts / bryozoan spicules
45
Sh. dark gry. pyritiferous / glauconite
N.S.
Sh. dark gry. pyritiferous / glauconite
5,550
5,945
Sh. gry.-silty
5,950

Sheet 2

STATE

COMPANY

COUNTY

FARM Exchange Bank WELL NO. 1

BLOCK

SURVEY

SEC.

T. R.

TOTAL DEPTH

CONTRACTOR

COMMENCED

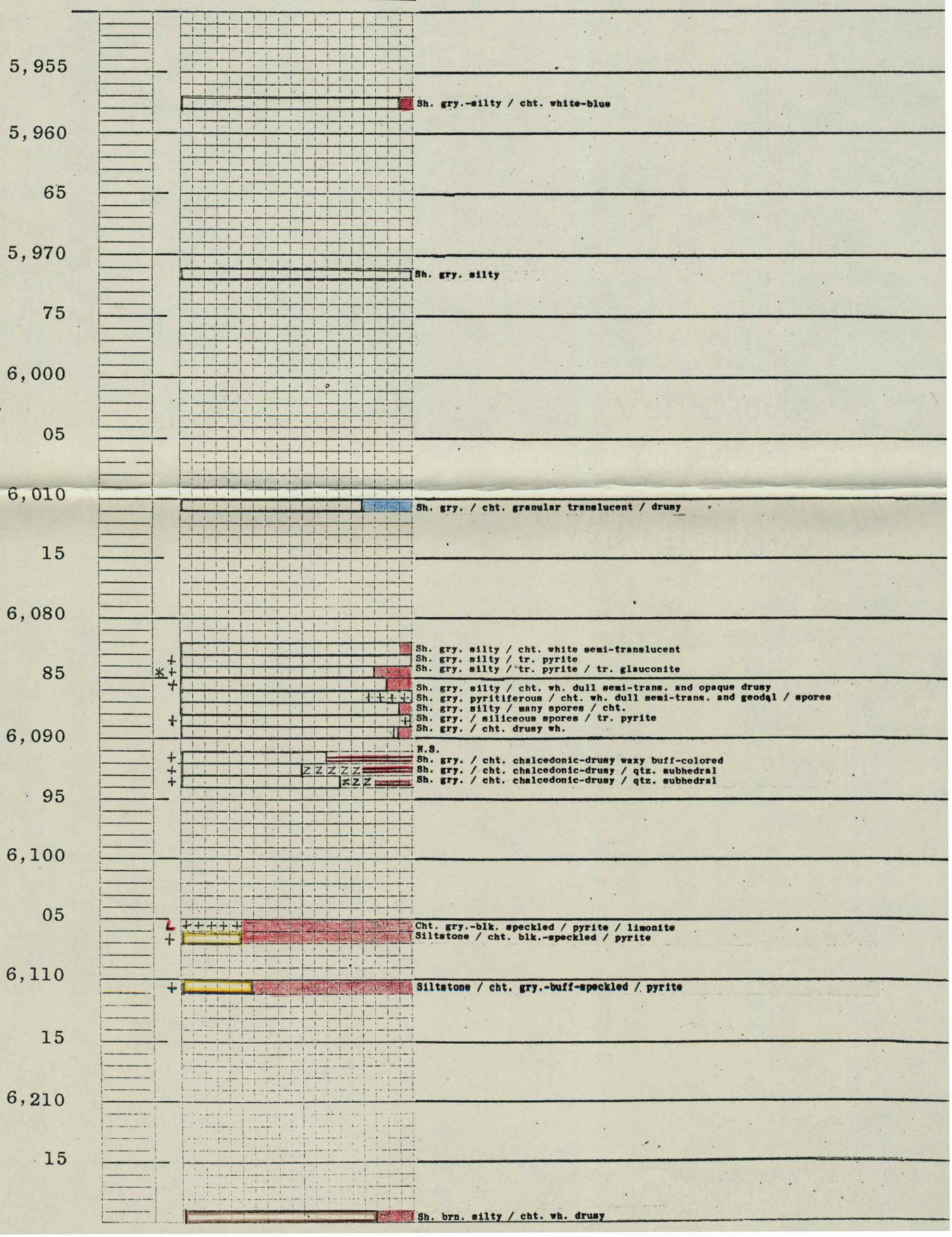
COMPLETED

REMARKS

ALTITUDE

PRODUCTION

Residue Description



Sheet 3

STATE

COUNTY

BLOCK

SEC.

T. R.

COMPANY

FARM Exchange Bank WELL NO. 1

SURVEY

TOTAL DEPTH

CONTRACTOR

COMMENCED

COMPLETED

REMARKS

ALTITUDE

PRODUCTION

Residue Description

6,220

Sh. brn. silty / cht. wh. drusy / cht. in aggregates

Sh. brn. silty / cht. wh. drusy / cht. in aggregates / qtz.

Sh. brn. / silty

25

Cht. blk.-brn. fossiliferous / sh. brn.

Cht. brn.-blk. speckled / sh. brn. / qtz. anhedral

Sh. brn. / qtz. anhedral

Sh. brn. / qtz. anhedral

6,230

Sh. brn. / qtz. anhedral

6,270

Sh. brn. qtz. anhedral

75

Qtz. drusy pyritiferous / sh. gry.

6,280

Sh. brn. ostracod gastropod casts / fossil casts

Sh. brn. ostracod gastropod casts / fossil casts

85

6,340

45

Sd. fine etched rounded

Table 2.--Chronologic history of selected classifications of Mississippian rocks.

Kansas (Moore and others, 1951)	Kansas (Meade Co.-Smith Co.) (Lee, 1953)	Kansas (Salina Basin) (Lee, 1956)	Ozark Region (Moore, 1957)	Southeastern Colorado (Maher, 1958)	Oklahoma (NE) (Huffman, 1958)	Missouri (SW) (Spreng, 1961)	Nebraska (Carlson, 1963)	Iowa (SE Iowa) (Harris and Parker, 1964)
Mississippian System	Mississippian System	Mississippian System	Mississippian System	Carboniferous system Mississippian system	Mississippian System	Mississippian System	Mississippian System	Mississippian System
Chesteran Series	Chesteran Series	Chesteran Series	(pre-Chesteran only)		Chesteran Pitkin Fayetteville Hindsville	Chesteran Series Carterville Fayetteville Batesville Hindsville		
Meramecian Series Ste. Genevieve ls. St. Louis ls. Spergen ls. Warsaw ls. Cowley fm.	Meramecian Series Ste. Genevieve ls. St. Louis ls. Spergen ls. Warsaw ls. Cowley fm.	Meramecian Series Spergen ls. "Warsaw" ls.	Meramecian Ste. Genevieve St. Louis Salem	Meramecian Beulah ls. (Middle Miss.) Hardscrabble ls. (Middle Miss.)	Meramecian Moorefield	Meramecian Series St. Louis Salem Warsaw	Meramecian Series Ste. Genevieve St. Louis Spergen Warsaw	Meramec Series Spergen
Osagian Series Keokuk ls. Burlington ls. Reeds Spring fm. St. Joe ls.	Osagian Series Keokuk ls. (Meade Co.) Burlington ls. Reeds Spring fm. (St. Joe ls.?)	Osagian Series Keokuk ls. Burlington ls. Upper zone Lower zone Reeds Spring ls. St. Joe ls.	Osagian Warsaw Keokuk Burlington Grand Falls Reeds Spring (Fern Glen) Pierson		Osagian Keokuk Reeds Spring	Osagian Series Keokuk Burlington Grand Falls Reeds Spring Pierson	Osagian Series Upper Keokuk--Burl. Lower Keokuk--Burl.	Osage Series Warsaw Keokuk Burlington Cedar Fork Haight Creek Dolbee Creek
Kinderhookian Series Gilmore City ls. Upper Sedalia dol. Lower Sedalia dol.= Northview sh. Chouteau ls.= Compton ls.	Kinderhookian Series Gilmore City ls. (Pawnee Co.)	Kinderhookian Series Gilmore City ls. Sedalia ls.	Kinderhookian Chouteau St. Joe Northview Sedalia Compton Hannibal Louisiana Saverton		Kinderhookian and Osagian St. Joe	Kinderhookian Series Chouteau group Northview fm. Compton fm.	Kinderhookian Series Gilmore City Hampton (Chouteau Group) Eagle City--Iowa Falls Maynes Creek (Wassonville) Chapin (Compton) Unnamed siltstone	Kinderhook Gilmore City (absent) Hampton
Devonian or Mississippian Boice sh. Chattanooga sh. Misener ss. mem.	Mississippian or Devonian Chattanooga sh. (Smith Co.)	Rocks of Devonian or Mississippian age Boice sh. Chattanooga sh.		Mississippian or Devonian Williams Canyon ls.	Kinderhookian and Devonian Chattanooga		Boice	

Southwestern Missouri (Moore, 1928) (1)	Southeastern Missouri (Weller and St. Clair, 1928)	Iowa (Laudon, 1933) (2)	Kansas (Lee, 1940)	Kansas (Forest City Basin) Lee, 1943	Kansas (Scott Co.-Otero Co., Colo.) (Maher, 1947)	Kansas (Western) (Clair, 1948)	Kansas (Barber-Salina) (Lee, 1949)	Colorado, Kansas, Oklahoma (Maher and Collins, 1949)
Carboniferous system Mississippian series	Mississippian series	Mississippian	Carboniferous system Mississippian series	Carboniferous system Mississippian sub-system	Mississippian system	Mississippian system	Mississippian system	Rocks of Mississipplan age
Chester group	Chester group		Rocks of Chester age Limestone of Batesville age (Cherokee Co.) Rocks of Chester age probably present in Southwestern Kansas		Chesteran series	Chesteran series		Chester group
Meramec group	Meramec group Ste. Genevieve ls. St. Louis ls. Spergen ls. Warsaw ls.	Meramec Pella beds St. Louis ls. Spergen ls.	Rocks of Meramec age Watchorn fm. (Undiff. rocks of Spergen, St. Louis, and possibly Ste. Genevieve age.) Warsaw ls. Cowley fm.	Meramecian series Ste. Genevieve ls. St. Louis ls. Spergen ls. Warsaw ls.	Meramecian series Ste. Genevieve ls. St. Louis ls. Spergen--Warsaw ls. (Undiff.)	Meramecian series Ste. Genevieve fm. St. Louis fm. Spergen fm. Warsaw fm.	Meramecian series Spergen ls. (McPherson Co.) "Warsaw" ls. Cowley fm. (Osagian-Meramecian)	Meramec group Ste. Genevieve ls. St. Louis ls. Warsaw-Spergen ls.
Osage group Boone fm. Warsaw Short Creek Keokuk Grand Falls Reeds Spring St. Joe/Pierson ls.	Osage group Keokuk ls. Burlington ls. Fern Glen ls.	Osage Warsaw ls. Keokuk ls. Burlington ls.	Rocks of Osage age Keokuk ls. Burlington ls. Reeds Spring ls. (Fern Glen age) St. Joe ls. (Fern Glen age)	Osagian series Keokuk--Burlington ls.	Osagian series Keokuk--Burlington ls. (Undiff.)	Osagian series Keokuk-Burlington (Undiff.) Fern Glen fm. Reeds Spring member St. Joe member	Osagian series Keokuk ls. Short Creek oolite (Reno Co.) Burlington ls. Reeds Spring ls. St. Joe ls.	Osage group Keokuk-Burlington ls. Fern Glen ls. (Southeast)
Kinderhook group Northview sh. Compton ls. Chattanooga sh. Sylamore	Kinderhook group Sulphur Springs fm. (Bushburg ss., Glen Park ls., and unnamed sh.)	Kinderhook Gilmore City ls. Hampton fm. Iowa Falls Eagle City Maynes Creek North Hill English River fm. Maple Mill sh.	Rocks of Kinderhook or Osage age Gilmore City ls. Sedalia ls. Rocks of Kinderhook age Chouteau ls. (NE Kans.) = Northview sh. = Compton ls. (SE Kans.) Chattanooga sh. (Kinderhook?)	Kinderhookian series Gilmore City ls. Sedalia ls. Chouteau ls.	Kinderhookian series Gilmore City ls. "Misener" ss.	Kinderhookian series Chouteau fm.	Kinderhookian series Gilmore City ls. (Saline Co.) Sedalia dol. (Kingman Co.)	Kinderhook group Gilmore City ls. (local, basal sandstone)

(1) Composite section from Barry, Christian, Dade, Greene, Jasper and Lawrence counties.

(2) Composite section North-central and Southeastern.

66-10

PLATE 1

STRATIGRAPHIC RANGES & OCCURRENCE OF SOME DISCRETE CONODONTS RECOVERED FROM CORES OF MISSISSIPPIAN & OTHER ROCKS IN WESTERN KANSAS

MISSISSIPPIAN

		OSAGIAN			MERAMECIAN		
		Fern Glen Fm.	Burlington Ls.	Keokuk Ls.	Warsaw Ls.	Salem Ls.	St. Louis Ls.
DEV.	KINDERHOOKIAN	Upper Sedalia Dol.	Gilmore City Ls.				

CHESTERAN: Ste. Genevieve Ls.

Apatognathus? gemina
Apatognathus? porcata
Apatognathus? n. sp. A
Cavusgnathus charactа
Bactrognathus hamata
Doliognathus sp.
Elictognathus sp.
Gnathodus antetexanus
Cavusgnathus cristata
Gnathodus girtyi?
Hibbardella fragilis
Hibbardella ortha
Hibbardella abnormis
Cavusgnathus convexa
Cavusgnathus regularis
Cavusgnathus unicornis
Cladognathodus sp.
Gnathodus commutatus
Gnathodus cuneiformis
Gnathodus delicatus
Gnathodus semiglaber
Gnathodus texanus
Ozarkodina sp. cf. *O. laevipostica*
Lambdagnathus fragilidens
Ligonodina lewis
Ligonodina roundyi
Lonchodina sp.
Magnilaterella robusta
Neoprioniodus loxus
Neoprioniodus tulensis
Ozarkodina recta
Polygnathus communis
Polygnathus inornata
Pseudopolygnathus multistriata
Siphonodella cooperi
Spathognathodus cristula
Icriodus sp.
Palmatolepis sp.
Polylophodonta sp.
Scaphignathus sp. ind.
Spathognathodus penescitulus
Spathognathodus scitulus
Symprioniodina laxilabrum
Taphrognathus varians
?

PENNSYLVANIAN

Idiognathodus sp.

ORDOVICIAN

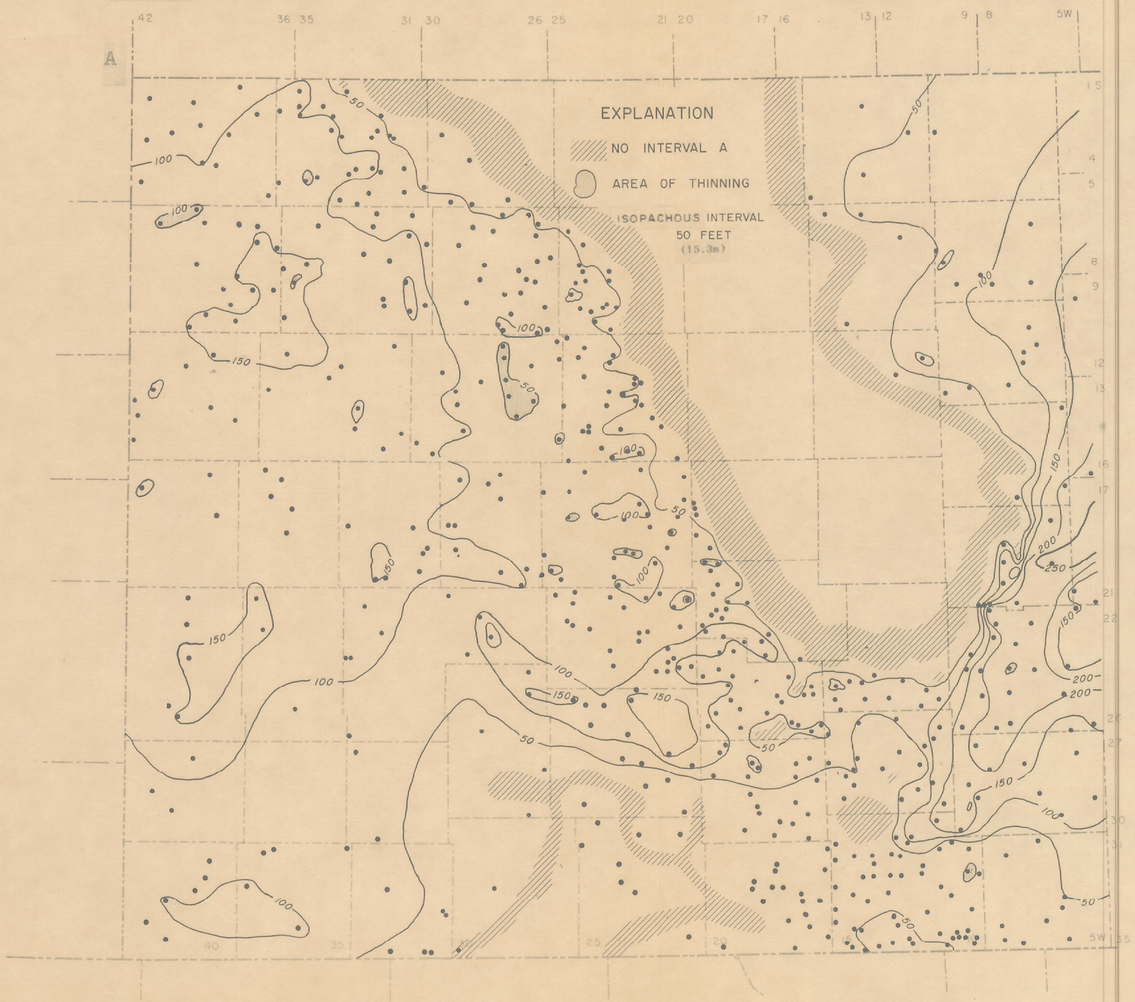
Belodus sp.
Scolopodus sp.

EXPLANATION

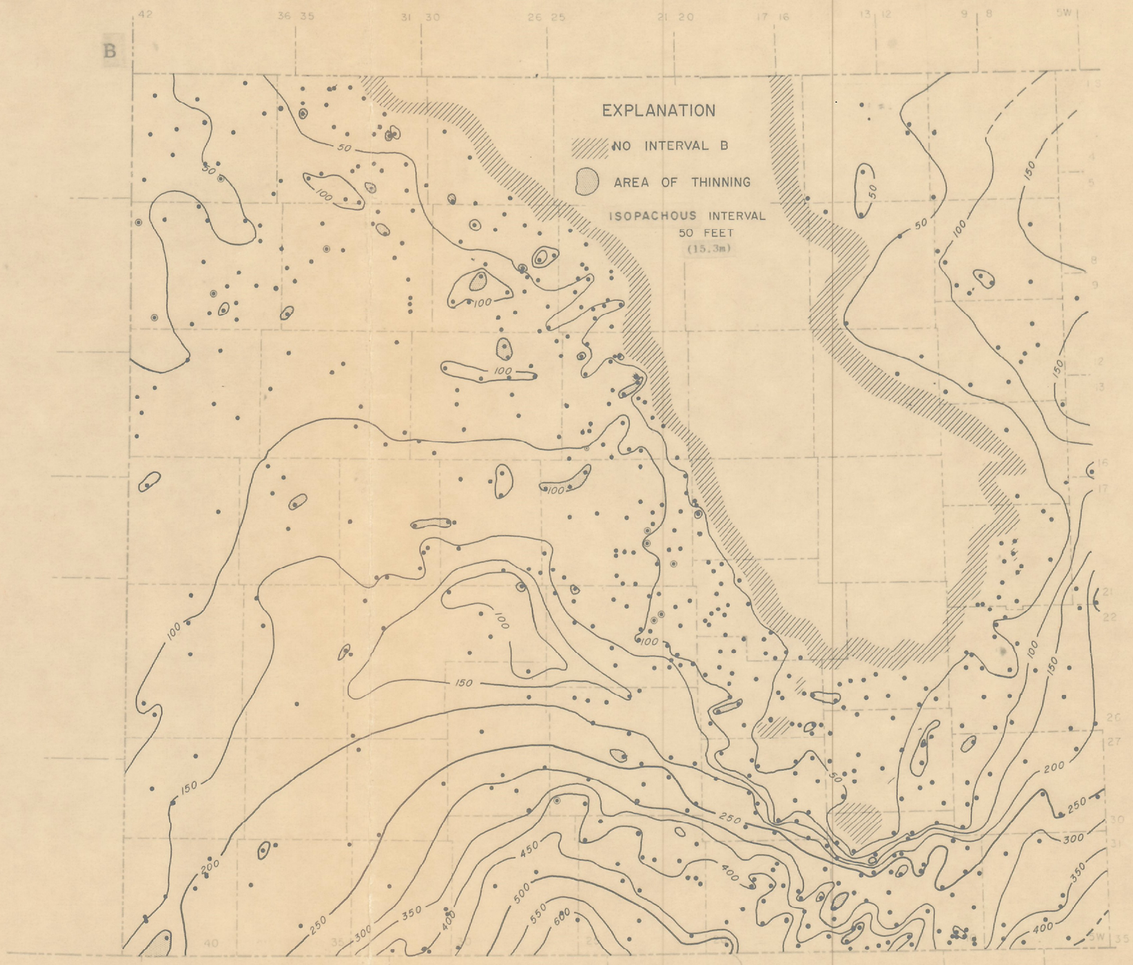
KNOWN RANGE
STRATIGRAPHIC OCCURRENCE

PREPARED BY EDWIN D. GOEBEL, 1966

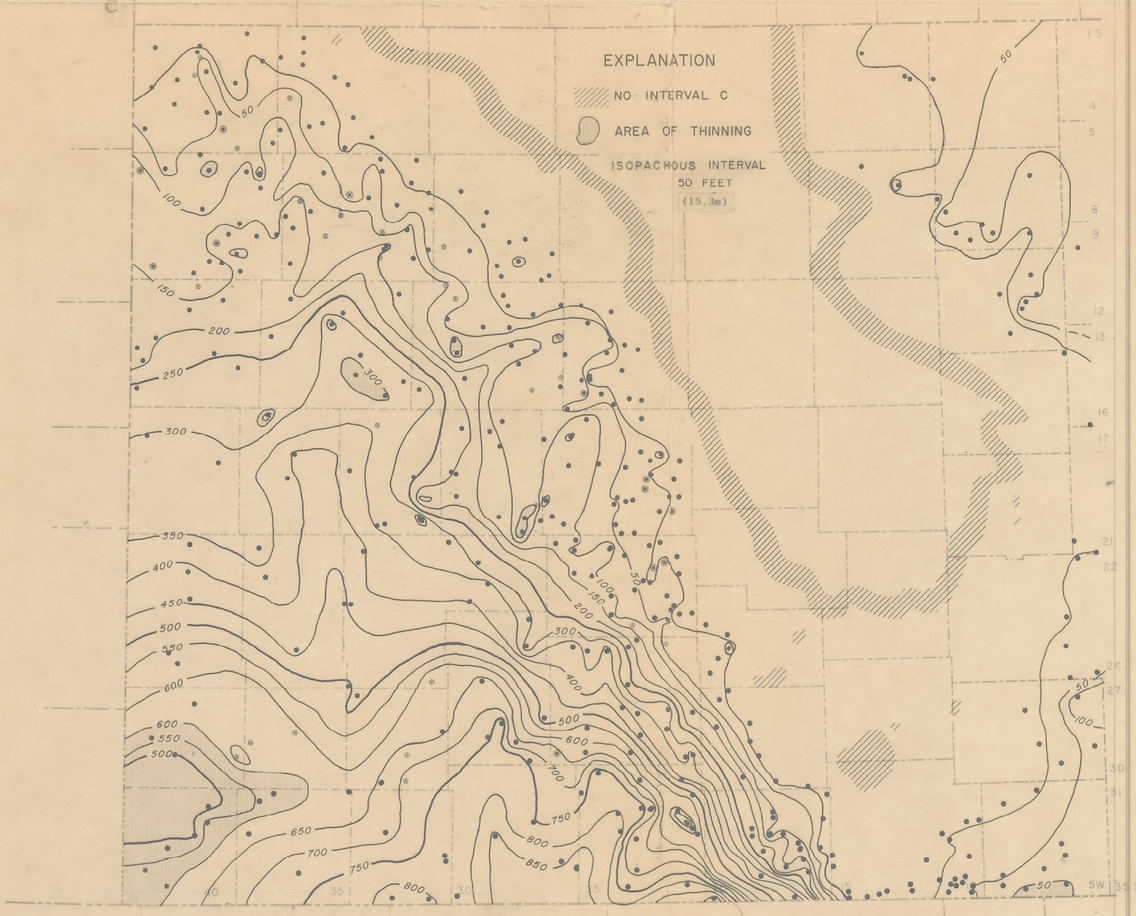
ISOPACHOUS MAP OF INTERVAL A (KINDERHOOKIAN ROCKS PLUS CHATTANOOGA SHALE).



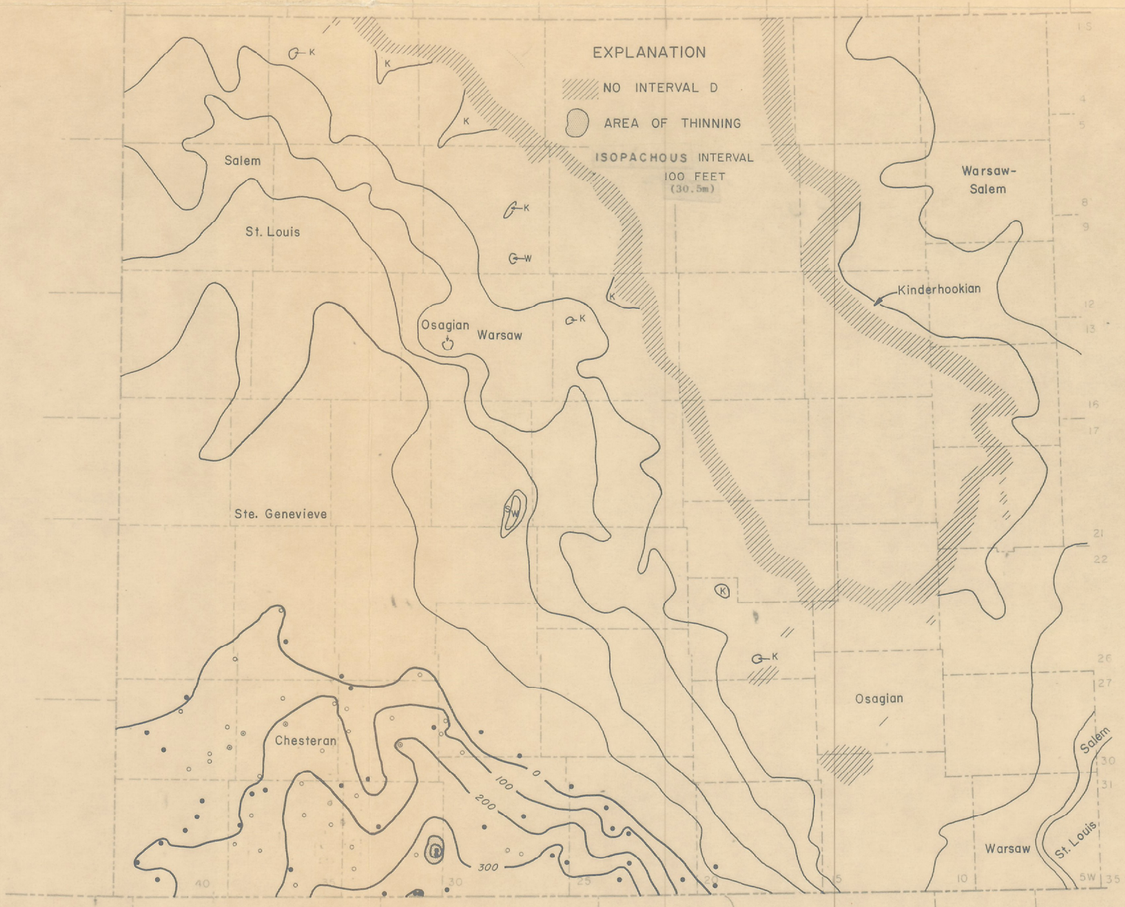
ISOPACHOUS MAP OF INTERVAL B (OSAGIAN ROCKS).



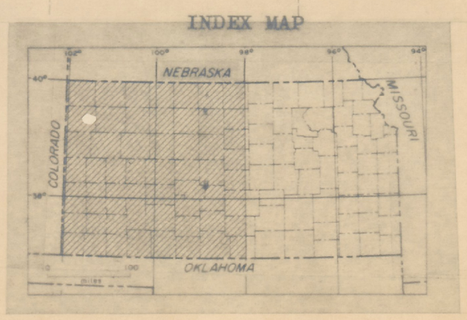
ISOPACHOUS MAP OF INTERVAL C (MERAMECIAN ROCKS).



MISSISSIPPIAN AREAL GEOLOGIC MAP AND ISOPACHOUS MAP OF INTERVAL D (CHESTERAN ROCKS).

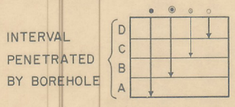


INDEX MAP



EXPLANATION OF WELL SYMBOLS

INTERVAL PENETRATED BY BOREHOLE



10 0 30 MILES

0 48 KILOMETERS

PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS

FROM MORTON COUNTY TO HARPER COUNTY, KANSAS

(EAST HALF)

PLATE 3
SHEET 1

West — A — East A'

OLSON-ALMA OIL CO.
No. 1 Satkins
Sec. 23, T 32 S, R 21 W
Clark County
Altitude 2005 ft.

SINCLAIR-PRAIRIE
No. 1 Exchange Nat. Bank
sec. 27, T 33 S, R 19 W
Comanche County
Altitude 1935 ft.

SUN OIL CO.
No. 1 Gates Ranch
sec. 18, T 34 S, R 16 W
Commche County
Altitude 1795 ft.

SINCLAIR-PRAIRIE
No. 1 Gentry
sec. 1, T 33 S, R 15 W
Barber County
Altitude 1894 ft.

SINCLAIR OIL CO.
No. 1 Circle
sec. 14, T 33 S, R 11 W
Barber County
Altitude 1436 ft.

SINCLAIR OIL CO.
No. 1 Helmley
Sec. 3, T 35 S, R 10 W
Harber County
Altitude 1286 ft.

KESSLER OIL CO.
No. 1 Wolfje
Sec. 17, T 33 S, R 6 W
Harper County
Altitude 1328 ft.

9 — 15 Miles — 10 — 13 Miles — 11 — 16 Miles — 12 — 14 Miles — 13 — 23 Miles — 14 — 12 Miles — 15 — 24 Miles

Ste. Genevieve Ls.
St. Louis Ls.
Salem Ls.
Warsaw Ls.
Keokuk Ls.
(Estimated top, Burlington Ls.)
Burlington Ls.
Fern Glen Fm.
Viola Ls.
"Cowley"
Reeds Spring Ls.
St. Joe Ls.
Chattanooga Sh.
Kookuk Ls.
Osagian rocks
Chattanooga Sh.
Maquoketa Sh.
Viola Ls.
Viola Limestone

See Pl. 11 for core lithology and Appendix for conodont list and distribution.

See Pl. 10 for core lithology and Appendix for conodont list and distribution.

See Pl. 12 for core lithology and Appendix for conodont list and distribution.

See Pl. 17 for core lithology and Appendix for conodont list and distribution.

See Pl. 16 for core lithology and Appendix for conodont list and distribution.

Vertical scale: 100 feet = 30.5 meters, 0

Horizontal distance not to scale

miles / kilometers CONVERSION GRAPH

NEBRASKA, COLORADO, KANSAS, OKLAHOMA

COLORADO — Greeley, Wichita, Scott, Lane, Ness, Rush, Barton, Ellsworth, Rice, Hamilton, Kearny, Finney, Hodgeman, Pawnee, Reno, Gray, Ford, Edwards, Stafford, Pratt, Kingman, Stanton, Grant, Haskell, Meade, Clark, Kiowa, Comanche, Barber, Harper, Morton, Stevens, Seward, PLATE 4, PLATE 7, PLATE 3, A, A', OKLAHOMA

0 30 miles
0 48 km

Formation — STAGE — SER. — SYS.

St. Louis Limestone — Mer. — UPPER MISS. — MISSISSIPPIAN
4500 ft.
Osagian — LOWER MISS. — MISSISSIPPIAN
4600
Osagian rocks
4700
Chattanooga Shale — 4800 ft. — MISS. - DEV.
Viola Limestone — MID ORD. — ORDOVICIAN

EXPLANATION

ELECTRICAL LOGS
Spontaneous-potential
Resistivity, normal
Resistivity, lateral

RADIOACTIVITY LOGS
Gamma-ray
Neutron

Limestone
Glauconitic limestone
Shaly limestone
Sandy limestone
Cherty limestone
Oolitic limestone
Dolomite
Glauconitic dolomite
Shaly dolomite
Cherty dolomite
Oolitic dolomite
Dolomitic limestone
Shale
Sandy shale
Cherty shale
Dolomitic shale
Siltstone
Chert
No samples
Doubtful correlation

Fossiliferous
Fossiliferous chert
Crinoids?
Brachiopods
Conodonts
Bryozoans
Foraminifera
Spicules (sponge?)
Ostracodes
Spores?
Scolecodonts

Top of Mississippian rocks used as datum

PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS

FROM MORTON COUNTY, TO HARPER COUNTY, KANSAS

(WEST HALF)

WEST — EAST

PLATE 3

64-10 SHEET 2

A — A'

SYSTEM	SERIES	STAGE	Formation
MISSISSIPPIAN	UPPER MISSISSIPPIAN	Chesteran	
			Ste. Genevieve Limestone
		Meramecian	St. Louis Limestone
			Salem Limestone
			Warsaw Limestone
	LOWER MISSISSIPPIAN	Osagian	
		Kinderhookian	Gilmore City Limestone
ORDOVICIAN	MID. ORD.		Viola Limestone

1 — CITIES SERVICE OIL CO.
No. 1 Greenwood "B"
sec. 14, T 33 S, R 42 W
Morton County
Altitude 3492 ft.

6 Miles

2 — PANHANDLE EASTERN
No. 2 Goltz
sec. 35, T 32 S, R 41 W
Morton County
Altitude 3425 ft.

27 Miles

3 — MOBIL OIL CO.
No. 1 Cunningham Estate
sec. 13, T 34 S, R 37 W
Stevens County
Altitude 3140 ft.

23 Miles

4 — STANOLIND
No. 1 Feather
sec. 15, T 35 S, R 33 W
Seward County
Altitude 2823 ft.

19 Miles

5 — STANOLIND
No. 1 Wheatley
sec. 23, T 33 S, R 31 W
Seward County
Altitude 2749 ft.

12 Miles

6 — STANOLIND
No. 1 R. L. Rickers
sec. 27, T 32 S, R 29 W
Meade County
Altitude 2703 ft.

18 Miles

7 — DEEP ROCK OIL CORP.
No. 1 Horner
sec. 29, T 33 S, R 26 W
Meade County
Altitude 2303 ft.

20 Miles

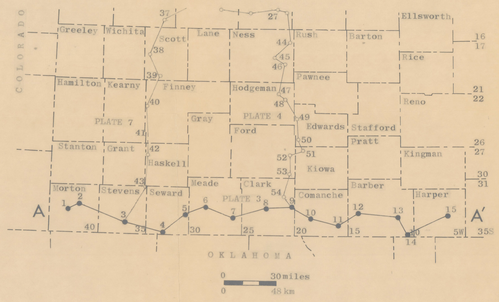
8 — SUNRAY-SINCLAIR-SUN
No. 1 Brodie
sec. 32, T 32 S, R 23 W
Clark County
Altitude 2204 ft.

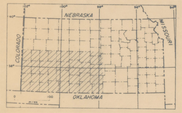
15 Miles

Chesteran rocks
Ste. Genevieve Ls.
St. Louis Ls.
Salem Ls.
Warsaw Ls.
Keokuk Ls.
Burlington Ls.
Fern Glen Fm.
Kinderhookian rocks
Viola Ls.
Cowley

See Appendix for conodont list and distribution.

Top of Mississippian rocks used as datum





EXPLANATION

- Limestone
- Glauconitic limestone
- Shaly limestone
- Sandy limestone
- Cherty limestone
- Oolitic limestone
- Arenaceous limestone
- Silty limestone
- Dolomite
- Glauconitic dolomite
- Cherty dolomite
- Dolomitic limestone
- Shale
- Sandy shale
- Sandstone
- Chert
- No samples
- Doubtful correlation

- Fossiliferous
- Fossiliferous chert
- Spicular chert
- Crinoids?
- Gastropods
- Brachiopods
- Conodonts
- Bryozoans
- E Endothyra
- C Ostracodes

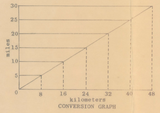
ELECTRICAL LOGS

Spontaneous-potential
Resistivity, normal
Resistivity, lateral

RADIOACTIVITY LOGS

Gamma-ray
Neutron

Vertical scale
100 feet
30.5 meters
0



PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS
FROM TREGO COUNTY TO CLARK COUNTY, KANSAS

PLATE 4

North

B'

C & G
No. 1 Augustine (Colberg)
sec. 22, T 14 S, R 21 W
Trego County
Altitude 2220 ft.

IRON
No. 1 Higgins
sec. 14, T 17 S, R 21 W
Ness County
Altitude 2174 ft.

MOBIL OIL CO.
No. 1 Elsasser Heirs
sec. 29, T. 18 S, R 22 W
Ness County
Altitude 2201 ft.

SINCLAIR
No. 1 Wilhelm
sec. 16, T 19 S, R 21 W
Ness County
Altitude 2215 ft.

MOBIL OIL CO.
No. 1 Salmans
sec. 3, T 22 S, R 22 W
Hodgeman County
Altitude 2202 ft.

ATLANTIC & CARTER
No. 1 Mooney
sec. 20, T 22 S, R 21 W
Hodgeman County
Altitude 2205 ft.

BRODERICK & GORDON
No. 1 Smith
sec. 17, T 24 S, R 20 W
Edwards County
Altitude 2269 ft.

SER. | Formation

CAMBRIAN-ORDOVICIAN | Arbuckle Group

28 — 17 Miles — 44 — 12½ Miles — 45 — 8 Miles — 46 — 16 Miles — 47 — 5 Miles — 48 — 13 Miles — 49

4650 ft. | 4200 | 4400 | 4500 | 4600 | 4500

Warsaw Ls.

Keokuk-Burlington?

Gilmore City Ls.

Viola Ls.

Reeds Spring Ls.?

700 ft.

See Appendix for conodont list and distribution.

See Appendix for conodont list and distribution.

South

E

VIRGINIA DRLG. CO.
No. 1 Millheisler
sec. 12, T 26 S, R 20 W
Edwards County
Altitude 2245 ft.

NORTHERN NATURAL
No. 2 "A" Fralick
sec. 14, T 27 S, R 20 W
Kiowa County
Altitude 2300 ft.

SINCLAIR-PRAIRIE
No. 1 Young
sec. 34, T 27 S, R 21 W
Ford County
Altitude 2330 ft.

CARTER OIL
No. 1 Everett
sec. 22, T 29 S, R 21 W
Ford County
Altitude 2539 ft.

TEXAS CO.
No. 1 Moore
sec. 25, T 31 S, R 22 W
Clark County
Altitude 2045 ft.

OLSON-ALMA OIL CO.
No. 1 Watkins
sec. 23, T 32 S, R 21 W
Clark County
Altitude 2005 ft.

50 — 13 Miles — 6 Miles — 51 — 7 Miles — 52 — 10 Miles — 53 — 14 Miles — 54 — 7 Miles — 9

4600 ft. | 4900 | 5000 ft. | 5100 | 5300 | 5400 | 5500 | 5600 | 5700 | 5800 | 5900 | 6000 | 6100 | 6200

Keokuk Ls.

Salem Ls.

Warsaw Ls.

Keokuk Ls.

Burlington Ls.

Fern Glen Fm.?

Gilmore City Ls.

Viola Ls.

"Cowley"

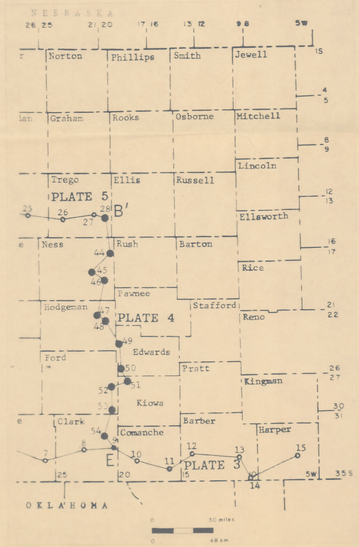
"Cowley"

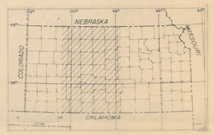
"Cowley"

*No. 1 Fralick, SWk SWk from 4900 to total depth.

See Pl.13 for core lithology and Appendix for conodont list and distribution.

Formation	STAGE	SERIES	SYSTEM
Ste. Genevieve Limestone	Meramecian	UPPER MISSISSIPPIAN	MISSISSIPPIAN
St. Louis Limestone			
Salem Limestone			
Warsaw Limestone			
Keokuk Limestone	Osagian	LOWER MISSISSIPPIAN	
Burlington Limestone			
Fern Glen Formation			
Viola Limestone		MIDDLE ORD.	ORDOVICIAN





EXPLANATION

- Limestone
- Glauconitic limestone
- Shaly limestone
- Sandy limestone
- Cherty limestone
- Oolitic limestone
- Dolomite
- Glauconitic dolomite
- Sandy dolomite
- Cherty dolomite
- Shaly dolomite
- Dolomitic limestone
- Shale
- Glauconitic shale
- Cherty sandstone
- Sandstone
- Chert
- Dolomitic chert
- No samples
- Doubtful correlation
- Fossiliferous
- Fossiliferous chert
- Spicular chert
- Crinoids?
- Brachiopods
- Conodonts
- Bryozoans
- E Endothyra
- F Foraminifera
- O Ostracodes
- Algae

Top of Mississippian rocks used as datum

ELECTRICAL LOGS

Spontaneous-potential

Resistivity, normal

Resistivity, lateral

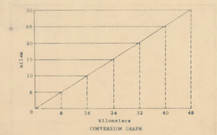
RADIOACTIVITY LOGS

Gamma-ray

Neutron

Vertical scale: 100 feet = 30.5 meters

Horizontal distance not to scale



PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS

FROM KIT CARSON COUNTY, (COLORADO) TO TREGO COUNTY, KANSAS

PLATE 5

WEST

B

SYS.	SER.	STAGE
MISSISSIPPIAN	UPPER MISS.	Meramecian
	LOWER MISS.	Osagian
		Kinderhookian
CAMBRIAN ORDOVICIAN		

Formation

Salem Limestone

Warsaw Limestone

Arbuckle Group

DEEP ROCK OIL CORP.
No. 1 R. L. Edmondson
sec. 33, T 6 S, R 44 W
Kit Carson County (Colorado)
Altitude 3895 ft.

VAN GRISSO
No. 1 Golden
sec. 24, T 10 S, R 42 W
Sherman County
Altitude 3852 ft.

SINCLAIR OIL CO.
No. 1 Mercer
sec. 28, T 10 S, R 40 W
Sherman County
Altitude 3756 ft.

PHILLIPS
No. 1 Goodland
sec. 7, T 10 S, R 39 W
Sherman County
Altitude 3643 ft.

PHILLIPS
No. 2 Goodland
sec. 10, T 10 S, R 39 W
Sherman County
Altitude 3632 ft.

SINCLAIR-PRAIRIE
No. 1 Cogswell
sec. 20, T 10 S, R 38 W
Sherman County
Altitude 3517 ft.

16 — 28 Miles — 17 — 9 Miles — 18 — 6 Miles — 19 — 3 Miles — 20 — 5 Miles — 21

5500 ft. 5600 5700 ft. 5300 5400 5300 5400 5500 5200 5300 5400 5500 3200 5300 5400 5500 5000 ft. 5100 5200 5300 5400 ft.

See Appendix for conodont list and distribution.

EAST

B′

TEXAS
No. 1 Smith
sec. 30, T 11 S, R 36 W
Logan County
Altitude 3238 ft.

PHILLIPS
No. 1 Monument Prospect
sec. 8, T 12 S, R 34 W
Logan County
Altitude 3212 ft.

MCCOY
No. 1 Teeter "A"*
sec. 26, T 13 S, R 30 W
Gove County
Altitude 2867 ft.

TIDEWATER
No. 1 Adams
sec. 8, T 14 S, R 27 W
Gove County
Altitude 2577 ft.

BENNET & ROBERTS
No. 1 Kline
sec. 19, T 14 S, R 24 W
Trego County
Altitude 2348 ft.

MURFIN
No. 1 Nelson
sec. 10, T 14 S, R 22 W
Trego County
Altitude 2240 ft.

C & G
No. 1 Augustine (Colberg)
sec. 22, T 14 S, R 21 W
Trego County
Altitude 2220 ft.

14 Miles — 22 — 13 Miles — 23 — 25 Miles — 24 — 18 Miles — 25 — 17 Miles — 26 — 15 Miles — 27 — 6 Miles — 28

4900 ft. 5000 5100 5200 ft. 4800 4900 5000 5100 5200 5300 4500 4600 4400 4500 4200 4300 4400 4200 4300 4400 4050 ft.

St. Louis Ls.
Salem Ls.
Warsaw Ls.
Keokuk Ls.
Gilmore City Ls.
Upper Sedalia Dol.
Arbuckle Grp.

Formation
Arbuckle Group

SERIES / SYSTEM: CAMBRIAN ORDOVICIAN

See Pl. 9 for core lithology and Appendix for conodont list and distribution.

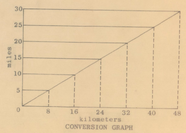
See Appendix for conodont list and distribution.

See Pl. 14 for core lithology and Appendix for conodont list and distribution.

* Old well worked over, originally Musgrove Petroleum, Inc. No. 1 Teeter

Vertical scale: 100 feet, 30.5 meters, 0

Horizontal distance not to scale



EXPLANATION

ELECTRICAL LOGS

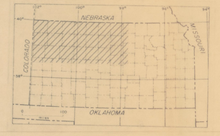
Spontaneous-potential
Resistivity, normal
Resistivity, lateral

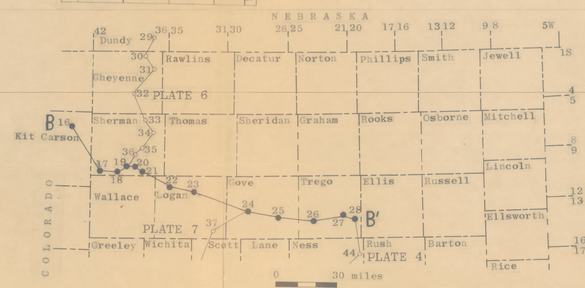
RADIOACTIVITY LOGS

Gamma-ray
Neutron

Limestone	Glauconitic dolomite	Sandstone	Fossiliferous
Glauconitic limestone	Cherty dolomite	Glauconitic sandstone	Fossiliferous chert
Oolitic limestone	Sandy dolomite	Chert	Crinoids?
Cherty limestone	Dolomitic limestone	Dolomitic chert	Brachiopods
Sandy limestone	Shale	No samples	Conodonts
Dolomite	Sandy shale	Doubtful correlation	Bryozoans
			Scolecodonts

Top of Mississippian rocks used as datum





PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS

FROM DUNDY COUNTY, (NEBRASKA) TO SHERMAN COUNTY, KANSAS

PLATE 6

North
C

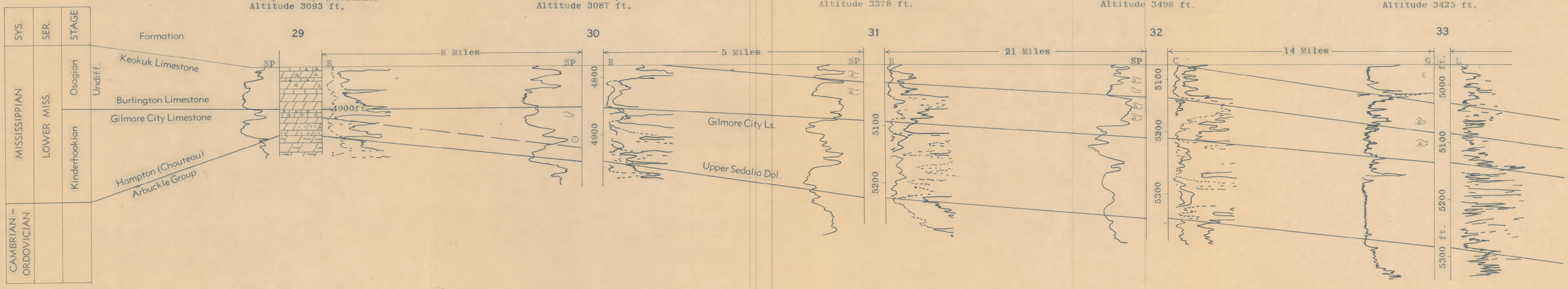
OHIO OIL CO.
No. 1 Cannon
sec. 33, T 2 N, R 37 W
Dundy County (Nebraska)
Altitude 3093 ft.

WESTHEIMER & NUSTADT
No. 1 Glasco
sec. 10, T 1 S, R 38 W
Cheyenne County
Altitude 3087 ft.

PHILLIPS
No. 1 Wilkins
sec. 16, T 2 S, R 37 W
Cheyenne County
Altitude 3378 ft.

PHILLIPS
No. 1 St. Francis
sec. 15, T 4 S, R 39 W
Cheyenne County
Altitude 3498 ft.

PHILLIPS
No. 3 Shermanville
sec. 21, T 6 S, R 38 W
Sherman County
Altitude 3425 ft.



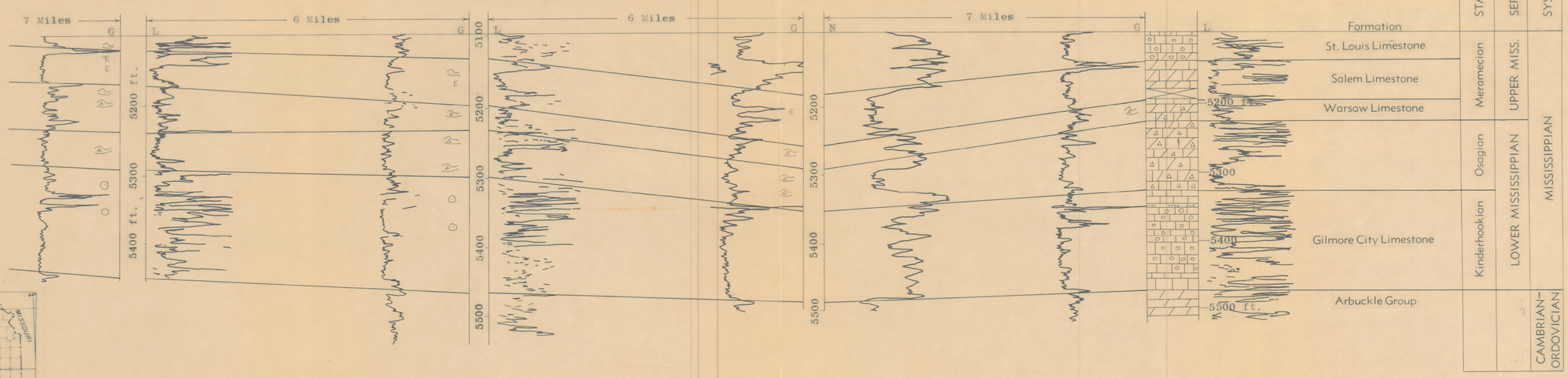
South
C'

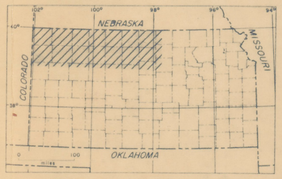
MIAMI
No. 1 Bear
sec. 18, T 7 S, R 37 W
Sherman County
Altitude 3498 ft.

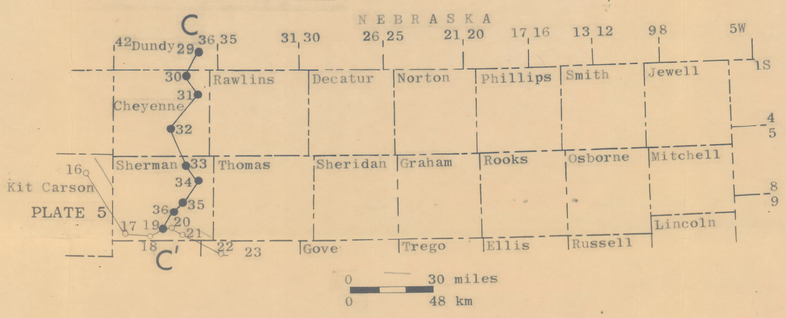
PHILLIPS
No. 6 Goodland
sec. 29, T 8 S, R 38 W
Sherman County
Altitude 3583 ft.

BADGER
No. 1 House
sec. 11, T 9 S, R 39 W
Sherman County
Altitude 3622 ft.

PHILLIPS
No. 1 Goodland
sec. 7, T 10 S, R 39 W
Sherman County
Altitude 3643 ft.







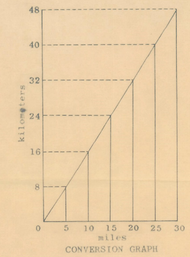
EXPLANATION

- Limestone
- Cherty limestone
- Oolitic limestone
- Dolomite
- Glauconitic dolomite
- Sandy dolomite
- Cherty dolomite
- Dolomitic limestone
- Sandstone
- No samples
- Doubtful correlation
- Fossiliferous
- Fossiliferous chert
- Crinoids?
- E Endothyra

Top of Mississippian rocks used as datum

Vertical scale
100 feet
30.5 meters
0

Horizontal distance not to scale



CONVERSION GRAPH

PREPARED BY EDWIN D. GOEBEL, 1966

STRATIGRAPHIC CROSS SECTION OF MISSISSIPPIAN ROCKS

FROM GOVE COUNTY, TO STEVENS COUNTY, KANSAS

PLATE 7

North

D

WYCOFF
No. 1 Teeter "A"*
sec. 26, T 13 S, R 30 W
Gove County
Altitude 2867 ft.

ALMA OIL CO.
No. 1 Watchorn
sec. 13, T 15 S, R 33 W
Logan County
Altitude 2780 ft.

DOZIER
No. 1 Shearmire
sec. 21, T 18 S, R 34 W
Scott County
Altitude 3136 ft.

ATLANTIC OIL
No. 1 Mark "A"
sec. 28, T 20 S, R 33 W
Scott County
Altitude 2943 ft.

CHAMPLIN
No. 4 Garden City
sec. 18, T 23 S, R 34 W
Finney County
Altitude 2981 ft.

SYSTEM	SERIES	STAGE
MISSISSIPPIAN	LOWER MISSISSIPPIAN	Osagian
		Kinderhookian
ORDOVICIAN	MIDDLE ORDOVICIAN	

Formation

Keokuk Limestone

Gilmore City Limestone

Viola Limestone

24 — 18 Miles — 37 — 21 Miles — 38 — 14 Miles — 39 — 18 Miles — 40

Ste. Genevieve Ls.

St. Louis Ls.

Salem Ls.

Warsaw Ls.

Keokuk Ls.

Gilmore City Ls.

4500 ft.

4600 ft.

4700

4800

4900

5000

5100

5200

5300

5400

5500

4800

4900

5000

5100

5200

5300

5400

5600ft.

See Pl.14 for core lithology and Appendix for conodont list and distribution.

* Old well worked over, originally Musgrove Petroleum, Inc. No. 1 Teeter

See Pl.19 for core lithology and Appendix for conodont list and distribution.

See Pl.15 for core lithology and Appendix for conodont list and distribution.

South

D

WHITE EAGLE OIL
No. 30-2 Jones "B"
sec. 30, T 26 S, R 34 W
Finney County
Altitude 3021 ft.

CITIES SERVICE OIL
No. 1 Kells "B"
sec. 5, T 28 S, R 34 W
Haskell County
Altitude 3100 ft.

MOBIL OIL CO.
No. 1 Cutter
sec. 1, T 31 S, R 35 W
Stevens County
Altitude 2974 ft.

MOBIL OIL CO.
No. 1 Cunningham Estate
sec. 13, T 34 S, R 37 W
Stevens County
Altitude 3146 ft.

41 — 21 Miles — 42 — 8 Miles — 18 Miles — 43 — 23 Miles — 3

Ste. Genevieve Ls.

St. Louis Ls.

5000 ft.

5100

5200

5300

5400

5500

5600

5800 ft.

5500

5600

5700

6100

6200

6300

6400

6500

6400 ft.

6500

6600

6700

6800

6900

7000

7100

7200

7300

7400

7500

7600 ft.

Formation

Ste. Genevieve Limestone

St. Louis Limestone

Salem Limestone

Warsaw Limestone

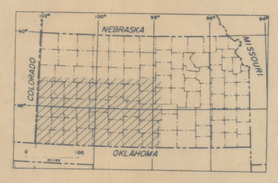
Gilmore City Limestone

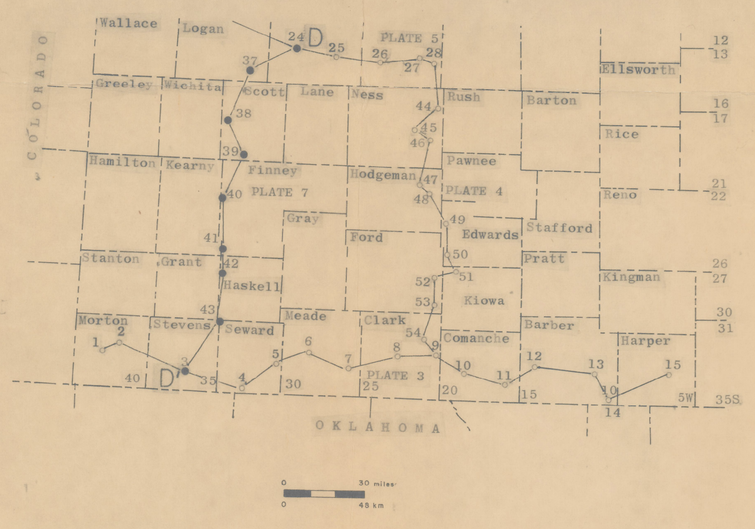
Viola Limestone

STAGE	SERIES	SYSTEM
Chesteran	UPPER MISSISSIPPIAN	MISSISSIPPIAN
Meramecian		
Osagian	LOWER MISSISSIPPIAN	
Kinderhookian		
MID. ORD.		ORD.

See Appendix for conodont list and distribution.

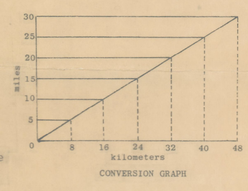
See Appendix for conodont list and distribution.





Vertical scale
100 feet
30.5 meters
0

Horizontal distance not to scale

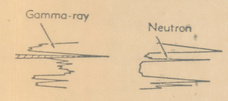


EXPLANATION

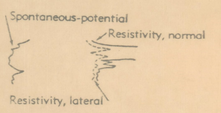
Limestone
Glauconitic limestone
Sandy limestone
Oolitic limestone
Shaly limestone
Cherty limestone
Dolomite
Glauconitic dolomite
Cherty dolomite
Dolomitic limestone
Shale
Sandy shale
Sandstone

Fossiliferous
Fossiliferous chert
Spicular chert
Crinoids?
Corals
Gastropods
Brachiopods
Conodonts
Bryozoans
E Endothyra
F Foraminifera
S Spicules (sponge?)

RADIOACTIVITY LOGS



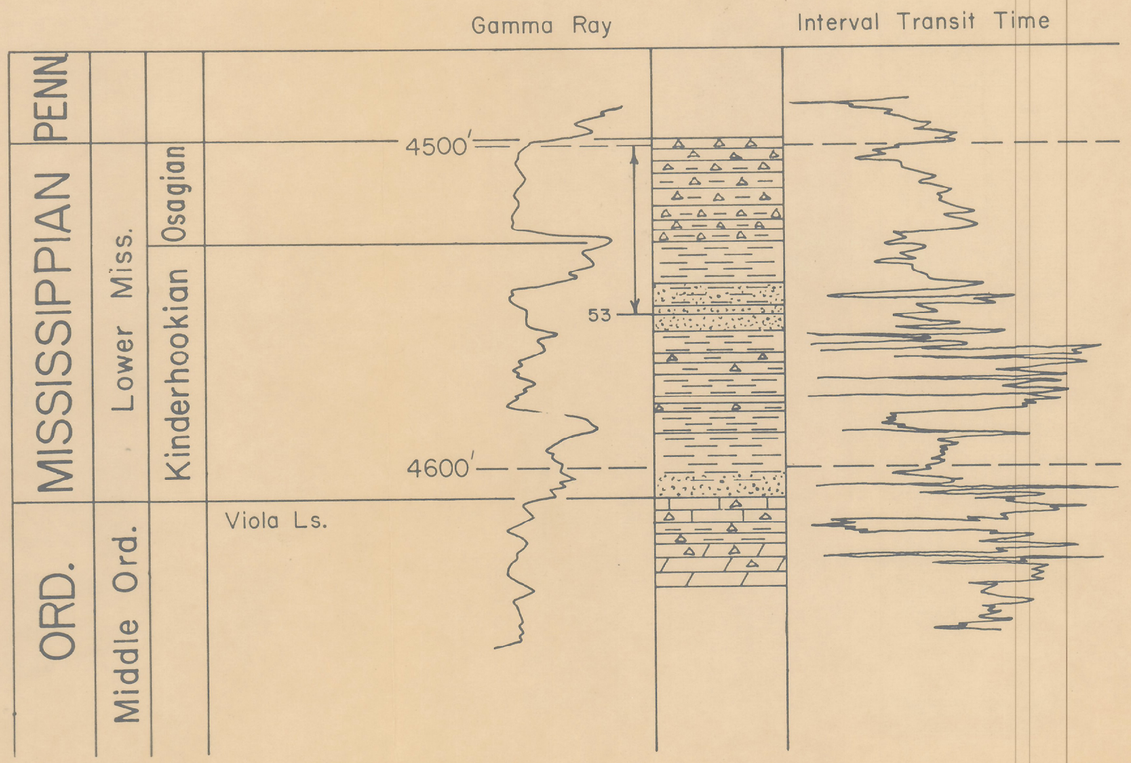
ELECTRICAL LOGS



Top of Mississippian rocks used as datum

PREPARED BY EDWIN D. GOEBEL, 1966

WESTERN PETRO. CO., INC.
NO. 1 HOFFMAN
Sec. 8, T. 25 S., R. 17 W., Edwards Co.
Elev. 2152 ft.
(655.9m)



OSAGIAN ROCKS

4498'

4526'

1 cm

(X3.2)

Peel-prints

4498'-4526' Chert fragments, white to tan, opaque, smooth to chalky in greenish-gray, limey shale matrix. Residue 98 percent insoluble, comprised chert, microfossiliferous chert, and green shale in lower part. No conodonts.

PLATE 8

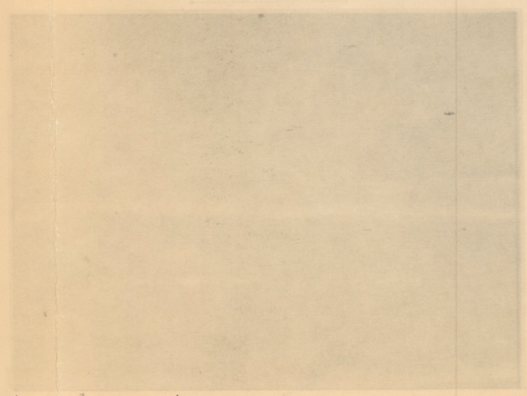
KINDERHOOKIAN ROCKS

4527'

1 cm

(X3)

4527'-4540' Shale, chocolate brown and reddish black, slightly micaceous, platy to fissle, hematitic. Residues about 90 percent insoluble, comprised of red shale and green shale with glauconite and sandy shale in lower part.

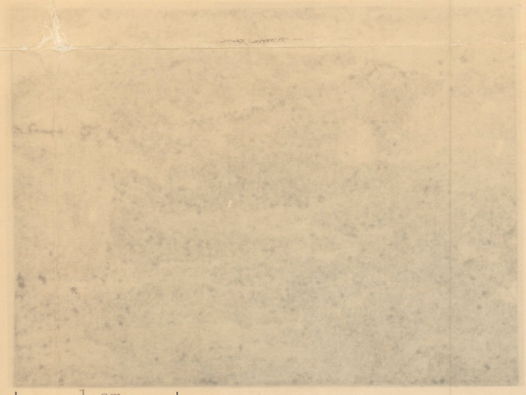


1 cm

(X3)

FAUNA FROM RESIDUES (4527'-4540')

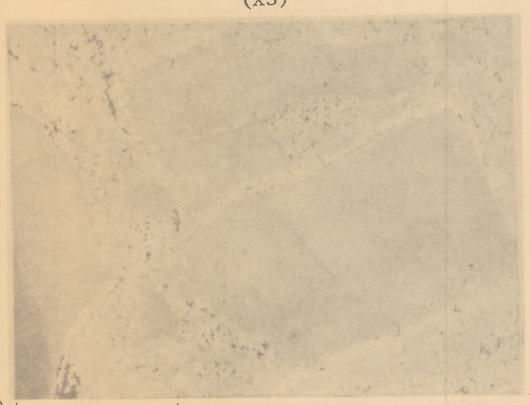
Icriodus sp.
Polygnathus sp.
Polylophodonta sp.
Pseudopolygnathus sp.
Siphonodella sp.
Spathognathodus sp.



1 cm

(X3)

4541'-4553' Sandstone, fine, subrounded, frosted, cemented, medium-sorted; red shale at base. Residue 95 percent consisting of clean sand, and red shale and hematitic-coated sand.



4553'

1 cm

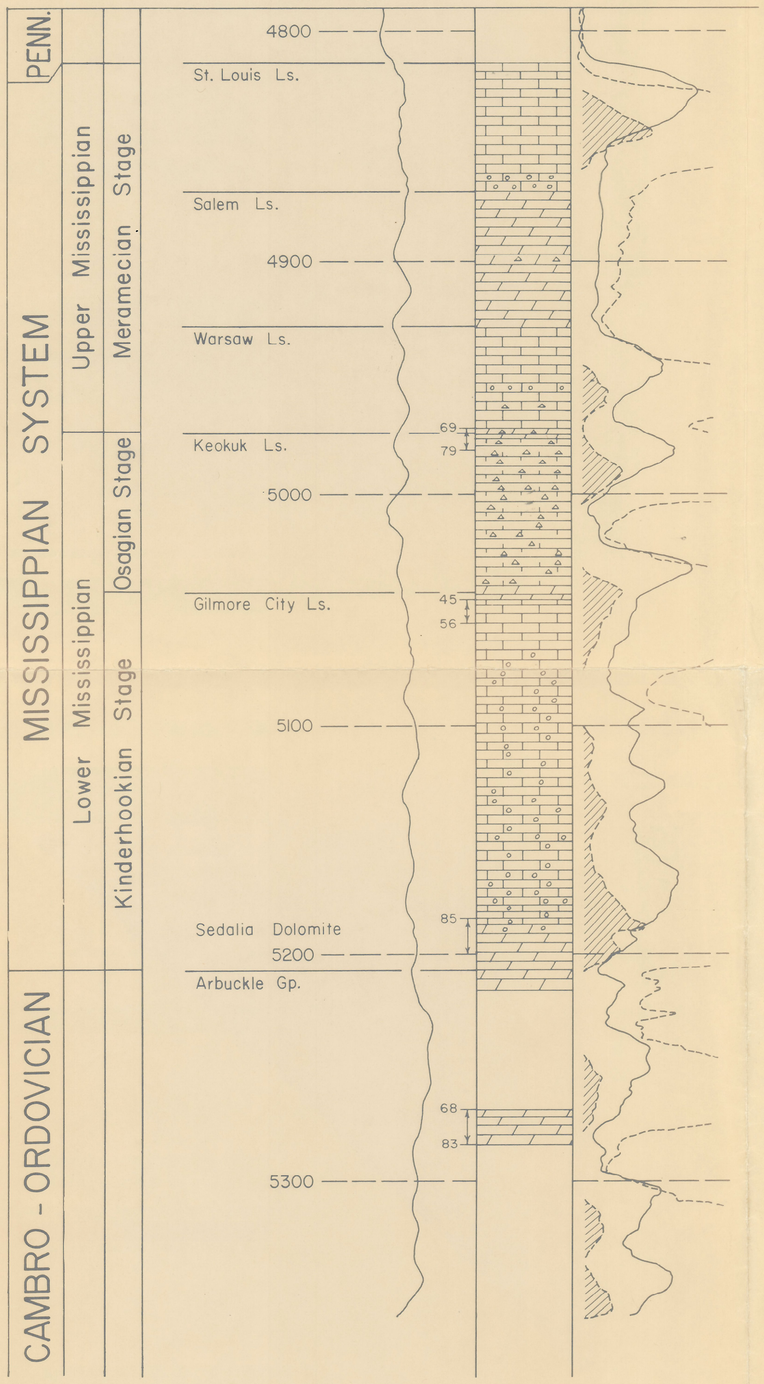
(X3)

FAUNA FROM RESIDUES (4541'-4553')

Elictognathus? sp.
Icriodus sp.
Palmatolepis sp.
Polygnathus sp.
Polylophodonta sp.
Pseudopolygnathus sp.

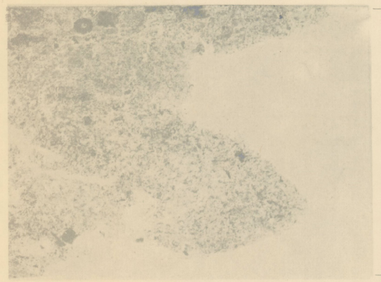
PREPARED BY EDWIN D. GOEBEL, 1966

THE TEXAS CO.
NO. 1 F.L. SMITH
Sec. 30, T.11S., R.36W. Logan Co.
Elev. 3239 ft.



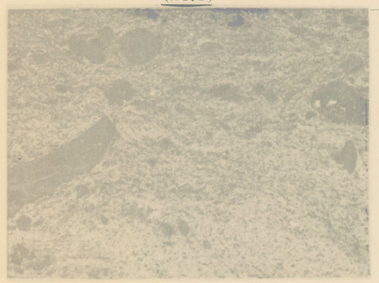
KEOKUK LIMESTONE

4969

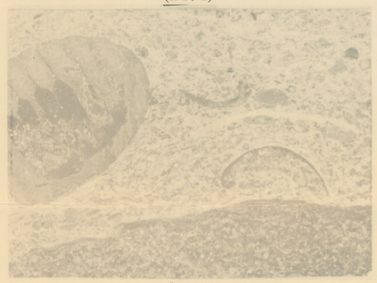


(X4.2)

4969-4973 Dolomite, fine-grained, gray to brown, with microfossiliferous, chalky and chalcedonic cherts. Residue greater than 65 percent insoluble with minor amounts of silt, pyrite and sphalerite.

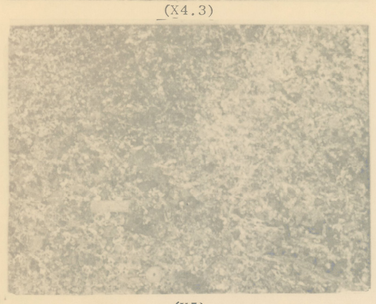


(X4.4)



(X4.3)

4974-4979 Limestone, crinoidal, gray, with microfossiliferous speckled, opaque chert. Residue less than 35 percent insoluble containing glauconite, pyrite, silty shale and traces of beekite and black waxy shale.



4979

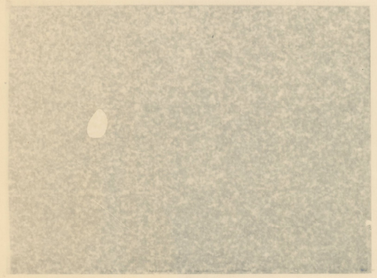
(X5)

FAUNA FROM RESIDUES (4969-79)

Gnathodus texanus
Hindeodella sp.
Ligonodina sp.
Taphrognathus varians
fish teeth

GILMORE CITY LIMESTONE

5045



5056

(X4.6)

5045-5056 Limestone, fine-grained to lithographic, gray to tan, faintly cross-bedded. Residues less than 1 percent comprised of pyrite, double-terminated euhedral quartz and trace of soft, black to chocolate shale.

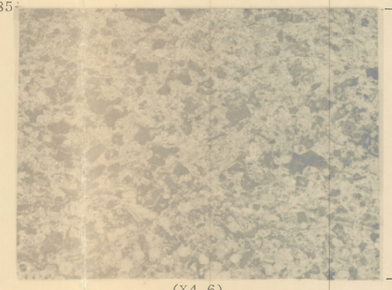
FAUNA FROM RESIDUES

Spathognathodus sp.
Hibbardella sp.

GILMORE CITY LIMESTONE

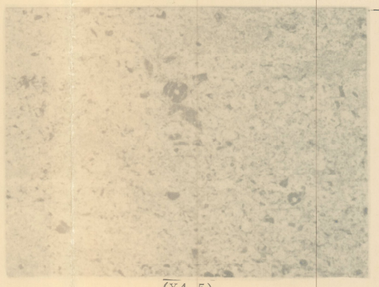
PLATE 9

5185

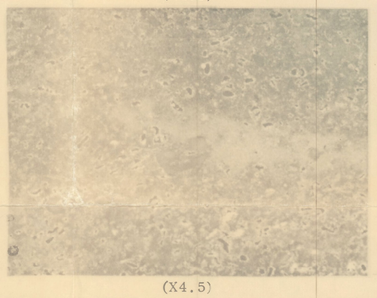


(X4.6)

5185-5187 Limestone, oolitic, gray, finely crystalline matrix. Residues less than 5 percent comprised of beekite replaced brachiopod valves and silicified crinoid? columnals.



(X4.5)



(X4.5)

5187-5196 Dolomite, finely crystalline, brown, honeycombed and abundant relict crinoid? columnals and oolites. Residues less than 3 percent comprised of silica replaced crinoid columnals and brachiopod valves; sphalerite, pyrite and beekite in minor amounts.

(X4.5)

5197-5200 Dolomite as above changing into fine-grained dolomite below a stylolite (5199). Residues to 5199 feet, less than 3 percent and dominated by double-terminated euhedral quartz; 5200 feet, residue greater than 40 percent, comprised of pyrite, sphalerite, glauconite, anhydrite, galena.

5200

(X4.8)

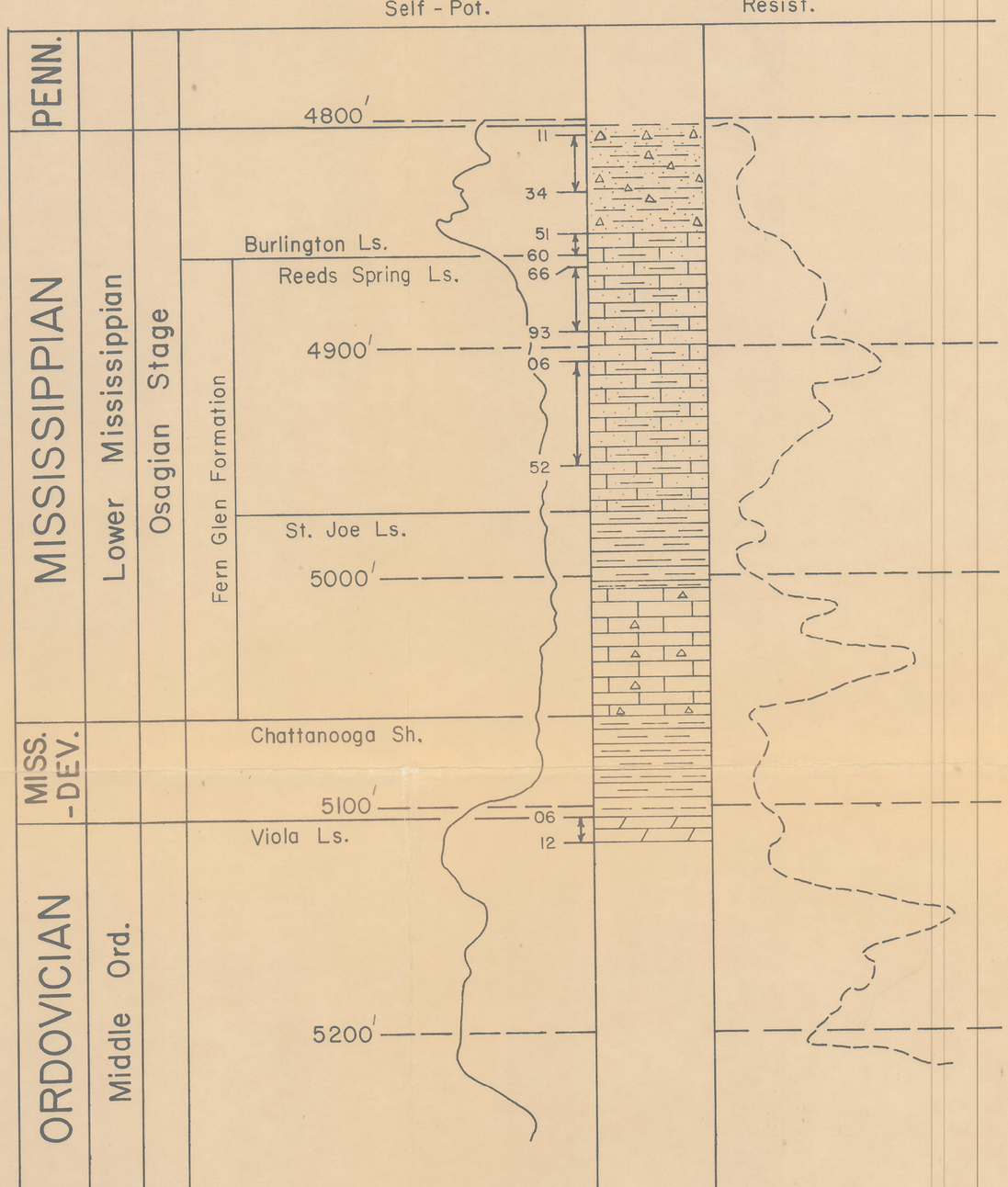
FAUNA FROM RESIDUES (5185-5200)

Elictognathus lacerata
Polygnathus inornata
Siphondella cooperi
S. crenulata
S. isosticha
S. quadriplicata
Spathognathodus crassidentatus
Synprioniodina sp.
fish teeth

PREPARED BY EDWIN D. GOEBEL, 1966

SINCLAIR PRAIRIE OIL CO.
NO. 1 ALICE GENTRY
Sec. 1, T. 33 S. R. 15 W. Barber Co.
Elev. 1894 ft.

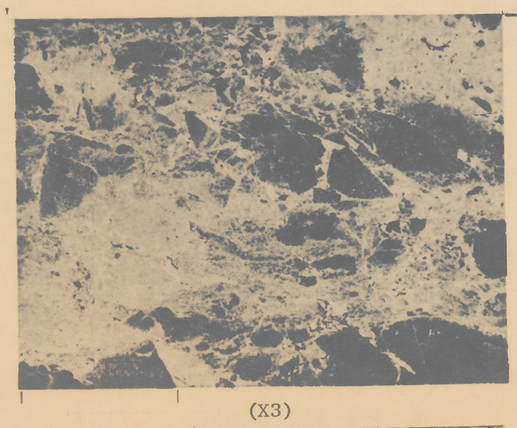
(577.3m)



Peel-prints

BURLINGTON LIMESTONE

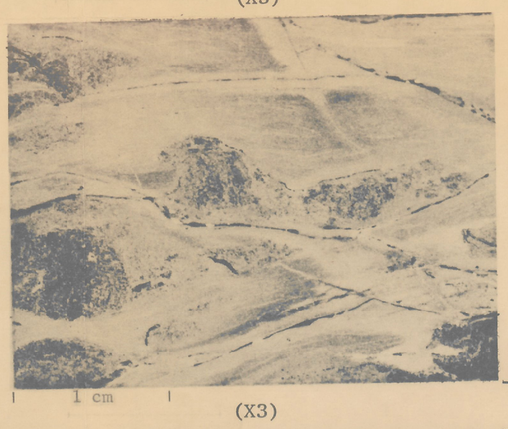
4811'



(X3)

FAUNA FROM RESIDUES (4811'-4860')

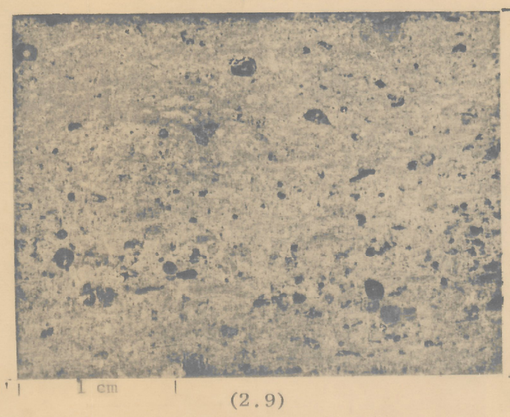
Gnathodus antetexanus
G. cuneiformis
G. semiglaber
G. texanus
Lonchodina sp.
Metalonchodina sp.
Polygnathus? sp.
fish teeth



1 cm

(X3)

4811'-34' Shale, green to gray, silty, in flow structure around chunks of bluish-white semi-translucent mottled to dull, bordered with chalcedonic to chalky chert. Residues greater than 90 percent, comprise shale and chert as above, and a trace of microfossiliferous chert.



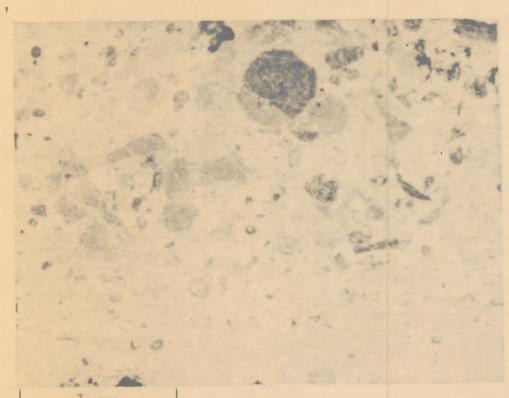
4860' 1 cm

(2.9)

4851'-60' Limestone, gray to green, semicrinoidal; crinoid ossicles occur in roughly delineated bands. Residues, 10 percent, comprise green shale, quartz, drusy and hackly, siliceous fossil fragments (crinoid ossicles and brachiopod valves); a trace of chert and a trace of glauconite in the lower part. Pentremites elongatus (Shumard) reported by Laudon (1937).

REEDS SPRING LIMESTONE

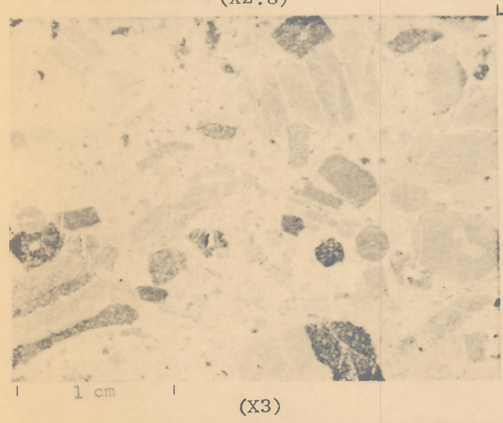
4866'



1 cm

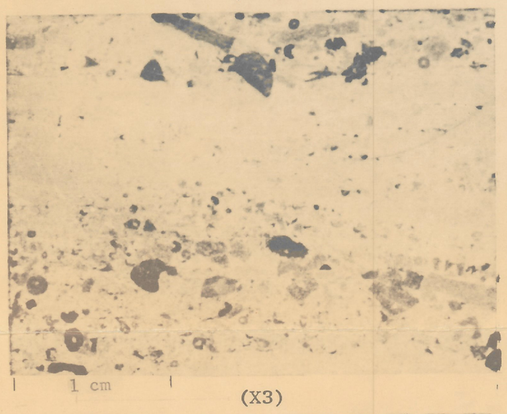
(X2.8)

4866'-70' Limestone, green to gray, semicrinoidal with wavy bands of green shales. Residue, less than 25 percent, comprised of shale, green, soft, flaky and siliceous fossil fragments.



1 cm

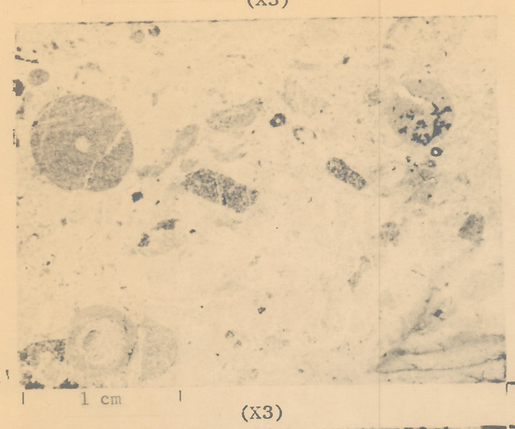
(X3)



1 cm

(X3)

4870'-93' Limestone, semicrinoidal, reddish, greenish, in thin beds with layering of fossil fragments (crinoid ossicles). Residues range from 5 to 40 percent, comprised of crinoid (silicified) ossicles, shale (hematitic) and trace of phosphatic pellets.

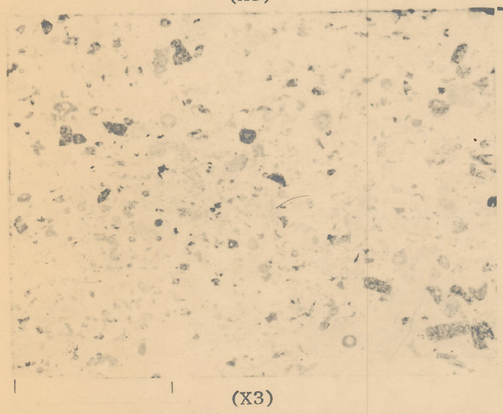


4893' 1 cm

(X3)

FAUNA FROM RESIDUES (4866'-93')

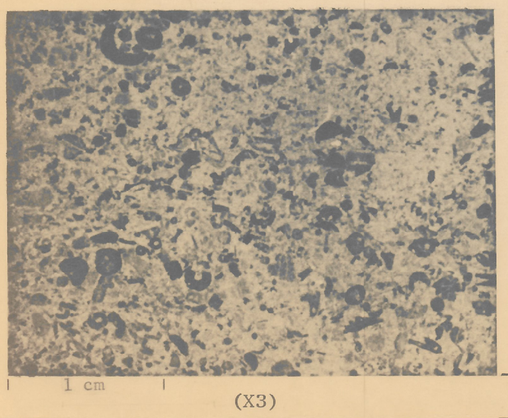
Bactrognathus?
Gnathodus antetexanus
G. cuneiformis
G. semiglaber
G. texanus
Lonchodina sp.
Metalonchodina? sp.
Polygnathus? sp.
Spathognathodus sp.
fish teeth



(X3)

FAUNA FROM RESIDUES (4906'-52')

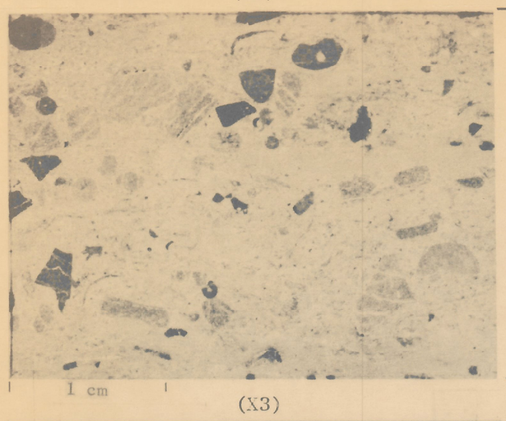
Bactrognathus sp.
Doliognathus sp.
Gnathodus antetexanus
G. cuneiformis
G. texanus
Polygnathus communis
Pseudopolygnathus sp.
Spathognathodus sp.
fish teeth



1 cm

(X3)

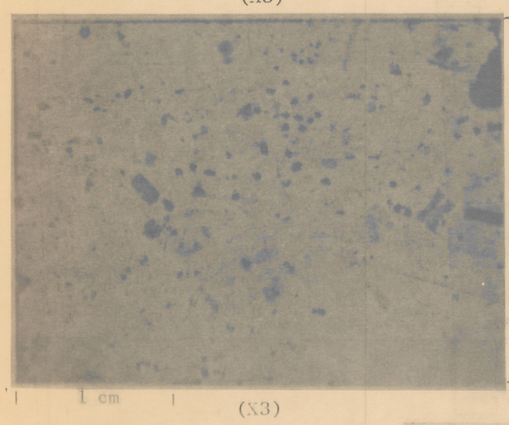
4906'-20' Limestone, reddish, semicrinoidal with crinoid ossicles in rough bands. Some thin green limestone beds. Residues less than 10 percent, comprised of hematitic shale and green shale, silicified crinoid ossicles and a trace of chert, glauconite in the upper part and a trace of marcasite in the lower part.



1 cm

(X3)

4921'-27' Limestone, green to gray, semicrinoidal with layering of ossicle fragments. Residues range from 10 to 40 percent, comprised mostly of shale and a trace of marcasite.



4953' 1 cm

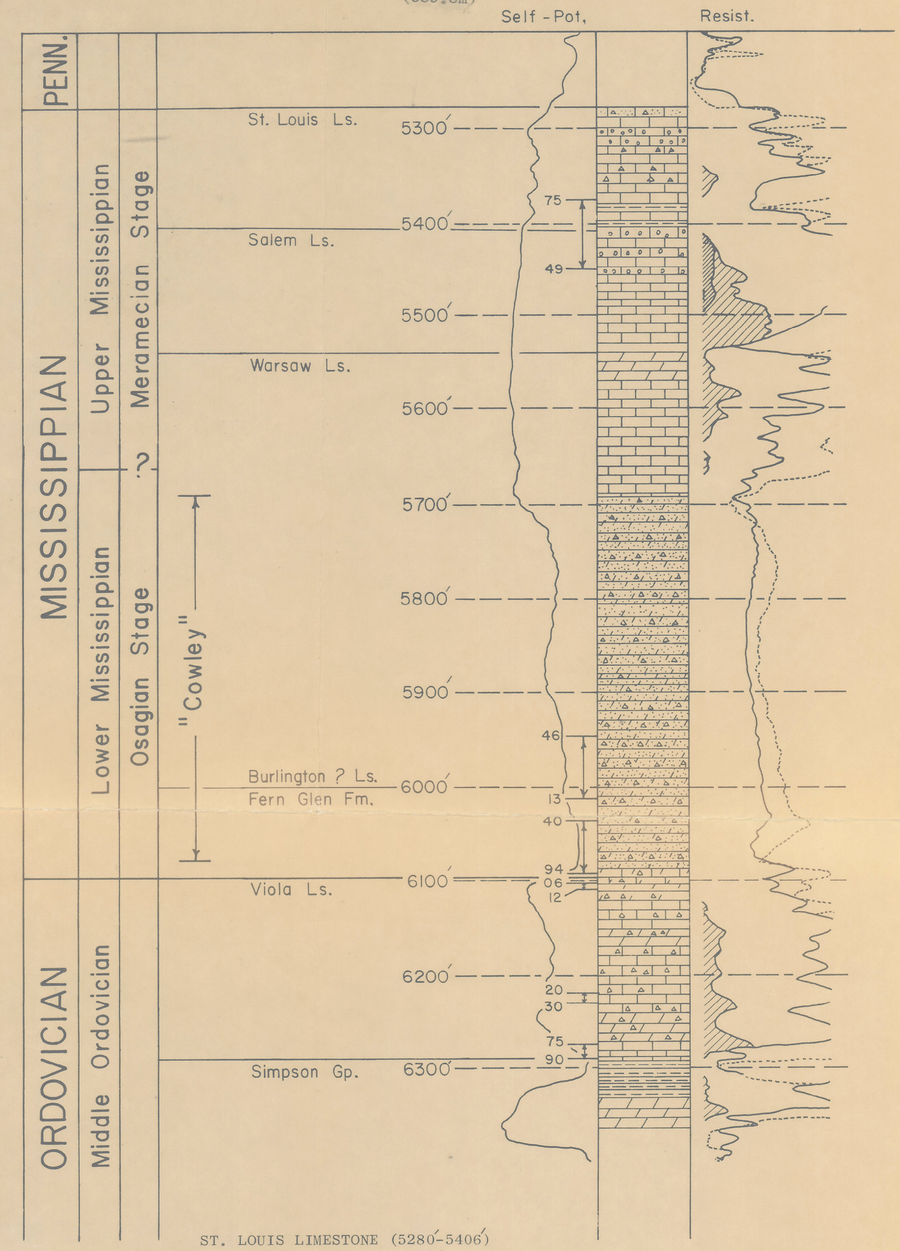
(X3)

4930'-53' Limestone, gray and shaly with scattered crinoid ossicle fragments. Residues from 5 to 30 percent increasing downward, comprised of fossiliferous gray shale and trace of marcasite, pyrite, and galena. Marcasite replaced fossil fragments.

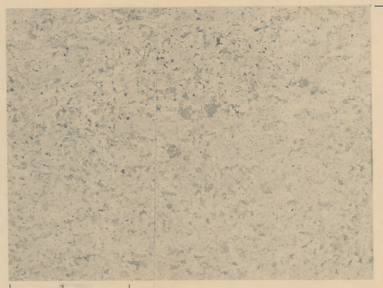
PLATE 10

Prepared by Edwin D. Goebel, 1966

SINCLAIR PRAIRIE OIL CO.
NO. 1 EXCHANGE BANK
Sec. 27, T. 33 S., R. 19 W., Comanche Co.
Elev. 1935 ft.
(589.8m)

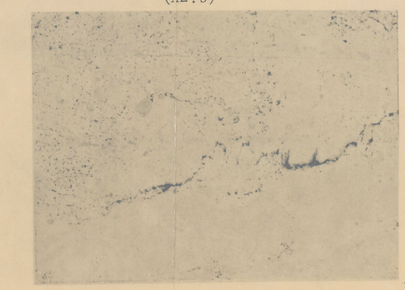


ST. LOUIS LIMESTONE (5280'-5406')



Peel-prints

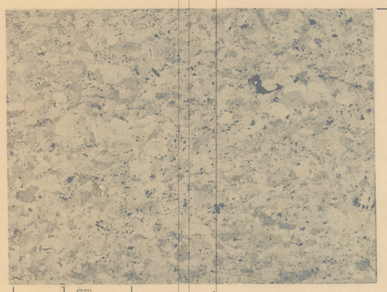
5375'-5406' Limestones (calcarenites), shaley to silty, light gray stylolitic, interbedded with green shales; scattered fragments of echinoderm plates, corals, and brachiopod valves; pyrite. Residues from less than 1 to more than 15 percent, generally less than 3 percent insoluble, comprised of silt and shale, anhedral quartz, blue-black chalky chert, pyrite and trace of dark green glauconite.

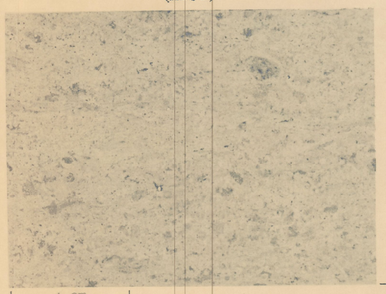


FAUNA FROM RESIDUES

Apatognathus? porcata
Cavusgnathus characta
C. regularis
C. unicornis
Gnathodus texanus
Lambdagnathus fragilidens
Ligonodina levis
L. roundyi
Neoprioniodus tulensis
Spathognathodus cristula
Taphrognathus varians

SALEM LIMESTONE (5407'-5050'?)



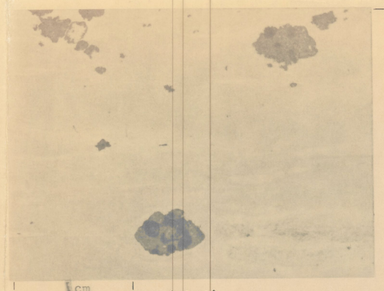


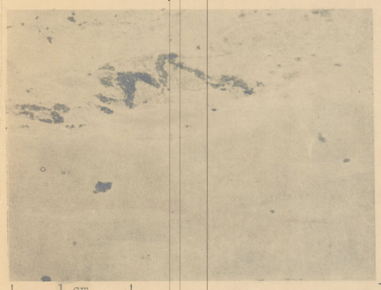
5406'-5448' Limestone, semi-crinoidal, light gray, medium crystalline matrix, scattered to abundant stylolites; scattered crinoid ossicles, intercalated oolitic beds. Residues less than 3 percent insoluble comprised of gray to brown shale, pyrite, anhedral quartz, chalky chert and glauconite. Heavy concentration of glauconite and pyritiferous shale at base; trace of sphalerite.

FAUNA FROM RESIDUES (5406'-48')

Hibbardella fragilis
Ligonodina levis
Neoprioniodus loxus
N. tulensis
Spathognathodus cristula
Taphrognathus varians

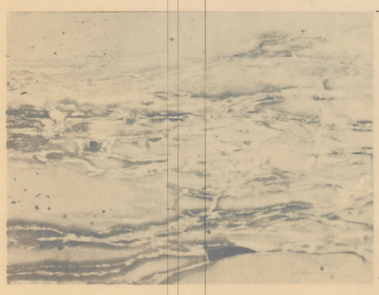
BURLINGTON? LIMESTONE (?-6000')





5946'-6013' Shale, argillaceous, siliceous, green-gray dolomitic, containing scattered blebs of dark blue opaque chert; few thin bands of shale (less than 1/4 inch thick near base); scattered chunks of milky, drusy quartz. Residues more than 98 percent insoluble. No fossils recovered.

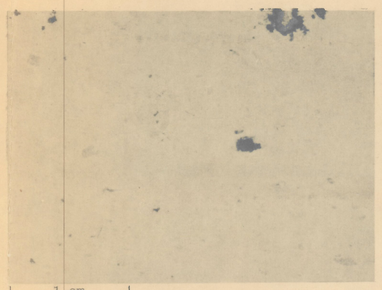
FERN GLEN FORMATION (6001'?-6100')



6040'-6095' Chert-clay rock, argillaceous as above with distinct gray shale partings; calcareous shale in lower part, thin bed of semicrinoidal limestones at 6092; green-black shale below. Generally, insoluble residues from 6080 - 6095 comprised of gray silty shale, chalcedonic chert, pyrite, drusy quartz, and trace of glauconite.

PLATE II

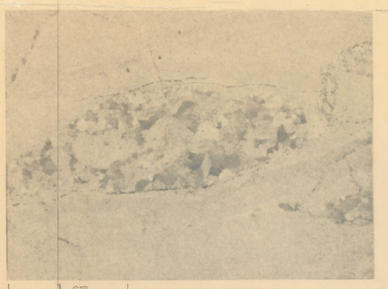
(Fern Glen Formation)



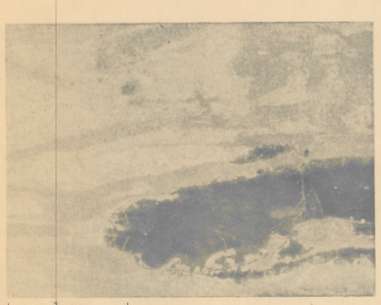
FAUNA FROM RESIDUES (5946'-6094')

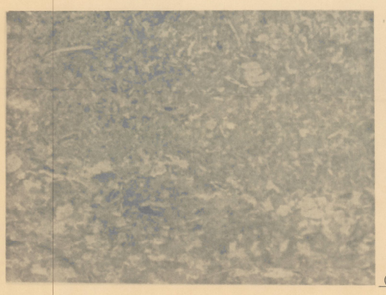
(6011'-15')
Gnathodus texanus
Polygnathus communis
(6085-95)
Gnathodus antetexanus
G. delicatus
G. semiglaber
G. texanus
Polygnathus communis
Pseudopolygnathus multistriata
"spores"

VIOLA LIMESTONE (6101'-6290')



6106'-6112' Dolomite, finely crystalline, gray to brown, with included chunks of coarsely crystalline limestone; dark blue to gray chert lenses. Residues comprised of chert and pyrite, scolecodonts.

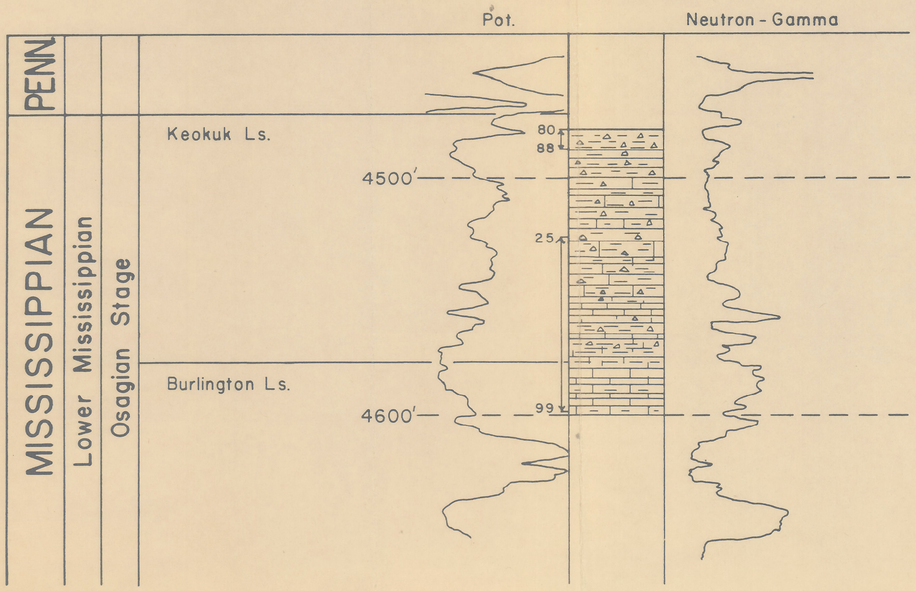




6220'-6230' Dolomite. Residues include scolecodonts and conodonts from the families Belonodontidae and Distaconodontidae.

PREPARED BY EDWIN D. GOEBEL, 1966

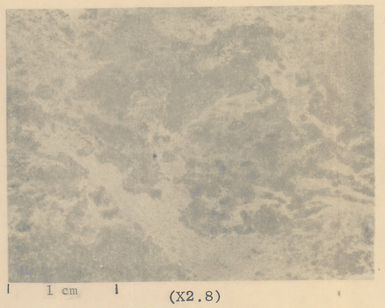
SINCLAIR OIL & GAS CO.
NO. 1 CIRCLE
Sec. 14, T. 33 S. R. 11 W. Barber Co.
Elev. 1436 ft.
(437.7m)



Peel-prints

KEOKUK LIMESTONE (4474'-4576') ——— FAUNA FROM RESIDUES (4480'-4576')

Gnathodus texanus
Hindeodella sp. ind.
Lonchodina paraclarki
Taphrognathus varians

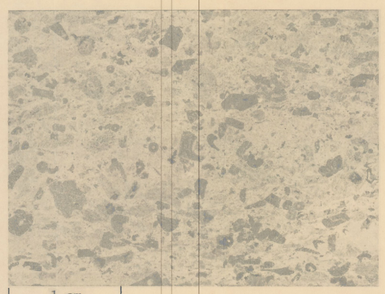

1 cm (X2.8)

4480'-4488' Shale, silty, gray-green with disseminated chalcedonic to chalky blue-black chert. Trace of pyrite and glauconite in insoluble residues (more than 60 percent).

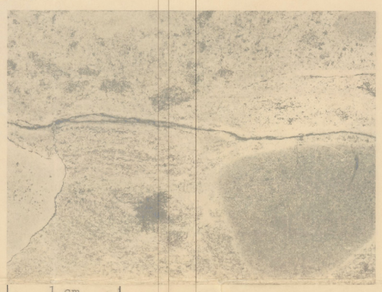
1 cm (X3)

4525'-4551' Shale, calcareous, green, waxy in wavy bands around white chalcedonic chert. Residues about 50 percent insoluble comprised of gray to green silty shale, and chert.

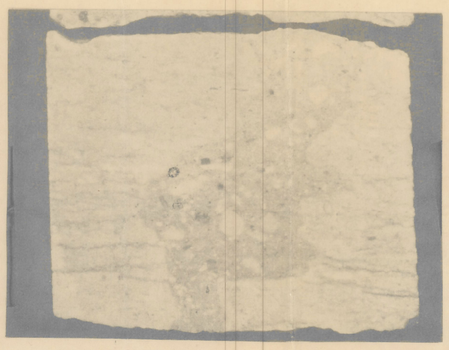
(Keokuk Limestone)

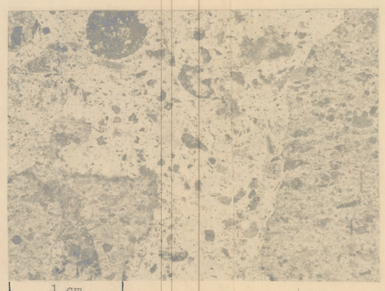

1 cm (X2.9)

4552'-4555' Calcarenite, medium to coarse grained; skeletal grains of echinoderm and brachiopod fragments. Residue less than 5 percent comprised of gray shale, up to 20 percent anhedral quartz and chalky to chalcedonic chert. Trace of glauconite near base.


1 cm (X2.9)

4556'-4562' Shale, calcareous, green with fresh and chalky, sparsely microfossiliferous chert. Residues from 40 to 90 percent insoluble include glauconite and pyrite.


Photograph of polished core slab. (4563'-4564')


1 cm (X3)
Peel-print. (4563'-4564')

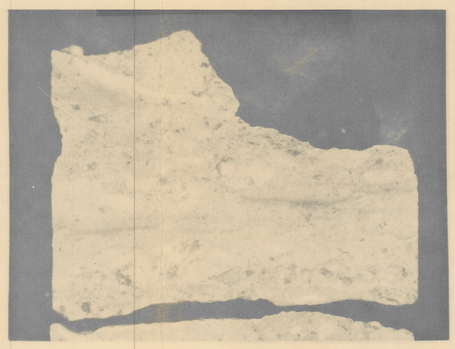
4563'-4564' Calcarenite, green medium-grained thin shale partings; large openings filled with encrinital limestone. Residues less than 5 percent consist of green shale, ordinary chert and a trace of glauconite.

4565'-4576' (not depicted) Shale, calcareous, green, containing fresh and chalky chert. Residues generally greater than 60 percent consist of ordinary granular and chalky chert.

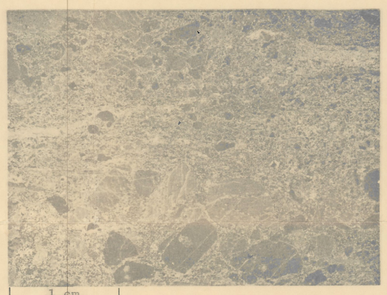
PLATE 12

BURLINGTON LIMESTONE (4577'-?) ——— FAUNA FROM RESIDUES (4577'-4599')

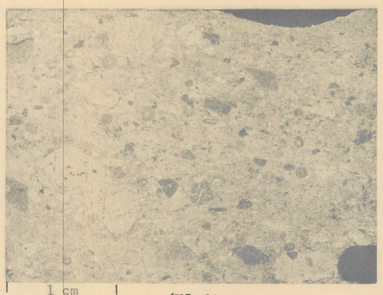
Bactrognathus hamata
Gnathodus antetexanus
G. semiglaber
G. texanus
Polygnathus communis
Pseudopolygnathus sp.


Photograph of polished core slab. (4585'-4586')

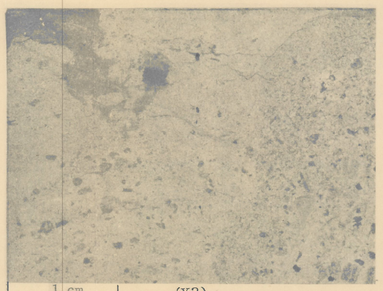
4577'-4585' (not depicted) Limestone, medium-grained, green-gray, with green shale laminations, limestone, semi-crinoidal near base. Residues small, less than 3 percent consist of green shale, anhedral quartz, trace of pyrite, beekite, and glauconite at base.


1 cm
Peel-print. (4585'-4586') (X2.9)

4586'-4589' Limestone, semi-crinoidal, green-gray. Residues nearly 10 percent consist of 75 percent pyrite, minor amounts of gray shale, and anhedral quartz.

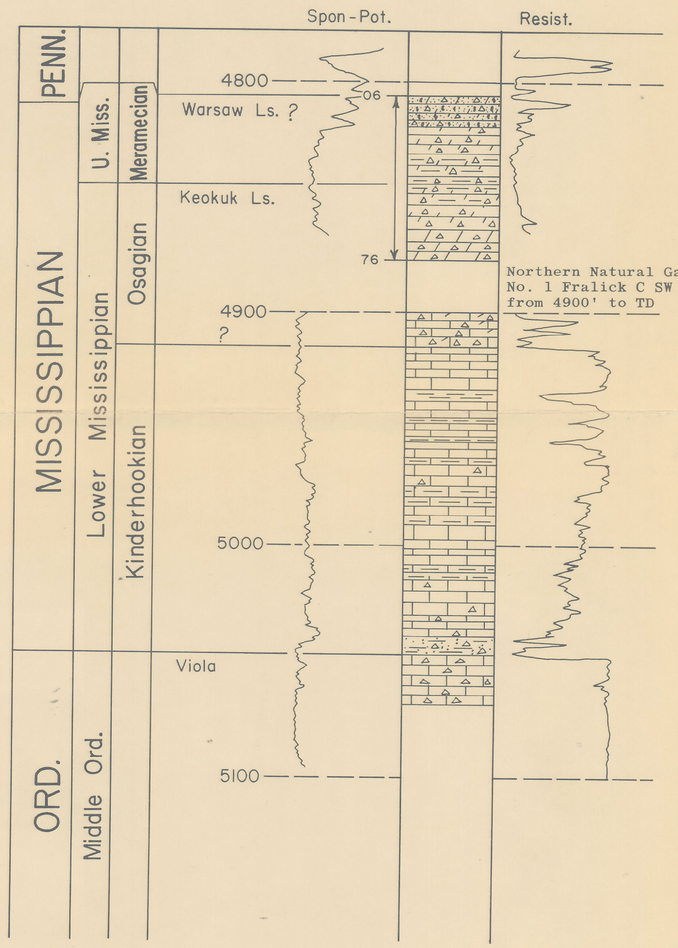

1 cm (X2.8)

4590'-4599' Limestone, semi-crinoidal in green shale matrix. Residues from less than 5 to more than 25 percent consist of shale, and silt with trace of pyrite at top.


1 cm (X3)

PREPARED BY EDWIN D. GOEBEL, 1966

NORTHERN NATURAL GAS PRODUCING CO.
NO. 2 FRALICK "A" C NE ¼ SW ¼
Sec. 14, T. 27 S., R. 20 W. Kiowa Co.
Elev. 2296 ft.



WARSAW LIMESTONE?

4806'

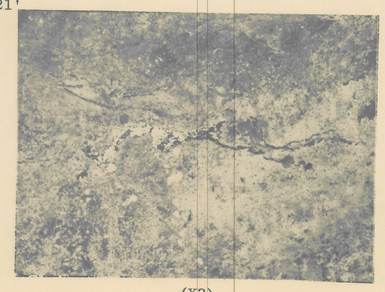
4820'

(X.8)

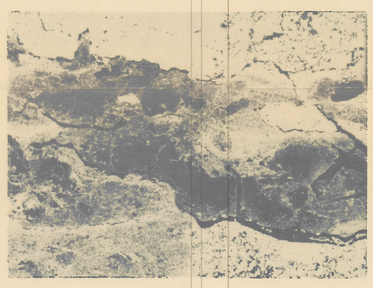
4806-4820 Shale, green to tan, waxy, conglomeratic, sandy, dolomitic with chunks of chert. Residue more than 75 percent insoluble, consists of green shale, and fine to medium sub-rounded frosted sand to 4816; porcelaneous drusy chert, green-gray shale and trace of pyrite and glauconite to 4820.

(Warsaw?)

4821'



(X3)



(X3)

4821-4844 Shale, green, with fresh and weathered geodal, vuggy, white, granular, opaque chert. Residue more than 75 percent insoluble comprised of granular, spicular, chalky chert.

4844'

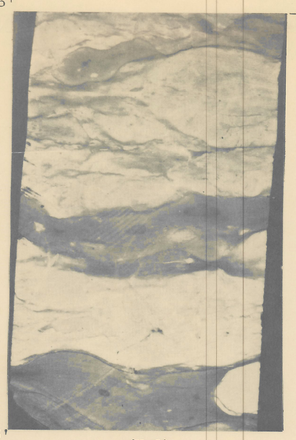
(X3)

FAUNA FROM RESIDUES (4806-4844)

conodont fragments

KEOKUK LIMESTONE

4845'



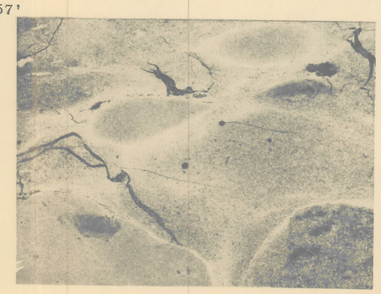
4856'

(X.8)

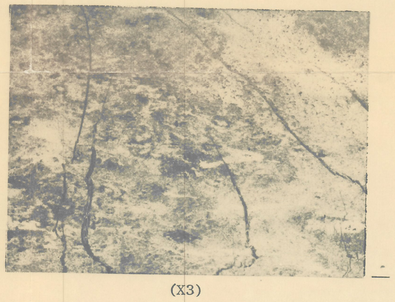
4845-4856 Chert, white, chalky granular and vugular, contained in wavy bands of dolomitic gray shale. Residue greater than 60 percent insoluble comprised of chert and drusy quartz; a trace of anhydrite, pyrite and sphalerite in lower half.

(Keokuk)

4857'

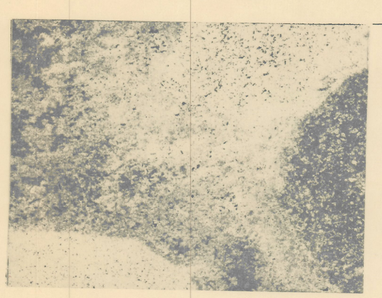


(X3)



(X3)

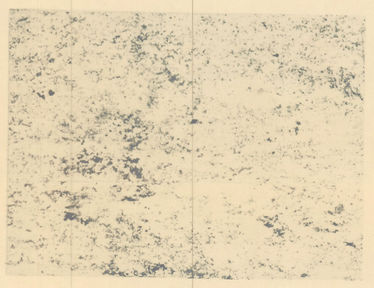
4857-4860 Chert, granular and chalky white, fissured, and in bands of green shale. Residues greater than 60 percent insoluble comprised of dolomoldic chert and trace of pyrite, and sphalerite and glauconite.



(X3)

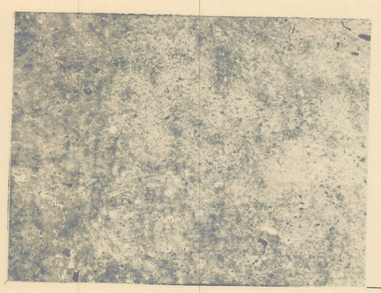
FAUNA FROM RESIDUES (4845-4860)

Gnathodus sp.
conodont fragments



(X3)

4861-4876 Dolomite, with decreasing percentage (downward) of chalky chert in bands. Residue percentage generally decreasing downward from about 50 percent to less than 10 percent; consists of chert, trace of black shale, pyrite; strong trace of glauconite.



4876

(X3)

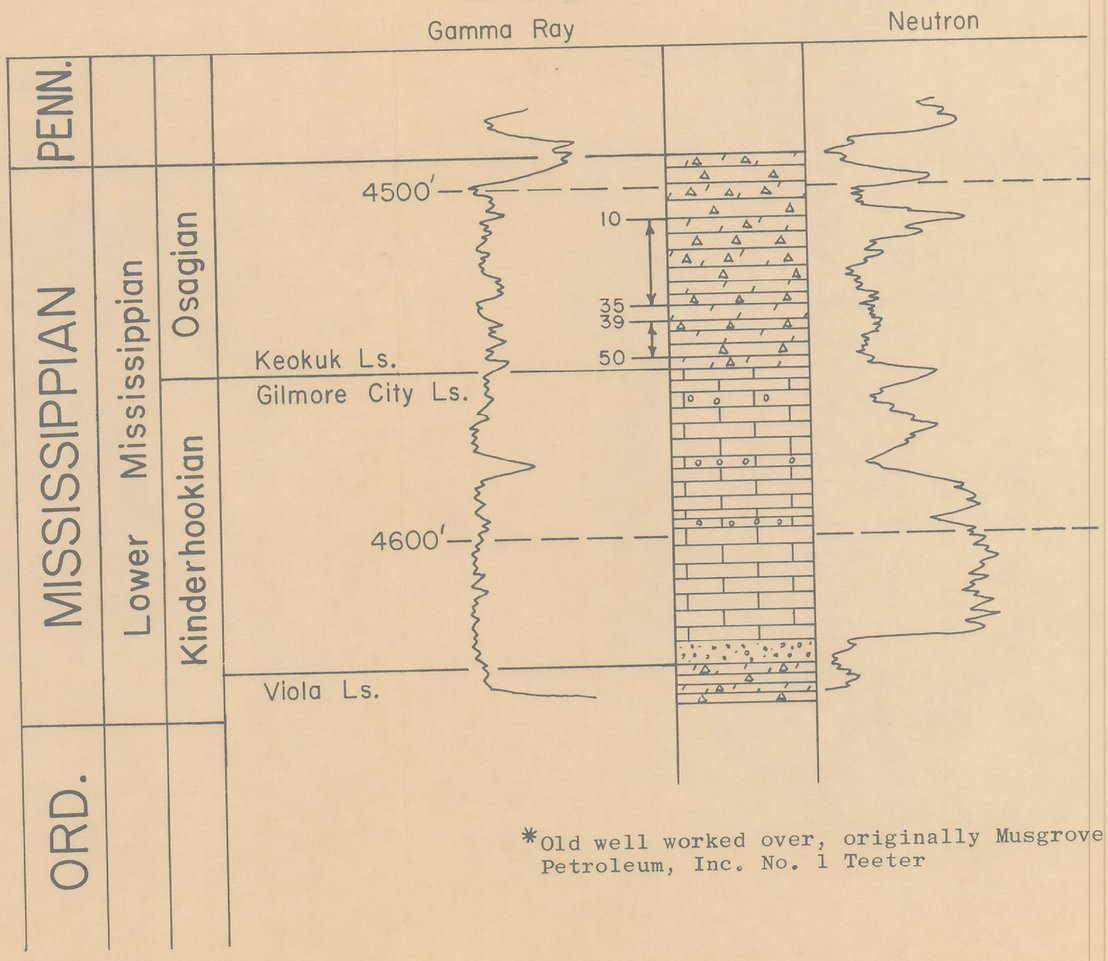
FAUNA FROM RESIDUES (4861-4876)

Gnathodus antetexanus
G. delicatus
G. texanus
Ligonodina sp.
Lonchodina sp.
Neoprioniodus sp.
Ozarkodina sp.
Spathognathodus sp.
Taphrognathus varians

PREPARED BY EDWIN D. GOEBEL, 1966

PLATE 14

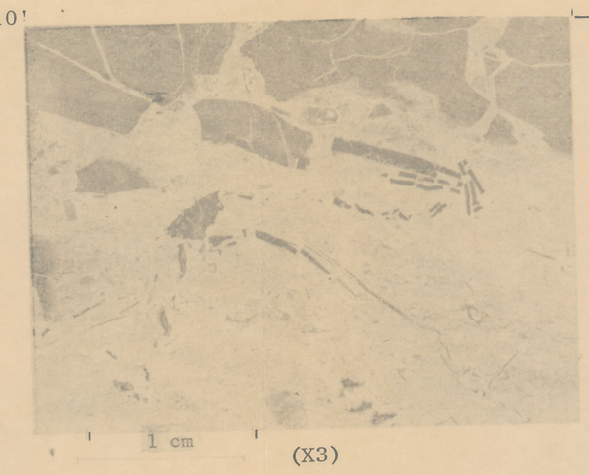
WYCOFF BROS.
NO. 1 TEETER "A"
Sec. 26 T. 13 S., R. 30 W., Gove Co.*
Elev. 2867 ft.
(873.9m)



*Old well worked over, originally Musgrove Petroleum, Inc. No. 1 Teeter

KEOKUK LIMESTONE

4510'



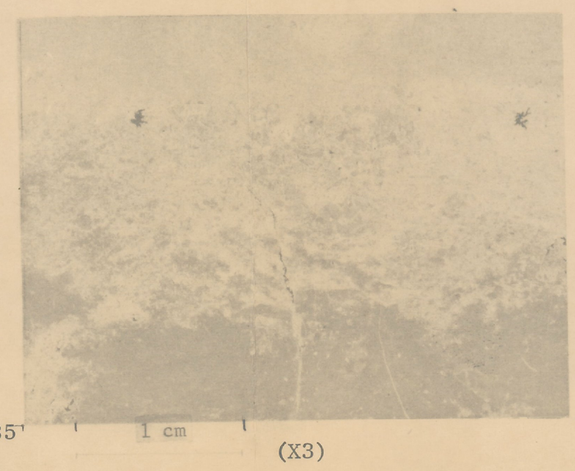
(X3)

Peel-prints

4510'-4535' Chert, blue-gray, granular to chalcedonic, bordered with chalky to tripolitic chert containing scattered microfossils; chert fractured to brecciated; void-filling limestone, fine-grained, brown, with stylolites and stringers of green-tan shale. Residues generally greater than 50 percent consist of chert as above, pyrite crystals, spicular glauconite, isolated euhedral quartz crystal, anhydrite, and trace of sphalerite.

FAUNA FROM RESIDUES (4510'-35')

Gnathodus texanus
Lonchodina paraclarki
Spathognathodus sp.
Taphrognathus varians
fish teeth



4535'

(X3)

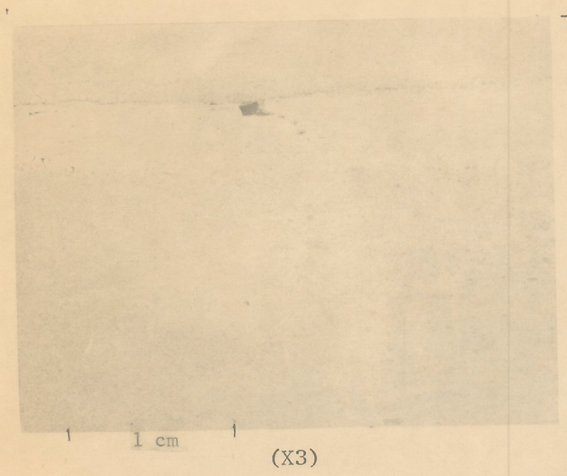
4515'

(X.8)

Photograph of slabbed rock core, note penetration of fractured chert, gray-white, by darker gray fine-grained limestone which exhibits a stylolite.

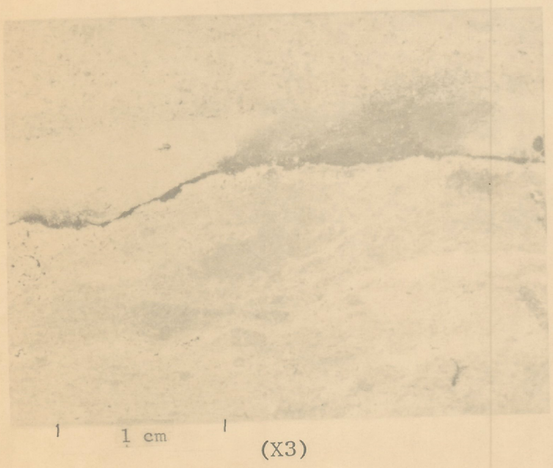
(Keokuk Limestone)

4539'

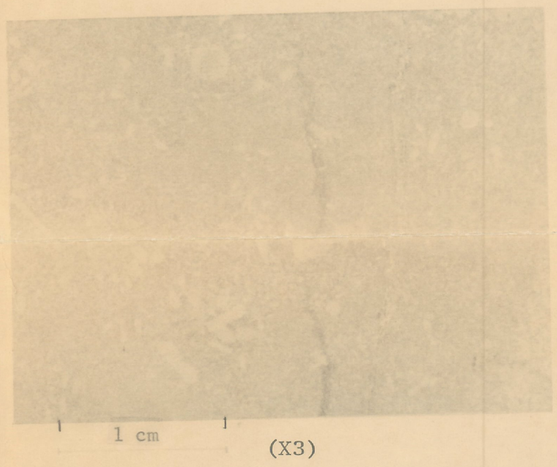


(X3)

Peel-prints

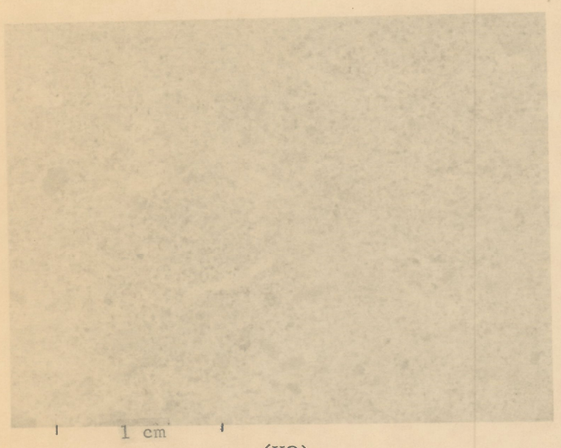


(X3)



(X3)

4539'-4550' Chert as above, microfossiliferous, to 4543. Dolomite and dolomitic limestone, fine-grained, tan to brown with thin green shale stringers, stylolitic; anhydrite-filled fractures transecting limestone and chert. Residues less than 50 percent consist of ordinary chert, pyrite and glauconite to 4543; green shale, drusy quartz and pyrite to 4546; gray granular chert (fossil-cast porosity) and strong trace of anhydrite.



(X3)

4550'

FAUNA FROM RESIDUES (4539'-50')

Gnathodus texanus
Ligonodina sp.
Lonchodina sp.
Magnilaterella? sp.
Palmatolepis glabra (reworked)
Polygnathus communis

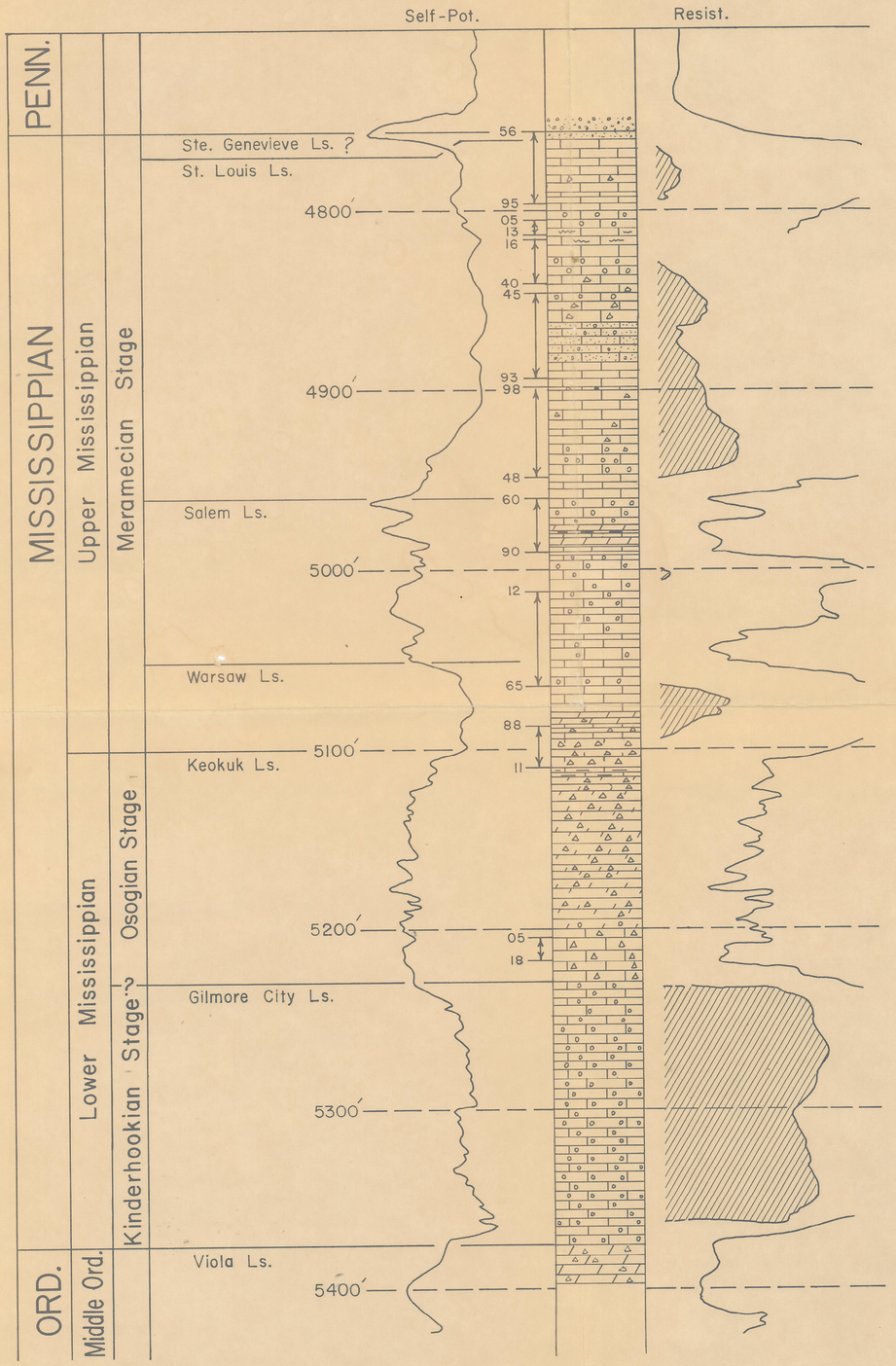
(X.8)

4548'

Photograph of slabbed rock core, note anhydrite-filled fracture which transects fossiliferous chert (center) and limestone.

PREPARED BY EDWIN D. GOEBEL, 196

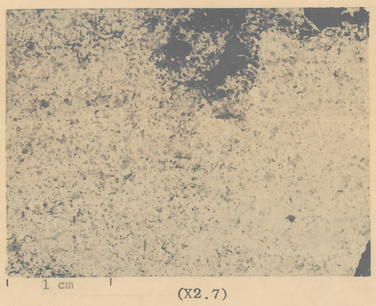
ATLANTIC OIL CO.
NO. I-A MARK
Sec. 28, T. 20 S., R. 33 W. Scott Co.
Elev. 2943 ft.
(894.3m)



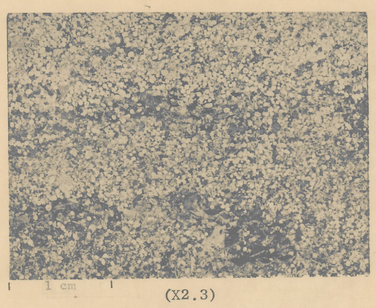
Peel-prints

ST. LOUIS LIMESTONE — FAUNA FROM RESIDUES (4756-4959')

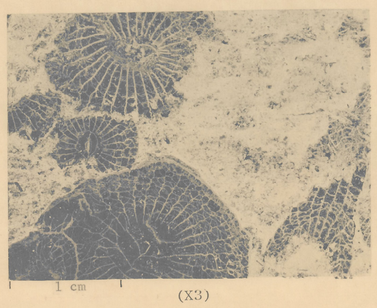
Apatognathus? gemina
Cavusgnathus regularis
C. unicornis
Neoprioniodus loxus
Spathognathodus scitulus
Taphrognathus sp.


1 cm
(X2.7)

4761'-4769' Limestone, brown, fine-grained, isolated fine sand grains, faintly oolitic structures. Residues (4756-95) less than 2 percent, sand grains, gray shale, silicified fossil fragments, trace of pyrite.

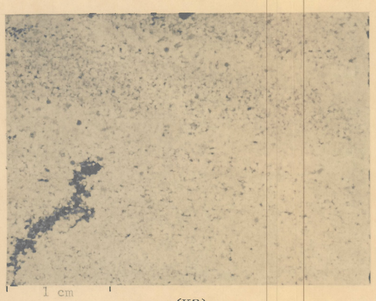

1 cm
(X2.3)

4811' Limestone, gray, oolitic.

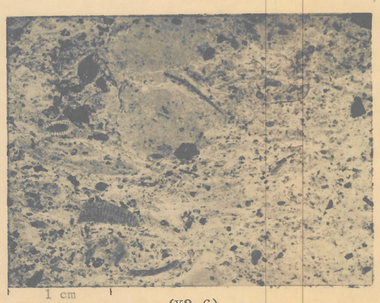

1 cm
(X3)

4812'-4813' Limestone, fine-grained ground mass with abundant corallites (Lithostrotion proliferum). Residues (4808-13') less than 2 percent, shale, trace of beekite, pyrite.

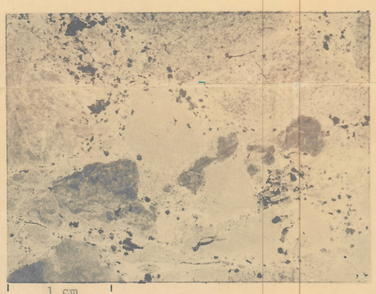
(St. Louis Limestone)


1 cm
(X3)

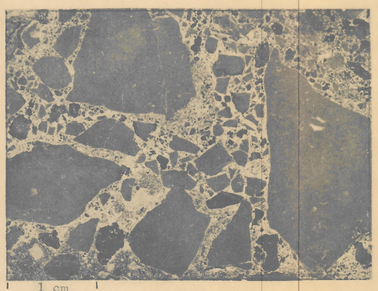
4836'-4840' Limestone, oolitic and arenaceous. Note banding of oolites, possibly representing cross-bedding. Residues (4816-40) less than 5 percent, silt and fine sand, trace of pyrite.


1 cm
(X2.6)

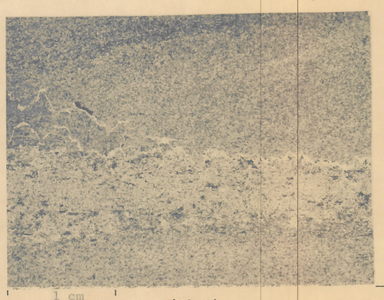
4861' Limestone, fossiliferous (calcarenite); scattered chunks of blue-black chert. Residue (4846-61) generally less than 5 percent, silt, green-brown shale, drusy quartz, beekite, fine sand.


1 cm
(X2.9)

4862' Limestone breccia, subangular, fine-grained limestone fragments in ground mass of calcareous silty shale. Residues (4862-65) less than 20 percent comprised of gray shale, ordinary chert, beekite and fine frosted sand.


1 cm
(X2.3)

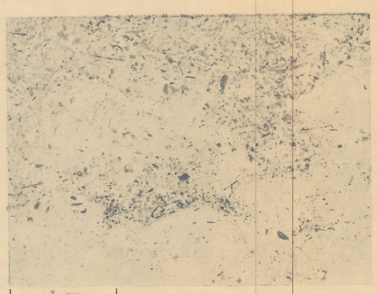
4898' Chert, fragmented in ground mass of silty calcareous shale. Residues (4886-98) generally less than 5 percent to 4896, greater than 70 percent to 4898, ordinary chert, platy gray shale, silicified fossil fragments (echinoderm and brachiopod).


1 cm
(X2.8)

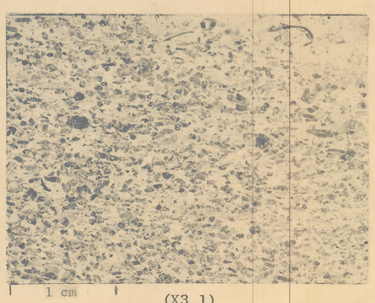
4948' Limestone, medium grained, brown, oolitic, with stylolites. Residues (4901-48) less than 3 percent to 4945, greater than 30 percent to 4948, comprised of brown shale, silicified fossil fragments, chert, and tract of sphalerite.

SALEM LIMESTONE — FAUNA FROM RESIDUES (4960'-5050')

Apatognathus? n. sp. A
Ligonodina levis
Taphrognathus varians


1 cm
(X2.9)

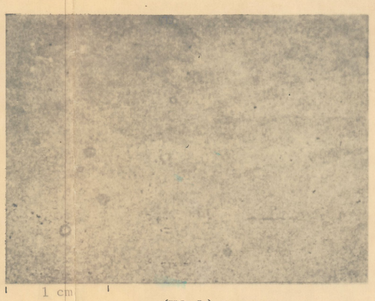
4966' Limestone, fossiliferous (calcarenite); fragments of echinoderms and bryozoans, sparse oolites. Note sponge spicules. Residues (4960-72) from 10 percent downward to more than 60 percent, green shale, white silicified echinoderm and brachiopod fragments, monaxon sponge spicules.


1 cm
(X3.1)

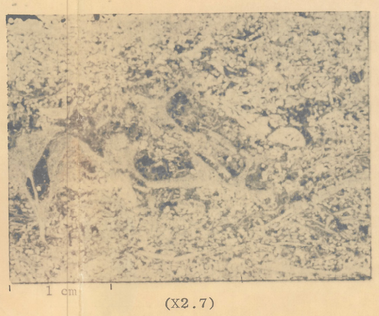
4983' Calcarenite, medium-grained, faint laminations. Residues (4973-88) generally less than 30 percent, fine gray silt, silicified fossil fragments.

(Salem Limestone)

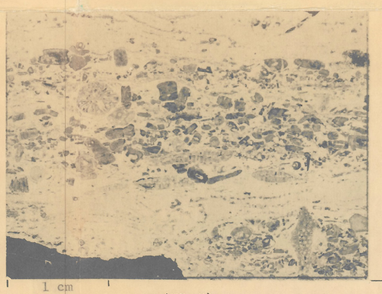
PLATE 15


1 cm
(X3.1)

4990' Dolomite, fine-grained, gray, sparse chert. Residues, less than 15 percent, green silty shale.


1 cm
(X2.7)

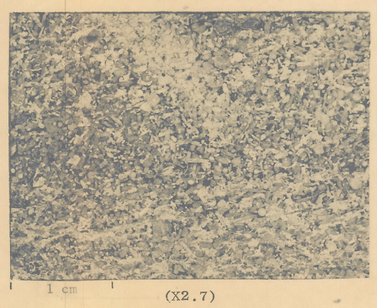
5026'-5030' Calcarenite, fine-grained, oolitic, note preservation of delicate fenestrate bryozoan fronds in lens. Residues (5012-35) less than 5 percent, gray shale, silicified fossil fragments, trace of pyrite.


1 cm
(X2.9)

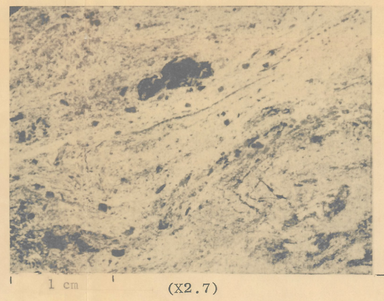
5055'-5060' Calcarenite, fine-grained with laminations of fossil fragments, corals, echinoderms, bryozoans. Residues less than 10 percent, brown shale, and siliceous fossil fragments.

WARSAW LIMESTONE — FAUNA FROM RESIDUES (5050'-5100')

Gnathodus texanus
Palmatolepis glabra (reworked)


1 cm
(X2.7)

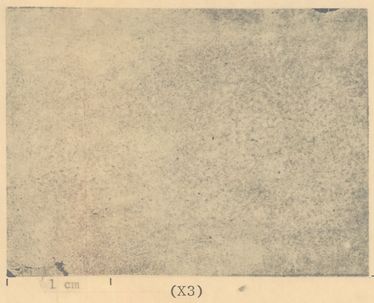
5065' Calcarenite, coarse-grained, oolitic. Residues (5060-65) less than 15 percent, silty shale and phosphatic pellets.


1 cm
(X2.7)

5090'-5096' Chert, blue-gray, chalky, in ground mass of fine-grained calcareous shale. Residues (5088-5111) more than 70 percent, silty shale, granular chert, silicified oolites and strong trace of glauconite.

KEOKUK LIMESTONE — FAUNA FROM RESIDUES (5205'-5218')

Gnathodus texanus
Taphrognathus varians


1 cm
(X3)

5205'-5218' Limestone, dolomitic, fine-grained, cherty. Residues less than 10 percent, gray granular, ordinary chert, fine silt, and trace of glauconite.

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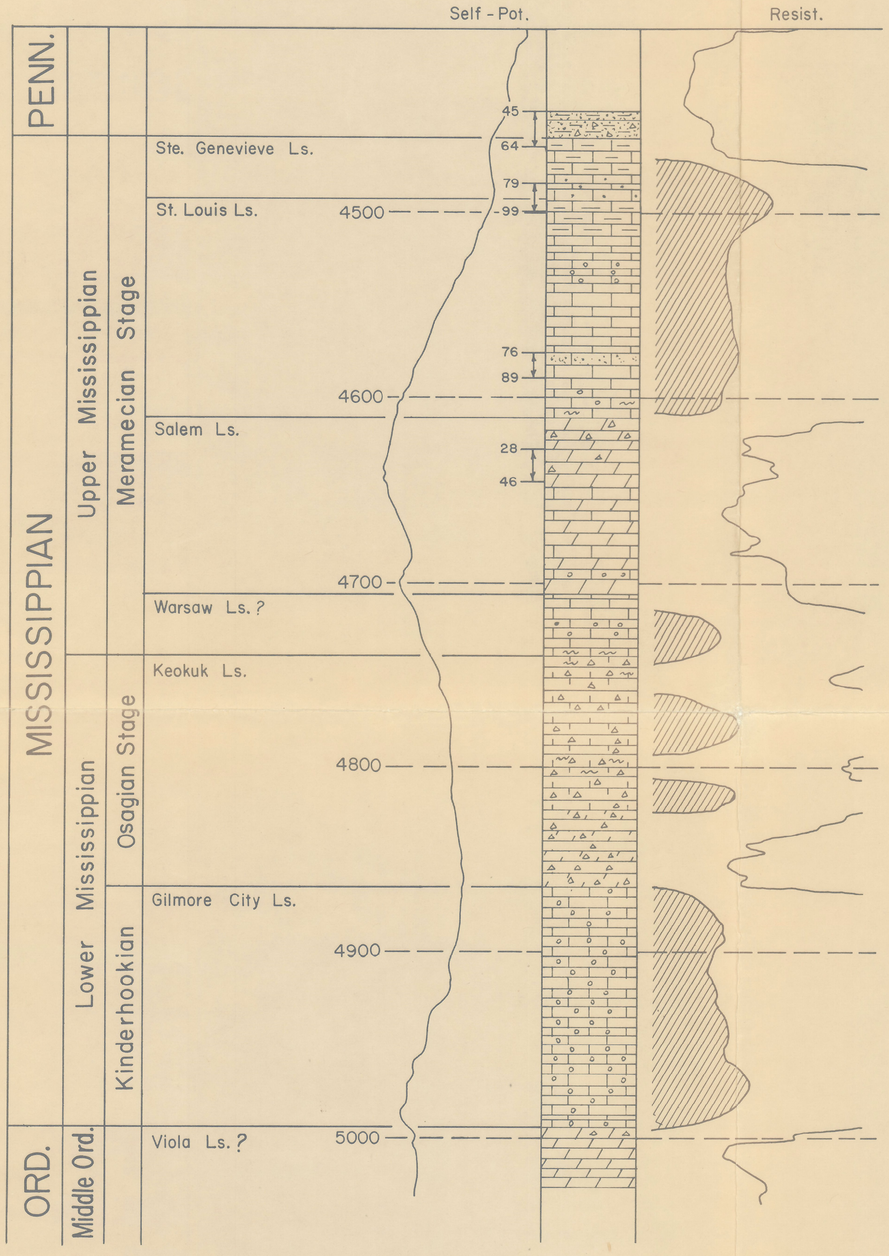
ALMA AND MCNEELEY
NO. 1 WATCHORN
Sec. 13, T 15 S., R. 33 W., LOGAN CO.
Elev. 2780 ft.



STE. GENEVIEVE LIMESTONE (4460-4488)

(X3)

4460-4464 Shale, wavy bedded, gray, silty, pieces of included siltstone. Residues (4460-64) greater than 65 percent consisted of quartz sand, chert, and shale.

(X3)

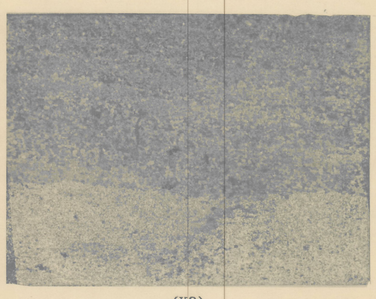
4479-4488 Calcarenite, fine-grained, thin black shale partings. Rounded grains (thin section examination) comprised of skeletal components which include foraminifers (mostly Endothyra sp.) and echinoderm debris but also brachiopods and bryozoans. Matrix comprised of spar and line mud. Pressure solution observed. Residues (4479-88) generally less than 1 percent, made up of shale, silt, fine sand and trace of pyrite.

(X3)

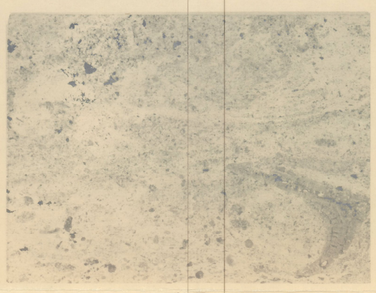
FAUNA FROM RESIDUES (4460-4488)

Cavusgnathus characta
C. convexa
C. regularis
C. unicornis
Neoprioniodus loxus
Spathognathodus scitulus

ST. LOUIS LIMESTONE (4489-4585)

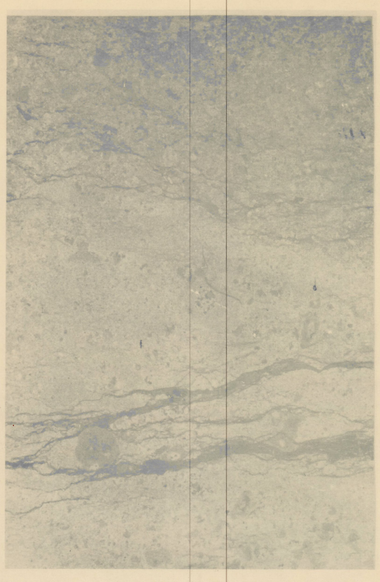


(X3)



(X3)

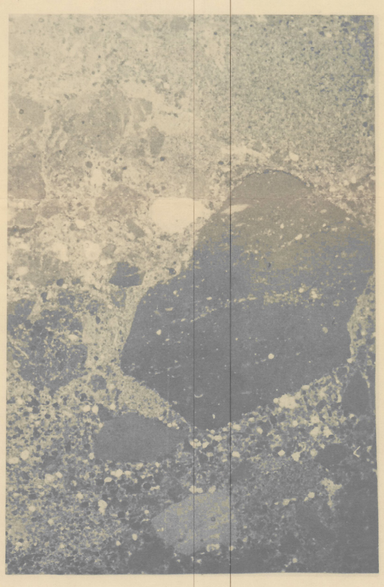
4489-4499 Calcarenite, fine-grained, shale partings numerous. Rounded grains (thin section examination) comprised of skeletal fragments of echinoderms, brachiopods, bryozoans, and foraminifers; some silicification of skeletal components; pressure solution of grains (4490-91); less than 5 percent spar in matrix, (4498-99). Residues less than 1 percent made up of shale, rounded frosted, very fine sand, beekite, and trace of limonite.



4498-4499 Photograph of thin section. Note shale partings and mixed fossil characteristics.

FAUNA FROM RESIDUES (4489-99)

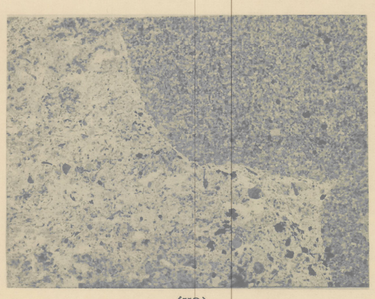
Apatognathus? porcata
Cavusgnathus regularis
Magnilaterella robusta
Neoprioniodus tulensis
Spathognathodus cristula



(X3)

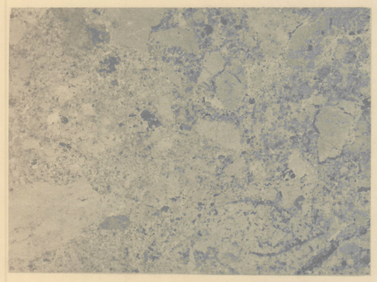
4576-4577 Photograph of thin section.

4576-4585 Conglomerate, lithiclasts of mixed-fossil lime mudstone in quartzose mixed-fossil lime groundmass. Skeletal fragments in groundmass--echinoderms, bryozoans, brachiopods, foraminifers, pellets, and fine quartz sand grains. Grains rounded, extensive pressure solution.

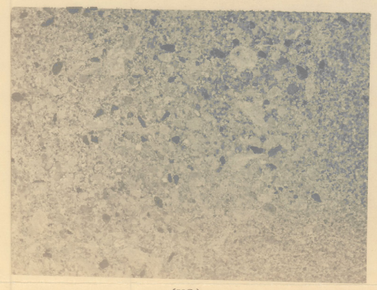


(X3)

(St. Louis Limestone, 4586-4611)

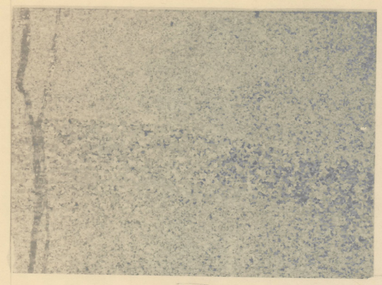


(X3)



(X3)

4586-4589 Calcarenite, fine-grained (about 70 percent skeletal). Grains (thin section examination) well rounded, mostly echinoderms, more than 30 percent spar groundmass, pressure solution moderate. Residues (4578-89) less than 1 percent, brown shale, anhydrite, beekite, frosted fine sand; trace of pyrite and glauconite at 4589.

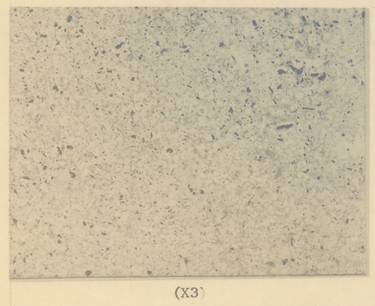


(X3)

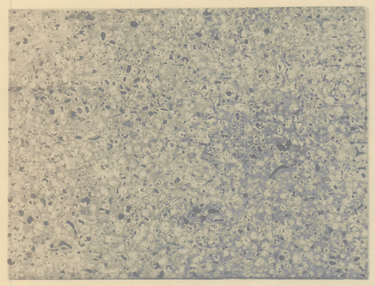
FAUNA FROM RESIDUES (4576-89)

Cavusgnathus convexa
Gnathodus texanus (reworked)
Taphrognathus varians (reworked)

SALEM LIMESTONE (4612-4710?)

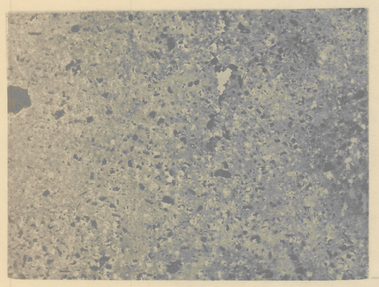


(X3)



(X3)

4628-4646 Dolomite, fossil-cast, fine- to medium-grained, tan to buff with white calcite crystals filling voids. Dolomite rhombs (thin section examination, 4629-30) medium to fine silt size and skeletal grains (ghost) of crinoid ossicles? (exhibit fossil-cast porosity. Residues (4628-46) less than 5 percent comprised of shale, silicified fossil fragments, euhedral to subhedral quartz, pyrite and trace of anhydrite and sphalerite.



(X3)

FAUNA FROM RESIDUES (4628-4646)

Apatognathus? n. sp. A
Taphrognathus varians
Scolecodonts

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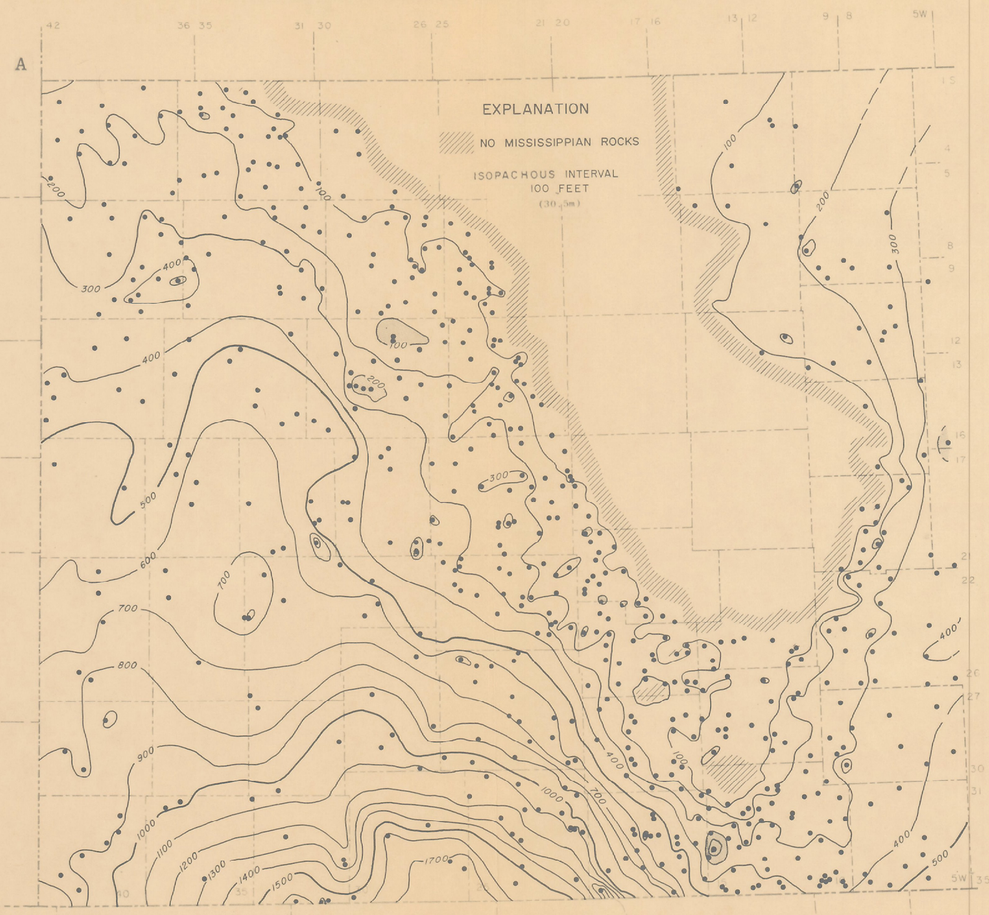
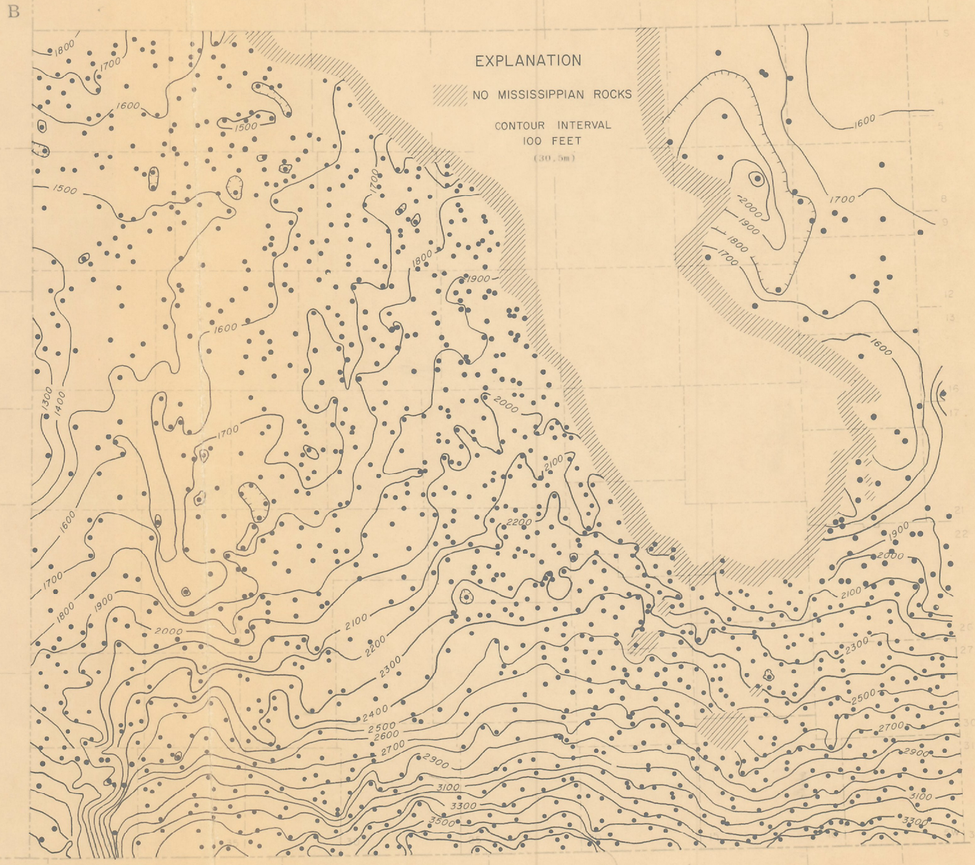
A

ISOPACHOUS MAP OF TOTAL MISSISSIPPIAN ROCKS



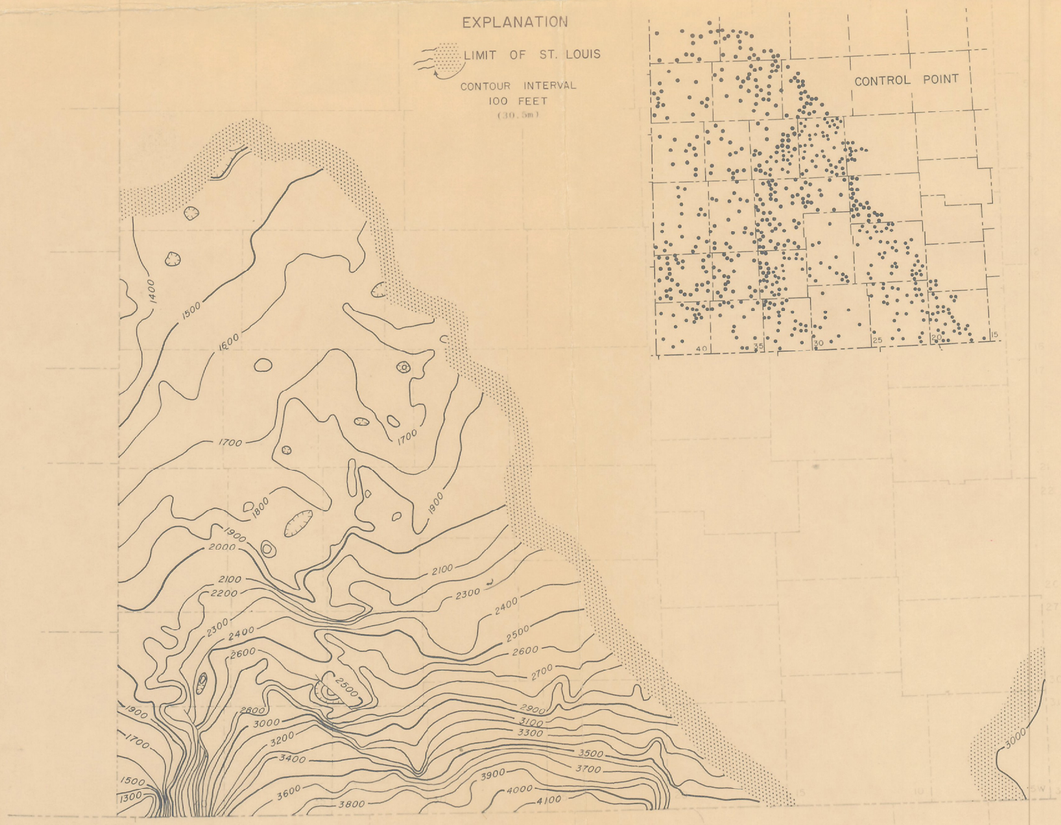
B

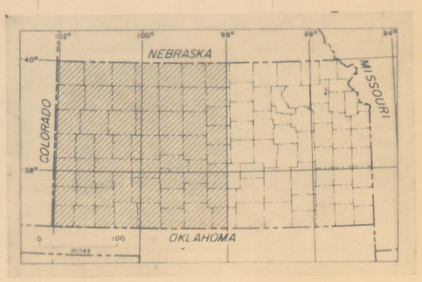
STRUCTURAL CONTOUR MAP ON TOP OF MISSISSIPPIAN ROCKS.



C

STRUCTURAL CONTOUR MAP ON TOP OF ST. LOUIS LIMESTONE.

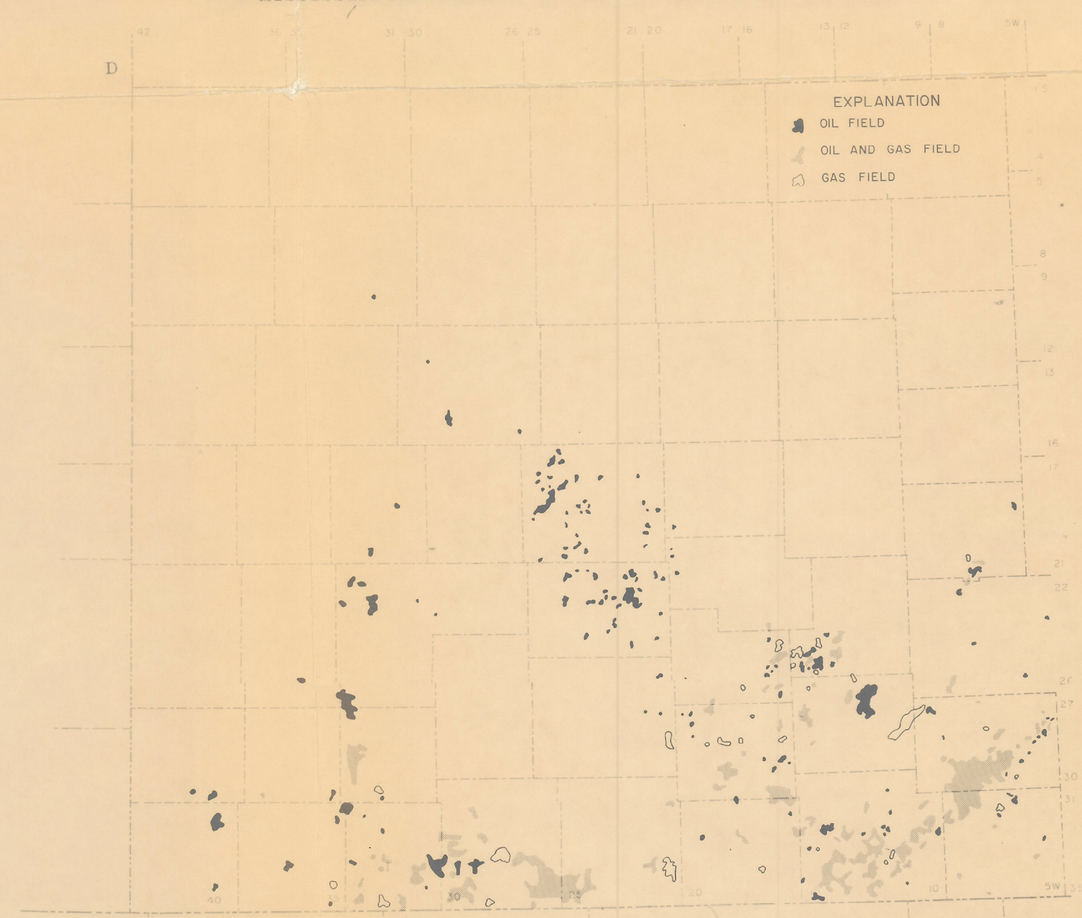




INDEX MAP

D

MISSISSIPPIAN OIL AND GAS FIELDS OF WESTERN KANSAS.



10 0 30 MILES
0 48 KILOMETERS

PREPARED BY EDWIN D. GOEBEL, 1966

EAST-WEST STRUCTURAL CROSS SECTIONS IN WESTERN KANSAS

PLATE 24

WEST
A

EAST
A'

SOUTHWESTERN AREA

HUGOTON EMBAYMENT

PRATT ANTICLINE

feet

Chesteran rocks

Meramecian rocks

Osagian rocks

Kinderhookian rocks

Trentonian rocks

Richmondian rocks

Kinderhookian-Upper Devonian rocks

100 ft.

115 ft.

62 ft.

50 ft.

24 ft.

(Vertical exaggeration x 100)

Sea Level Datum

Horizontal scale

Vertical space

-500 feet
-152.5 meters

WEST
B

EAST
B'

NORTHWESTERN AREA

WEST FLANK OF
CENTRAL KANSAS UPLIFT

Meramecian rocks

Osagian rocks

Kinderhookian rocks

Lower Ordovician rocks

Trentonian rocks

124 ft.

120 ft.

NEBRASKA

COLORADO

OKLAHOMA

Dundy
Chase
Hayes
Frontier
Gosper
Furnas
Harlan
Franklin
Webster
Nuckolls
Thayer
Jefferson
Republican
Gage
Johnson
Nemaha
Brown
Doniphan
Cheyenne
Rawlins
Decatur
Norton
Phillips
Smith
Jewell
Republic
Washington
Marshall
Sherman
Thomas
Sheridan
Graham
Rooks
Osborne
Mitchell
Cloud
Clay
Kit Carson
Wallace
Logan
Gove
Trego
Ellis
Russell
Lincoln
Ellsworth
Saline
Ottawa
Greeley
Wichita
Scott
Lane
Ness
Rush
Barton
Rice
Mitchell
Osborne
Hamilton
Kearny
Finney
Hodgeman
Pawnee
Stafford
Reno
Gray
Ford
Edwards
Pratt
Kingman
Stanton
Grant
Haskell
Meade
Clark
Kiowa
Barber
Harper
Morton
Stevens
Seward
Comanche
PLATE 3
PLATE 4
PLATE 5
PLATE 6
PLATE 7

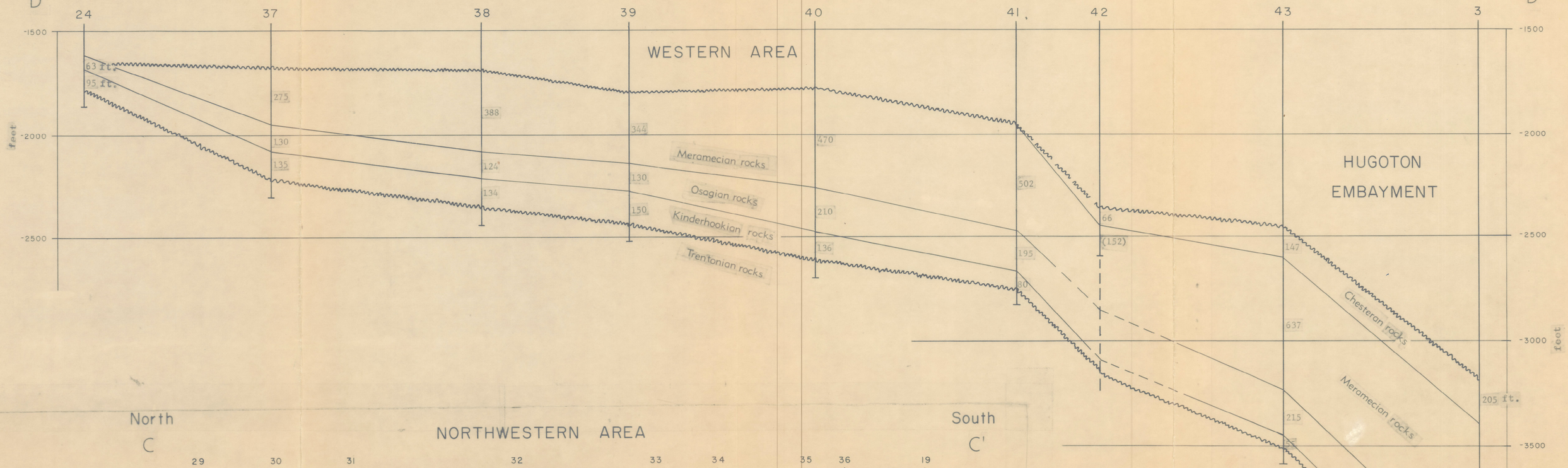
PREPARED BY EDWIN D. GOEBEL, 1966

NORTH-SOUTH STRUCTURAL CROSS SECTIONS IN WESTERN KANSAS

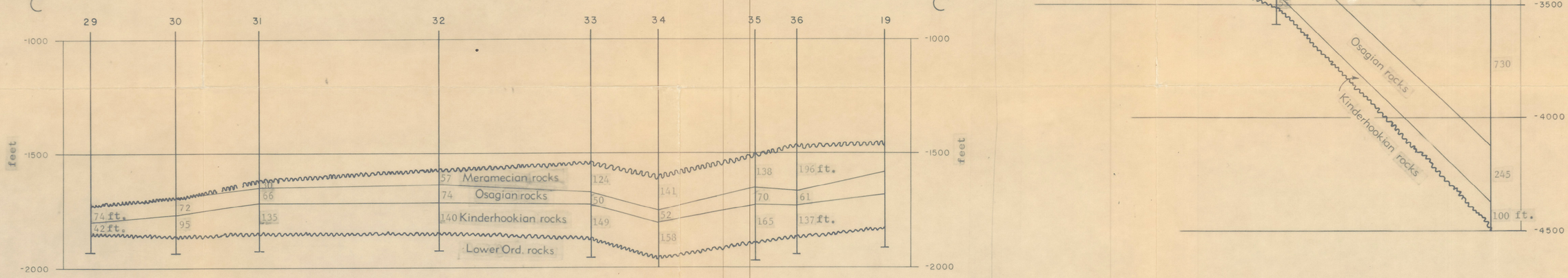
PLATE 25

66-10

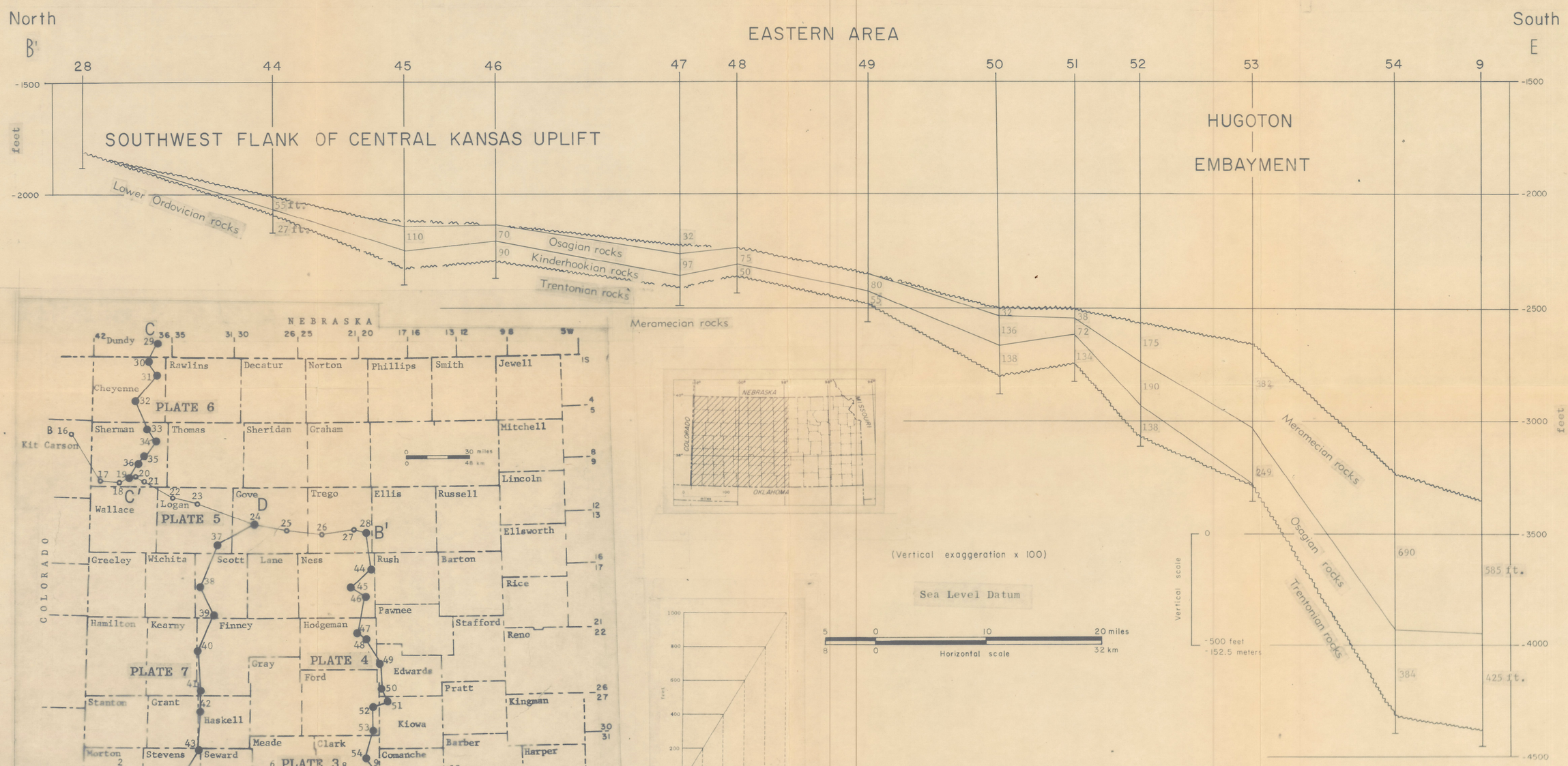
North D — WESTERN AREA — South D'

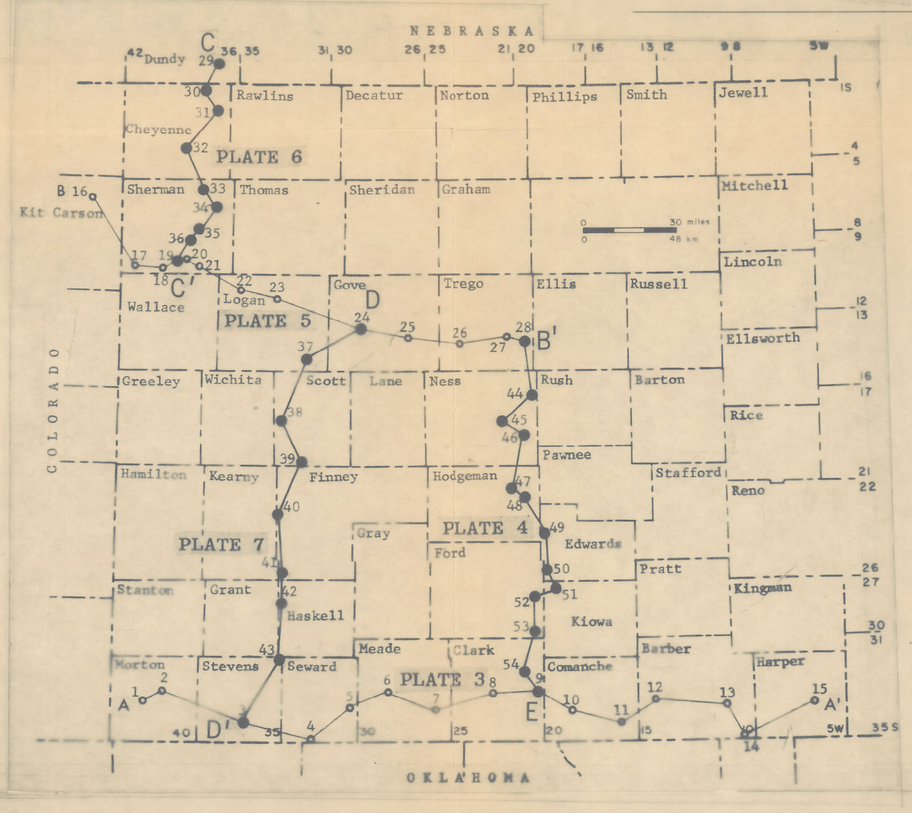


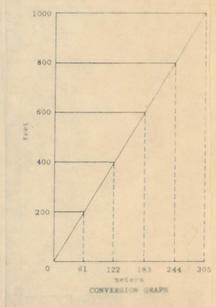
North C — NORTHWESTERN AREA — South C'



North B' — EASTERN AREA — South E







(Vertical exaggeration x 100)

Sea Level Datum

5 0 10 20 miles
8 0 Horizontal scale 32 km

Vertical scale: 0 — -500 feet — -152.5 meters

PREPARED BY EDWIN D. GOEBEL, 1966