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DEVONIAN ROCKS IN KANSAS
AND
THEIR EPEIROGENIC SIGNIFICANCE

by

Paul L.Hilpman

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by

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A.B., Brown University, 1954
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ABSTRACT

In Kansas, Devonian rocks are restricted to the subsurface and knowledge of these strata is severely limited. previous investigations have not included discovery of diagnostic fossils adequate to subdivide the sequence or or to permit correlation with distant outcrops in surrounding states.

On the basis of cores from 27 wells, supplemented by more than 2,500 sample, geophysical, and driller's logs, Devonian rocks are subdivided into eight distinct lithologic units. Conodonts recovered from insoluble residues of cores indicate that two units are Middle Devonian in age, three units are early Late Devonian in age and three units range in age from Late Devonian to Early Mississippian. No evidence of Early Devonian rocks was found and widespread erosion is inferred to have occurred in this time interval.

The distribution and lithologic character of the units indicate that the Middle Devonian seas were restricted to the North Kansas Basin and earliest Late Devonian (Frasnian) seas occupied the Southwest Kansas Basin. Late Devonian (Famennian) and Early Mississippian (Kinderhookian) seas were widespread throughout the state and rocks deposited during this interval lie unconformably on older rocks and are unconformably overlain by younger strata (Osagian Stage).

In this study interpretations of epeirogenic events differ from those of Sloss, Wheeler, and Ham and Wilson.

INTRODUCTION

Kansas is centrally located within a 300,000 square mile (777,000 square kilometers) portion of the Central Stable Interior of the North American Continent in which Devonian rocks are not exposed. Accordingly, knowledge of Devonian strata and their relationships to underlying and overlying units is severely limited. Except for a few isolated cores, subsurface studies of these rocks have been based on well cuttings, insoluble residues, and geophysical data. Age relationships have been largely inferred from lithologic similarity with distant outcrops in surrounding states (Fig. 1). Previous investigations in the study area have not provided diagnostic fossils adequate to subdivide the sequence of Devonian rocks or to permit correlation based on paleontological evidence.

Clearly, the extension of time stratigraphic units from one locale to another and the placing of these units in proper geochronologic sequence demands careful evaluation of both physical and paleontological criteria. To pursue these objectives solely on the basis of lithic aspects is to invite miscorrelation and misinterpretation.

During the past 20 years, two significant developments have emerged within geology which directly relate to investigations of Devonian rocks in Kansas and to fundamental concepts of the science that reach far beyond the accurate reading of Kansas' subsurface stratigraphy. The first of these is the establishment of the exceptional value of

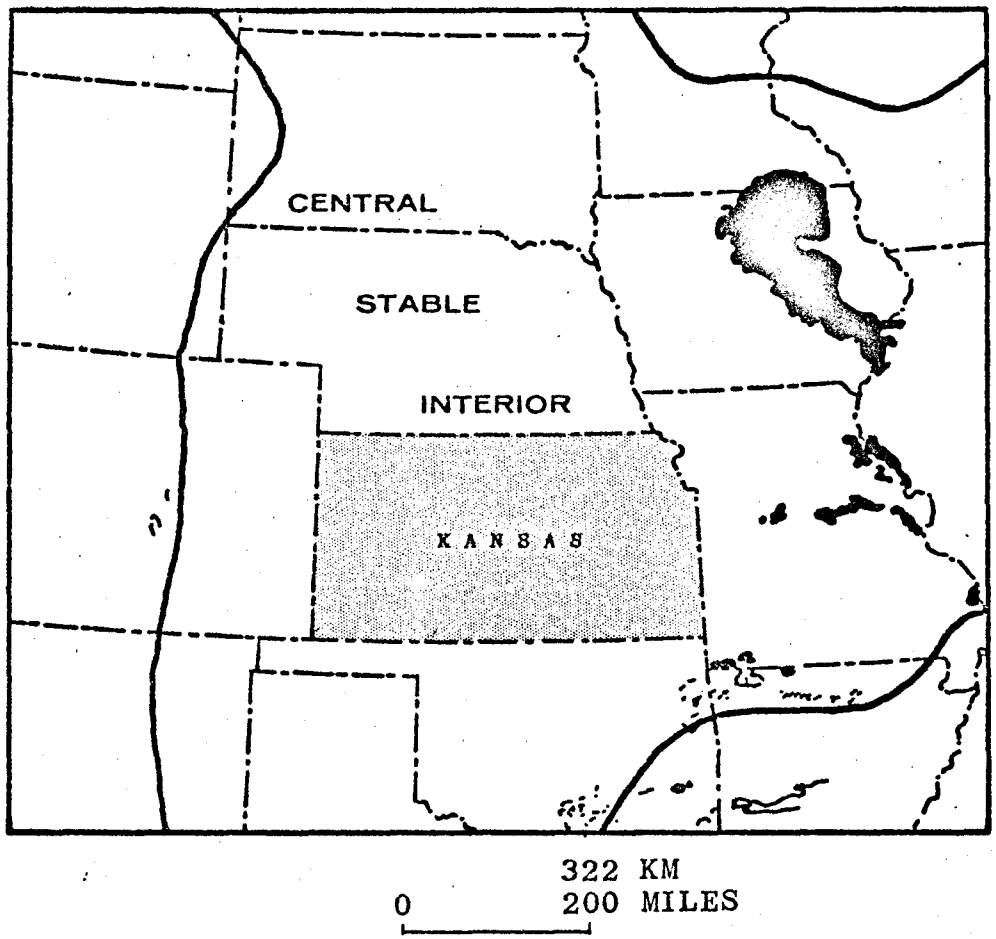


Figure 1. State of Kansas in relation to Central Stable Interior and Devonian outcrops in adjacent states. Black indicates outcrops.

conodonts for stratigraphic correlation and age determination in Paleozoic sediments. Although their taxonomic placement is as yet to be determined, conodonts seemingly have a world-wide distribution and are present in rocks representing most marine environments. These microfossils range from one to three millimeters in length and can be recovered with equal ease from surface samples, well cuttings, and subsurface cores.

The second development referred to is the concept of sequences--major rock stratigraphic units bounded by inter-regional unconformities traceable over major areas of the continent (Sloss and others, 1949). In subsequent years, Sloss (1959, 1960, 1963, 1964, 1966) has revised and refined the concept which in its present form effectively purports epeirogeny as the "ultimate basis of correlation."

Superficially, it would seem that conodonts and stratigraphic sequences offer the stratigrapher highly useful tools with which to study lithostratigraphic and biostratigraphic units within the Devonian System of the western Midcontinent area. Conodonts reach their highest level of diversity during this period (Lindström, 1964) and the sedimentary sequence (Kaskaskia) encompassing Devonian rocks of the area has been touted as a model of such "sequences" (Sloss, 1964). Accordingly, the primary goal of this investigation has been to study both the lithologic and some biologic aspects of Devonian rocks in Kansas in an attempt to delineate and relate facies within these strata. A secondary goal has been

to reconstruct the Devonian paleogeology and relate it to epeirogenic interpretations of the Central Stable Interior.

PREVIOUS WORK

Throughout the subsurface of northeastern Kansas, southeastern Nebraska, and parts of Missouri, carbonate strata of Devonian age and underlying Silurian rocks are collectively referred to as "Hunton Group." This sequence of rocks comprises limestones and dolomites stratigraphically next above the Maquoketa Shale (Ordovician) and next below the Chattanooga Shale (Devonian-Mississippian). The term "Hunton" has been applied to these rocks by workers in the petroleum industry since the early 1900's, primarily because they occupy the same relative position with respect to Ordovician and Mississippian strata as does the Hunton Group in outcrops in Oklahoma.

For more than 60 years there has been disagreement as to the exact correlation of rocks within this interval. Ulrich (1915), Barwick (1928), Edson (1929), and McClellan (1930) reported both lithologic and paleontologic evidence indicating that the Devonian portion of the "Hunton" strata in Kansas is Middle Devonian in age and cannot be correlated with the Devonian portion of the Hunton Group (Early Devonian) in Oklahoma. Lee (1943, 1946, 1948, and 1956) revealed lithologic similarities between Devonian "Hunton" carbonates in Kansas and Middle Devonian carbonates at the outcrop in Missouri, further discrediting correlation with the Oklahoma

section. Ireland (1966, 1967a, 1967b) in studies based on insoluble residues and arenaceous foraminifera confirmed the equivalence of the Silurian portion of "Hunton" in Kansas with the Oklahoma type section but supported correlation of the Devonian portion with the previously mentioned beds in Missouri. With the exception of an earlier progress report by the present investigator (Hilpman, 1967), no detailed paleontologic evidence has been reported to support or refute these conflicting correlations of Devonian rocks in Kansas.

Thousands of wells have penetrated a sequence of black and gray shales that lie next above the problematic Devonian carbonates in northeastern Kansas. These shales are correlated with the Chattanooga Shale that crops out in southwestern Missouri (Adams and Ulrich, 1905) and with the Woodford Shale of Oklahoma (Hass and Huddle, 1965). Because the shale sequence offers small promise of petroleum reservoirs, subsurface stratigraphers have focused little attention upon its age and stratigraphic relationships. The interval is generally regarded as comprising both Upper Devonian and Lower Mississippian rocks.

No mention of Devonian rocks of any lithology has appeared in literature describing the stratigraphy of the Southwest Kansas Basin or the Ellis-Chautauqua Arch areas (Fig. 2).

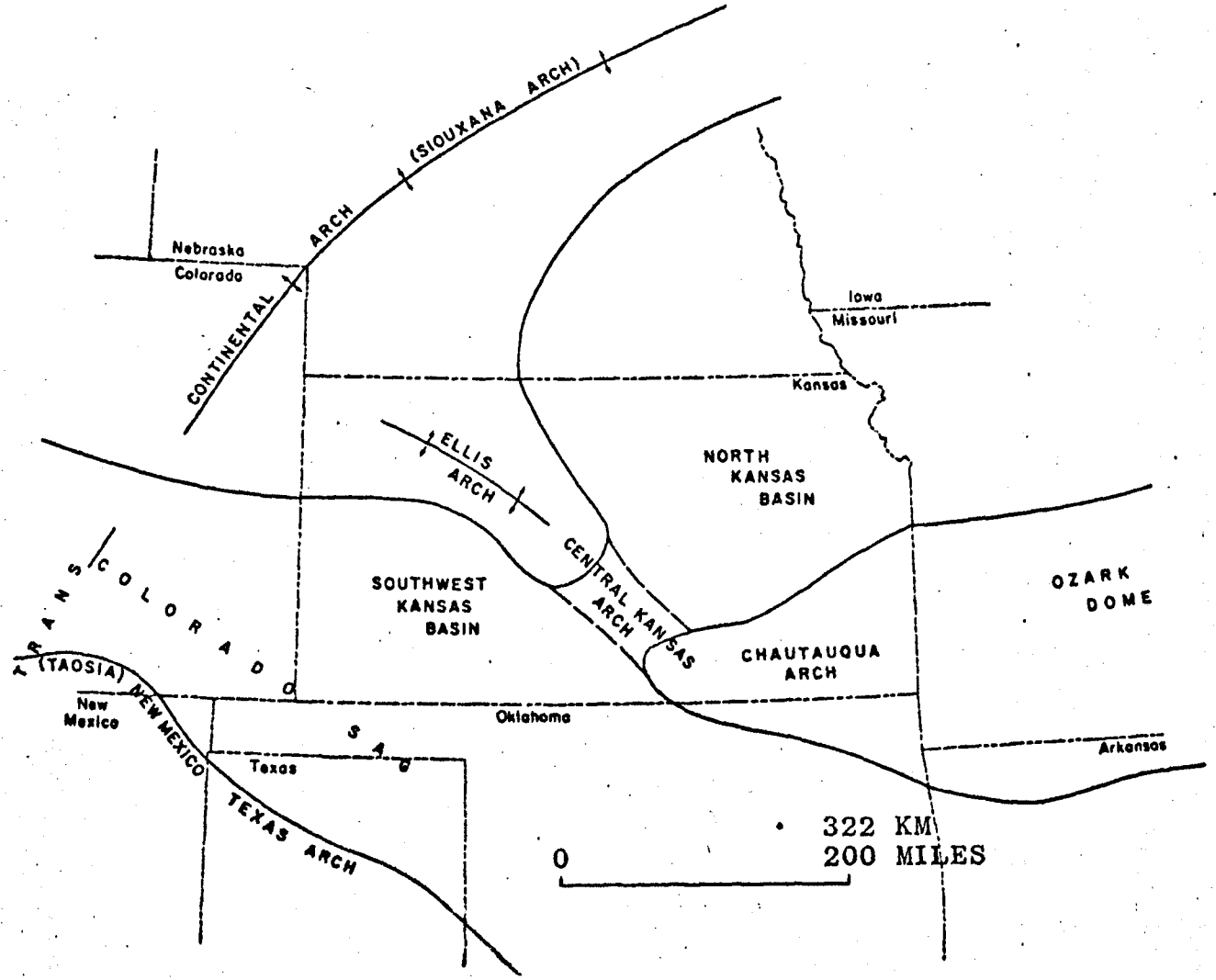


Figure 2. Major Devonian structural provinces in Kansas and surrounding states.

METHODS AND PROCEDURES

Field Methods

The initial phase of this investigation centered on evaluation of Devonian lithologies at outcrops in Missouri and Oklahoma (Fig. 1). Selected samples were collected for recovery of conodonts and insoluble residues. The outcrops examined in Oklahoma were described in detail by Amsden (1960, 1961) and outcrops examined in Missouri were described by Johnson (1962) and Freeman (1967).

Laboratory Methods

Both surface samples and subsurface cores were processed during the course of this investigation. To maximize the information gained, a detailed program was designed to process each sample. Major steps in the program are shown schematically in Appendix A. Procedures used to recover conodonts are essentially those described by Collinson (1963) and Thompson and Goebel (1963). Alizarin Red S acid stain (Friedman, 1957) was used on cores to differentiate calcite and dolomite. Quaternary "O" (Zingula, 1968) was used to break down noncalcareous shales. Acetate peels used to prepare Plates I through V of this report were prepared by standard procedures. Thin sections to enable detailed study of chert facies were prepared by Rudolph von Huene, Pasadena, California. A registry of cores processed and examined in this investigation is given in Table 1.

Table 1. Registry of cores studied.

	Company Name	Well Name	Location	Elev.	Total Depth	Intervals Cored
1.	Derby Oil Company	#3 Lehmann Core	13-22S- 2W	1463	3,608	3,296-3,335
2.	E. J. Shaffer	#1 Steele	12-23S- 2W	1446	3,615	3,364-3,379
3.	Derby Oil Company	#1 Sperling	17-22S- 3W	?	3,530	3,484-3,514
4.	Lauck & Moncrief	#1 Krehbiel	27-21S- 2W	1482	3,665	3,415-3,444
5.	Carter Oil Company	#1 Oreon Strahm	13- 2S-14E	1254	3,929	2,829-2,874
6.	Carter Oil Company	#2 Davis Ranch "A"	33-13S-10E	1428	3,425	2,980-2,997 3,013-3,023
7.	Derby Oil Company	#1 Lehman	13-22S- 2W	?	3,314	3,285-3,314
8.	Marathon Oil Company	#4 S. E. Van Sickle	23-23S- 4W	1469	3,605	3,585-3,592½
9.	Marathon Oil Company	#2 S. E. Van Sickle	23-23S- 4W	1971	3,621	3,596-3,603
10.	Derby Oil Company	#1 Hetzke Core	20-21S- 1W	1473	3,428	3,282-3,289
11.	Derby Oil Company	#4 Arnold Core	16-21S- 1W	1482	3,330	3,304-3,327
12.	Derby Oil Company	#1 L. E. Wood Core	36-22S- 5W	1531	3,809	3,759-3,777
13.	Cities Service Oil Company	#2 Koepsel Core	36-11S- 8E	1432	1,794	1,764-1,794
14.	Cities Service Oil Company	#2 Gehrt Core	25-11S- 8E	1222	1,660	1,527-1,627
15.	Braden-Zenith, Inc.	#1 Zenith Waterflood Unit	11-24S-11W	1816	3,872	3,761-3,789
16.	Skelly Oil Company	#1 Wm. Middlekauff	21-13S-19E	840	1,855	1,664-1,670
17.	Ohio Oil Company	#11 J. H. Decker	20-21S- 1W	1486	3,344	3,290-3,327
18.	Western Petro. Co., Inc.	#1 Hoffman	8-25S-17W	2152	4,705	4,500-4,553
19.	Braden-Zenith, Inc.	#3 Zenith Waterflood Unit	11-24S-11W	1813	3,820	3,706-3,712
20.	Braden-Zenith, Inc.	#2 Zenith Waterflood Unit	11-24S-11W	1813	3,860	3,744-3,754
21.	Derby Oil Company	#5 Glenn C. McComb	24-24S-11W	1799	4,723	3,796-3,803
22.	(restricted)	#247 Drill Hole (Nebr.)	11-13N-13E	976.6	2,004	579-1,993
23.	Mobil Oil Company	#1 Cunningham Estate	13-34S-37W	3149	8,714	7,838-7,861
24.	Olson Oil Co.-Skelly Oil Co.	#1 J. C. Elsea	27-32S-14W	1903	5,248	4,955-4,974
25.	Sinclair Oil Company	#1 Mercer	28-10S-40W	3756	5,923	5,460-5,490
26.	Mobil Oil Company	#1 Hogsett (Nebr.)	12- 5N-41W	3480	5,433	5,350-5,374
27.	Texas Company	#1 F. L. Smith	30-11S-36W	3238	5,360	5,185-5,200

Sample logs from more than 2,500 wells were examined in addition to more than 50 sets of rotary and cable tool cuttings from boreholes. Goebel (1966) discussed limitations imposed upon well-sample studies.

In evaluating the various types of subsurface data used in this report, cores are judged to be most reliable, followed closely by cable tool sample logs and rotary sample logs of the Kansas Sample Log Service. Least reliable are electric logs, driller's logs and scout "top cards." When supplemented by cores or samples, electric logs are extremely useful in pinpointing thicknesses of subsurface units.

ACKNOWLEDGMENTS

This investigation was undertaken as part of the program on subsurface studies of the State Geological Survey of Kansas. The author has drawn heavily upon the staff and facilities of the Survey in preparing this report and that contribution is gratefully acknowledged.

The greatest single contribution to this study was made by Dr. Edwin D. Goebel, Senior Geologist, State Geological Survey of Kansas. Through more than half a decade of encouragement, criticism, and collaboration, he has displayed a never-ending interest in this investigation. Largely through his efforts the author gained access to several key cores in western Kansas in addition to several hundred cable tool logs from his personal files. His generosity is hereby acknowledged with sincere appreciation.

Drs. M. E. Bickford, Theodore Eaton, H. A. Ireland, R. L. Kaesler, and E. J. Zeller supervised the study, reviewed this manuscript, and made numerous helpful suggestions. Dr. H. A. Ireland is specifically recognized for his guidance during the formative stages of this investigation. Drs. R. C. Moore and J. M. Jewett provided advice and counsel on numerous occasions. Dr. William M. Merrill, Chairman of the Department of Geology, provided space for the construction of an acid laboratory to process cores, and his assistance is gratefully acknowledged.

Many geologists within the petroleum industry of Kansas and surrounding states provided access to subsurface data to supplement the files of the Kansas Geological Survey. The names of individuals who assisted in this manner are: Earl Brandt, Virgil B. Cole, Lee H. Cornell, James B. Davies, Walter E. DeLozier, Norman Knapp, Harold V. Knupp, Edward E. Pugh, Charles F. Roach, and Robert L. Walters. Gilbert Klapper (Iowa University), Charles Collinson (Illinois Geological Survey), Raymond Ethington and Dietmar Schumacher (University of Missouri), and Walter C. Sweet (Ohio State University) provided assistance in recognizing important conodont genera and their contribution is greatly appreciated. Larry Fellows (Missouri Geological Survey), Marvin P. Carlson (Nebraska Geological Survey), and Thomas W. Amsden (Oklahoma Geological Survey) immeasurably aided the author in his study of Devonian stratigraphy within their respective states.

REGIONAL SETTING

During Paleozoic time, the western portion of the Central Stable Interior was characterized by cratonic basins separated by broad arches and domal uplifts (Ham and Wilson, 1967). Major Devonian tectonic elements in Kansas were the Ellis and Chautauqua arches and the North and Southwest Kansas basins (Fig. 2). The sedimentary record of early Paleozoic time indicates that shallow epeirogenic seas were widespread throughout the region, for Upper Cambrian, Ordovician, and Silurian rocks were continuous across arch areas as well as in the basins. At least six major episodes of uplift and erosion are represented by unconformities traceable throughout the region, further substantiating that arch areas and basins were generally active together, rather than as independent tectonic units.

During Early Devonian time the entire area was emergent, and pre-Devonian rocks were subject to widespread erosion. In Middle Devonian time epeirogenic differentiation gave rise to the arches and basins depicted in Figure 2, but by Late Devonian time the arches became submergent and widespread seas covered the entire region.

Post-Mississippian tectonic elements (Fig. 3) had no bearing on early Paleozoic sedimentation but bear on this investigation in that they influenced the present distribution of earlier Paleozoic rocks that were eroded from the crests of the uplifts and arches (Fig. 4).

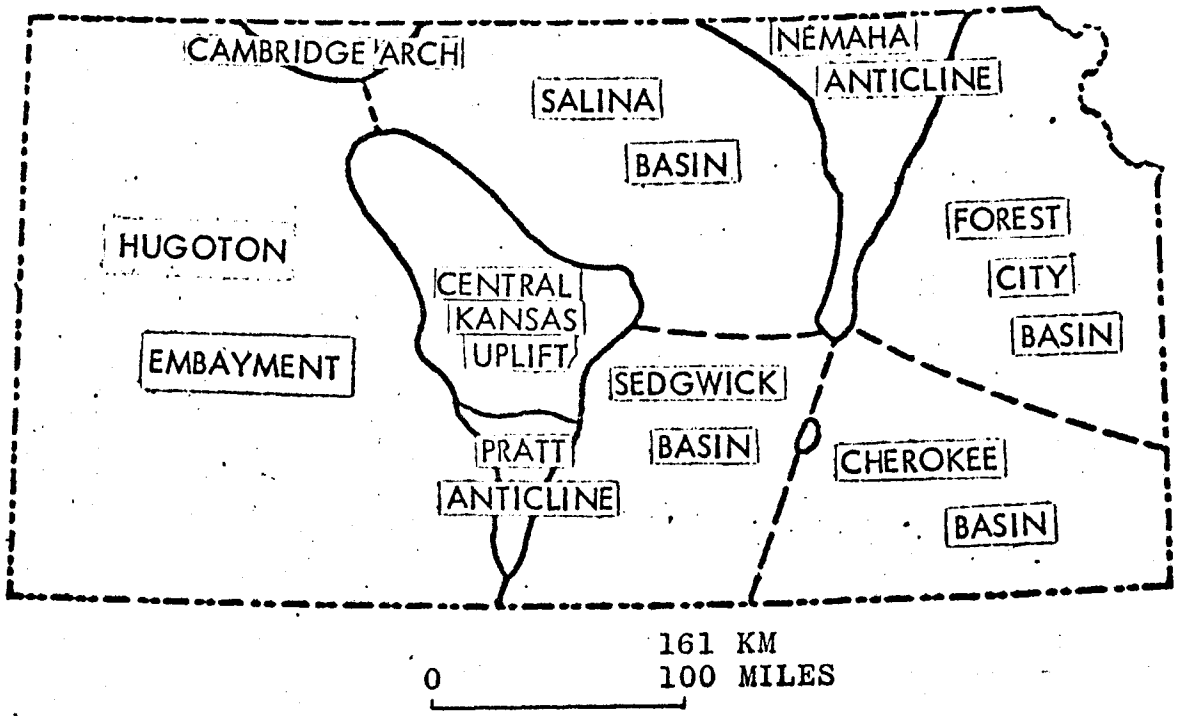


Figure 3. Major post-Mississippian tectonic elements in Kansas.

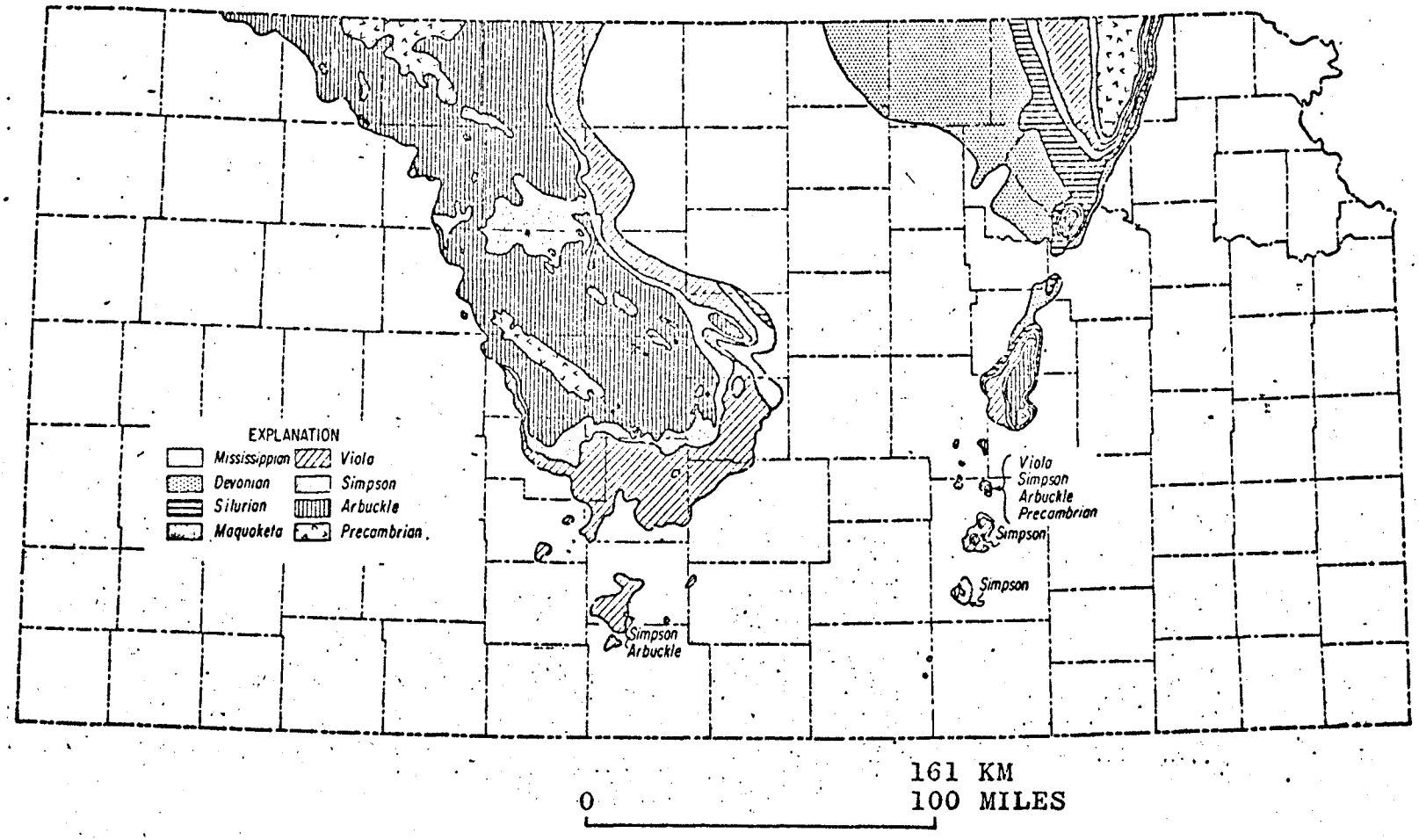


Figure 4. Pre-Pennsylvanian geologic map of Kansas.

STRATIGRAPHY AND PALEONTOLOGY

General Statement

Lee (1956) subdivided Devonian carbonates of the "Hunton Group" into two zones based on lithologic characteristics observed in northeast Kansas. The zones have no time significance within the Middle Devonian other than that the lower zone is older than the upper zone. The lower zone includes sandy beds at the base and cherty beds at the top. The dominant lithology is dolomite of saccharoidal texture, characteristically containing rounded and frosted sand grains in the basal beds. The cherty facies at the top of the zone is characterized by gray opaque, and white tripolitic chert. In referring to the white tripolitic chert found in insoluble residues of the interval, Ockerman (1931, 1935) described it as dolocastic chert, useful in distinguishing Devonian strata.

Lee's Upper Devonian zone was simply described as including the rocks above the lower zone and next below the Misener sandstone (basal sandstone of the Chattanooga Shale). The upper zone provides no useful datum beds and Ireland (1967b) described it as having no diagnostic insoluble residues. Lee provided no description of the lithology of this interval and stated only that it includes interbedded limestone and dolomite of various types. Lee doubted the reliability of the white chert beds at the top of the lower zone as a useful datum. Furthermore, west of the Sixth Principal Meridian (Fig. 5), it is impossible to separate these two zones from each other or from underlying Silurian strata because sandy beds are locally absent at the base of the lower zone.

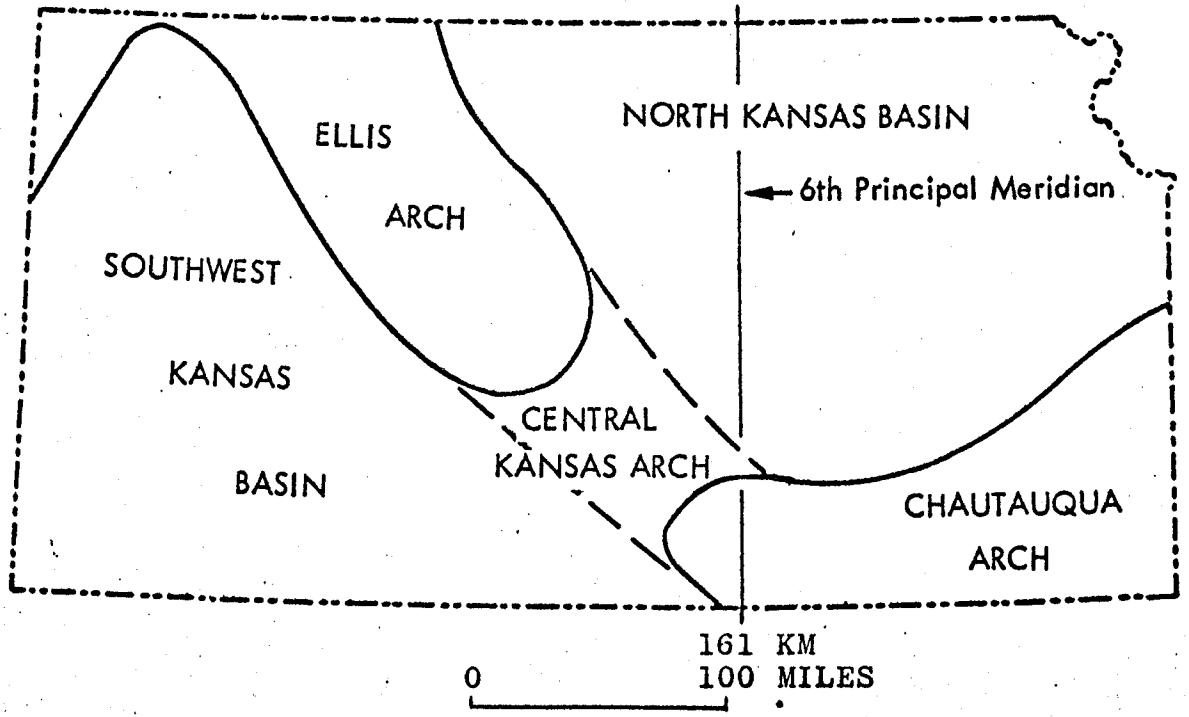


Figure 5. Major Devonian tectonic elements in Kansas.

The overlying Chattanooga Shale and its basal sand member (Misener sandstone) were considered by Lee to be Late Devonian and Early Mississippian (Kinderhookian) in age. He described the Chattanooga as black fissile shale, slightly silty and finely micaceous, containing conspicuous amounts of pyrite. Lee further recognized that in northern and western Kansas the black shales are interstratified with gray and green shales called "Kinderhook" shale by the petroleum industry. Lee considered the two shales as equivalent and in his last major publication (Lee, 1956) stated:

> The use of the term 'Kinderhook' shale for Chattanooga Shale has become standard usage among oil geologists, however inappropriate, but, like the term 'Nemaha Mountains' or 'Nemaha Granite Ridge' for Nemaha Anticline, is, unfortunately, not likely to be discarded.

Lee's work has been generally accepted by stratigraphers in the area. Unfortunately, the stratigraphic relationships espoused by Lee are based solely on lithologic criteria observed in northeast Kansas. Elsewhere in Kansas and in the subsurface of surrounding states, rock units have been reported that are not present in northeast Kansas and correlation has not been possible in terms of Lee's lithologic criteria. Furthermore, Lee did not describe fossils characteristic of his zones, and cores from his type wells are not available from which to recover a representative microfauna. Accordingly, within the plan of this report, Lee's zones are not used and Devonian rocks are subdivided into eight distinct lithologic units lettered A through H. Names in

common usage are substituted for some lettered units in the latter part of this report. In the following pages, lithologic criteria for recognition of each unit are described, along with the characteristic conodonts recovered from cores of the units. Maps showing the inferred areal distribution of each unit are included. The accuracy of these maps is not uniform throughout and is directly related to the density of wells penetrating the units.

The inferred relationships of rock units used in this report to Lee's zones and to units recognized in surrounding states are shown in Figures 6 and 7. The stratigraphic range of key conodonts used to establish these relationships are shown in Figure 8.

Unit A

Lithology

Rocks of this unit are characteristically gray to light-gray, medium- to fine-grained dolomite, commonly displaying prominent laminations. Two distinct types of laminae have been observed. Some laminae are composed entirely of medium to coarse, well-rounded frosted quartz sand grains. Other laminae are composed of white tripolitic chert containing sand grains, rhombohedral calcite crystals and fossil fragments. The calcite crystals dissolved in acetic or hydrochloric acid leave a porous white chert residue described in the literature as "dolocastic" (Ockerman, 1931, 1935) or "dolomoldic" (Ireland, 1947). Locally, both types of laminae are strongly contorted and disturbed,

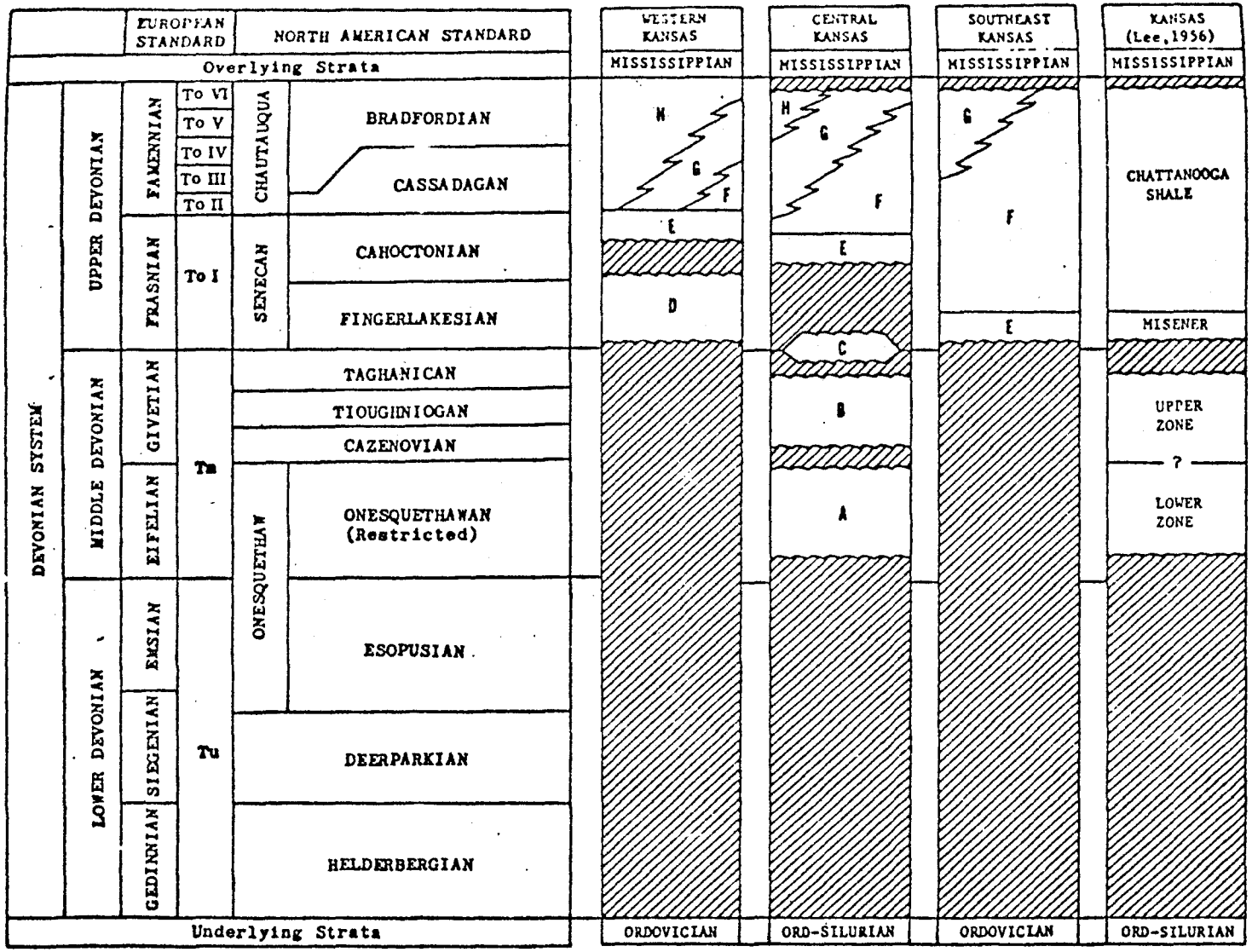


Figure 6. Correlation chart of Devonian rock units described in this report in relation to zones recognized by Lee, 1956.

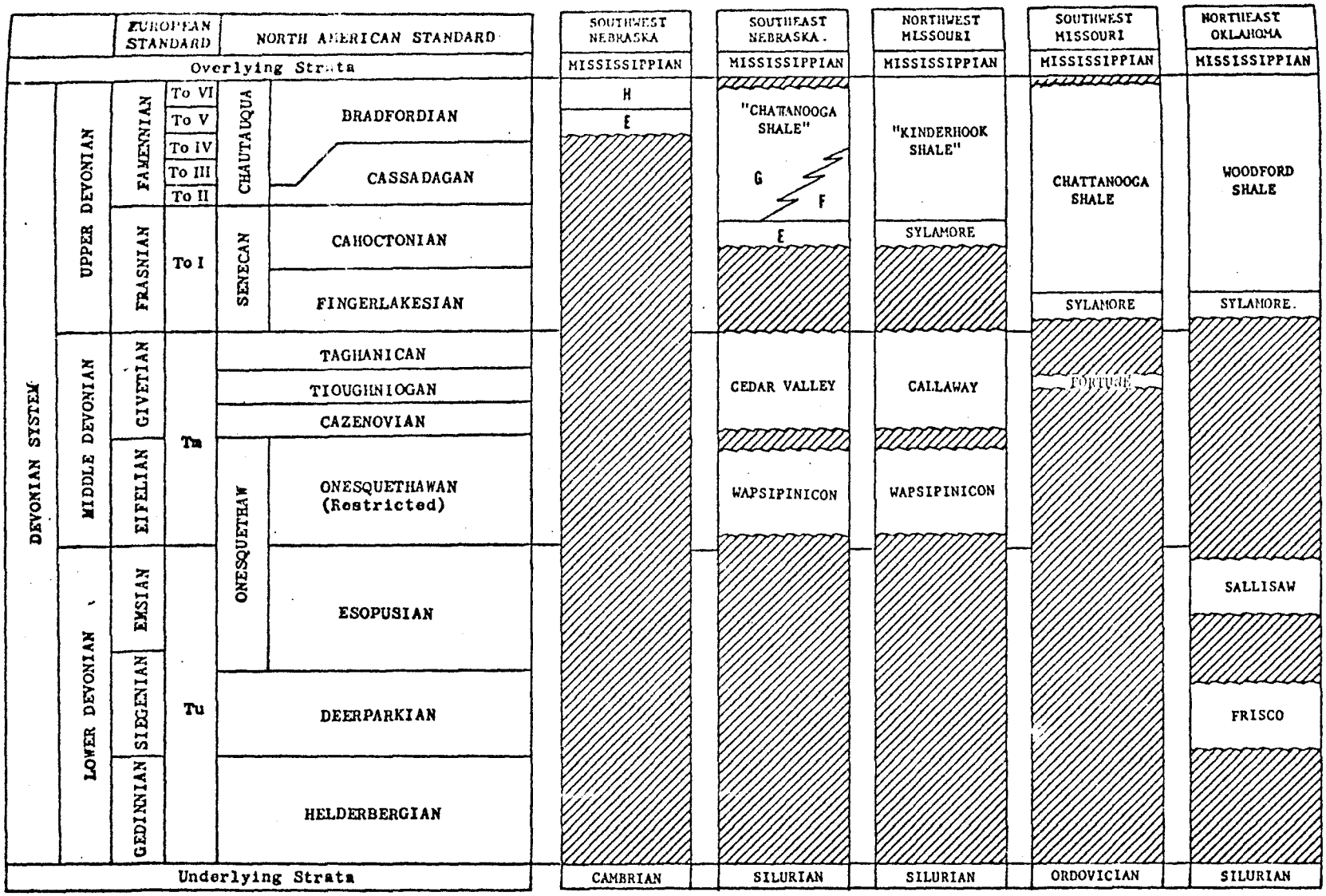


Figure 7. Correlation chart of Devonian rock units recognized in surrounding states.

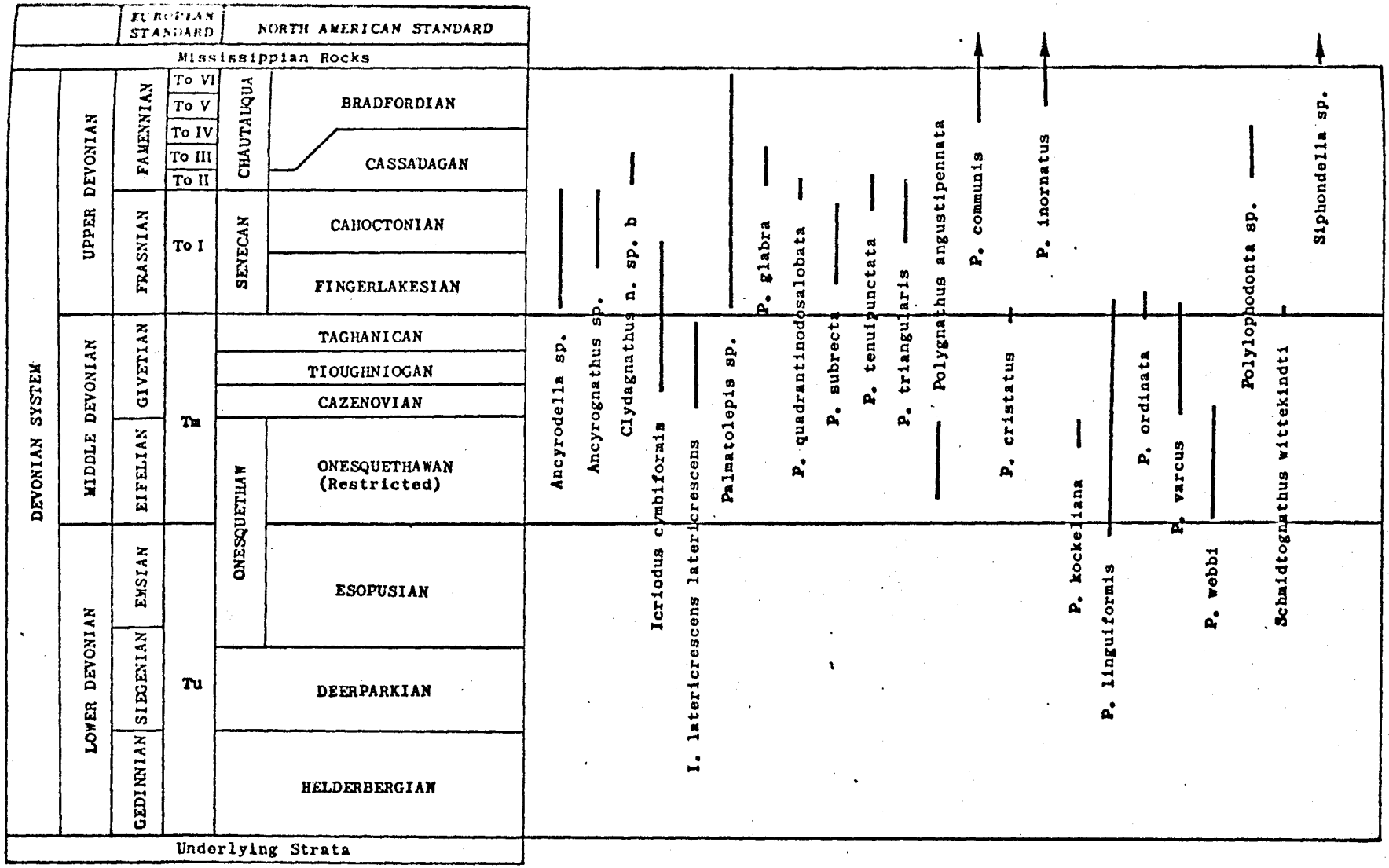


Figure 8. Stratigraphic range of key Devonian conodont forms recognized in this study. (Adapted from Anderson, 1966; Collinson, 1967; Glenister and Klapper, 1966; Hass and others, 1962; Klapper, 1966; Lindström, 1964; Orr and Klapper, 1968; Rhodes and others, 1969.

probably a function of wave or current action and boring organisms. Megafossils are conspicuously absent from these rocks and are assumed to have been destroyed during dolomitization. Fractures, where observed, are filled with sparry calcite. Acetate peel-prints of representative lithologies of this unit are shown in Plate I.

Conodonts

Insoluble residues from 12 cores of this unit are characterized by the following conodont forms: Polygnathus linguiformis, P. webbi, P. angustipennatus, and P. kockelianus. Other genera recognized but not useful in correlation include: Ozarkodina sp., Hindeodella sp., and Icriodus sp. The occurrence of Polygnathus kockelianus and P. webbi supports correlation of this unit with uppermost Eifelian rocks.

Distribution

The inferred distribution of rock unit A is shown in Figure 9. It rests unconformably on Silurian rocks in northeast Kansas and overlaps successively older rocks southward. In Sedgwick County, outliers of unit A rest unconformably on Viola rocks (Middle Ordovician) exposed along the crest of the Ellis-Chautauqua arch by pre-mid-Devonian erosion. Unit A is overlain by unit B with seeming conformity, but there is a sharp break in lithology and fauna. In two cores, however (No. 1 Sperling and No. 11 Decker), a thin sandstone bed at the base of unit B suggests

EXPLANATION OF PLATE I

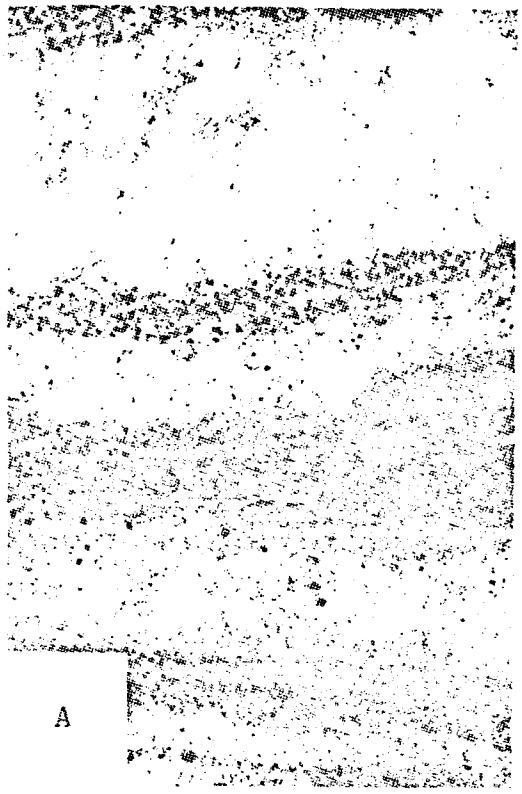
Typical facies of unit A. Illustrations are enlarged acetate peel-prints of core sections oriented with top of specimen toward top of page. (X 3.2)

A. White areas represent dolomite; gray areas are tripolitic chert with darker calcite-filled pores; dark-gray areas are sand grains, and black areas are voids and peel bubbles. (No. 1 Krehbiel, at a depth of 3,424 feet)

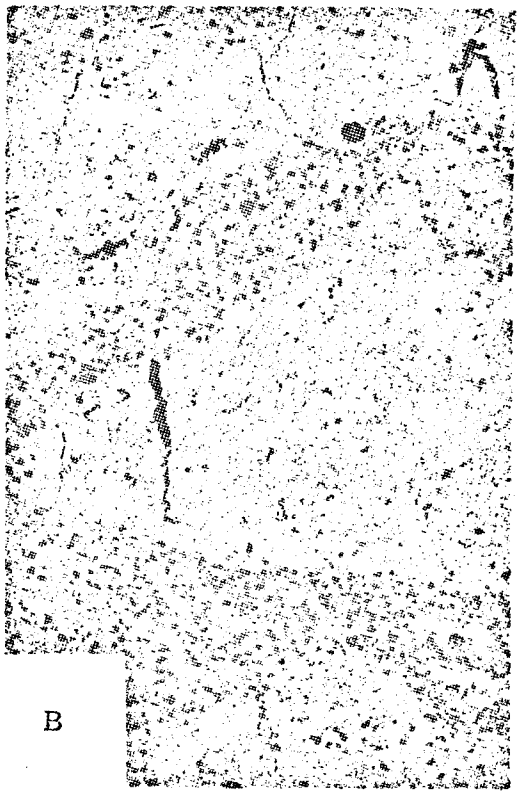
B. Light-gray areas represent dolomite; dark-gray areas are sand grains; black areas are sparry calcite void and fissure fillings. (No. 1 Lehman, at a depth of 3,303 feet)

C. White and gray areas represent dolomite; dark-gray and black areas are sand grains and some open voids. (No. 1 Krehbiel, at a depth of 3,440 feet)

D. White and gray areas represent dolomite; black areas are finely disseminated sand grains and some open voids. (No. 1 Steel, at a depth of 3,378 feet)

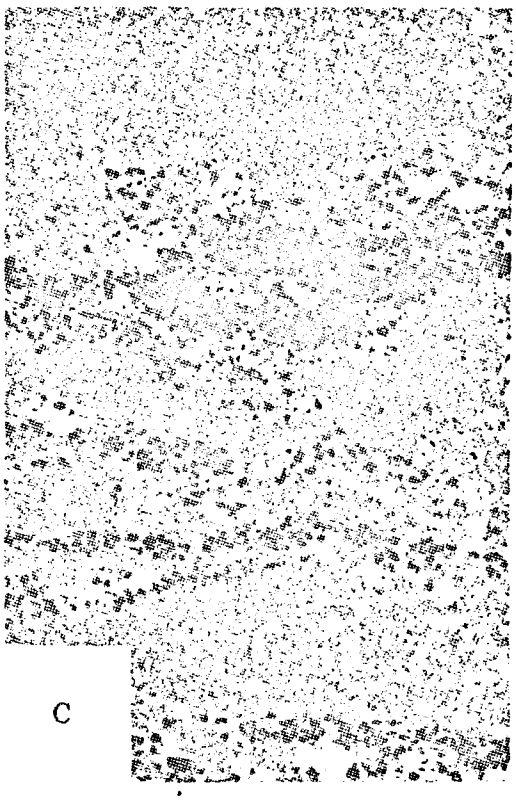


A

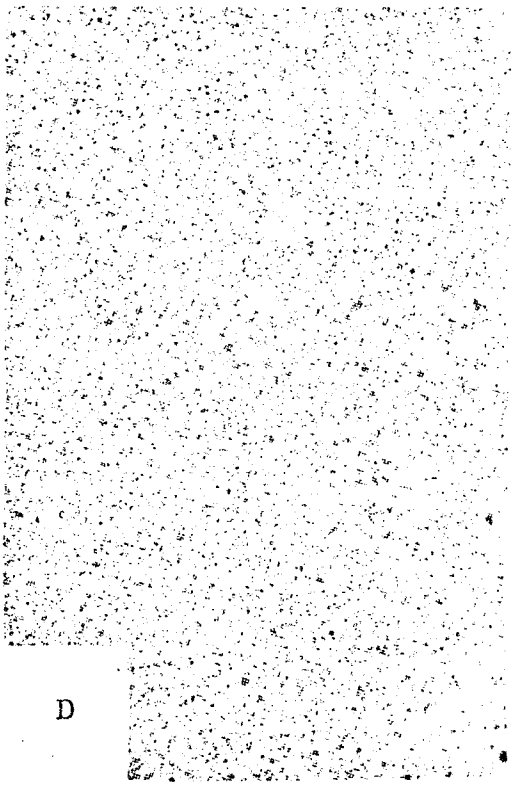


B

Plate I



C



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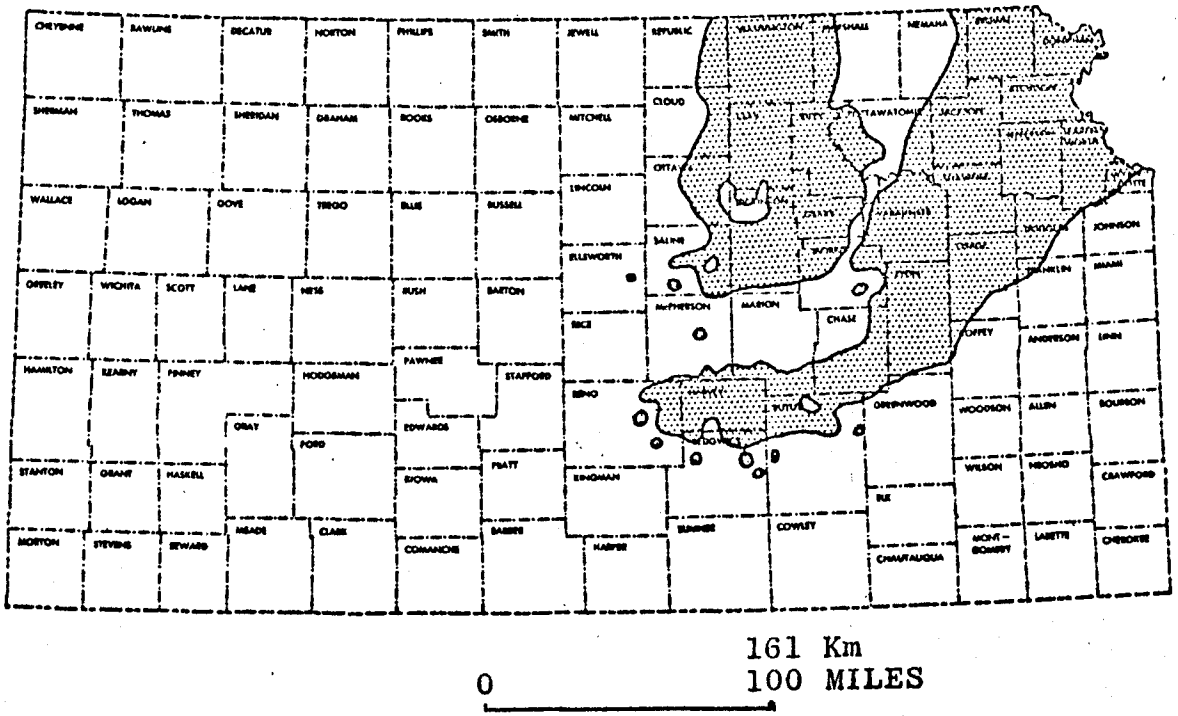


Figure 9. Inferred distribution of rock unit A. (stippled pattern)

an unconformable relationship between the two units. The absence of the sandy zone in other wells need not preclude the presence of an unconformity for it has been conclusively shown that unconformities can exist between carbonate units where no basal detrital zone is preserved. The common occurrence of Polygnathus kockeliana in the uppermost beds of unit A and its complete absence from all cores of unit B further suggest that this contact is not conformable.

Over wide areas in northeastern Kansas, unit B is missing and unit A is unconformably overlain by unit E. Unit A ranges in thickness from zero at the erosional margins to 40 feet in the No. 2 Gehrt core. Greater thicknesses of this unit are probably present in extreme northeastern Kansas but data to confirm this view are not available.

Unit B

Lithology

Throughout Harvey County and parts of Reno, McPherson, and Marion counties, unit B is characteristically a gray to dark-gray skeletal limestone composed of a mixed debris of rounded to subrounded fossil fragments and coarse sand grains (Plate II-A, C, D). Intergranular cement is coarse, sparry calcite. This lithology contrasts sharply with the underlying dolomite of unit A and is readily recognized in hand specimens. North of the Harvey County outlier in the deeper part of the North Kansas Basin (Fig. 2), the unit is recognized as a coarse-grained dolomitic limestone with rounded, frosted sand

EXPLANATION OF PLATE II

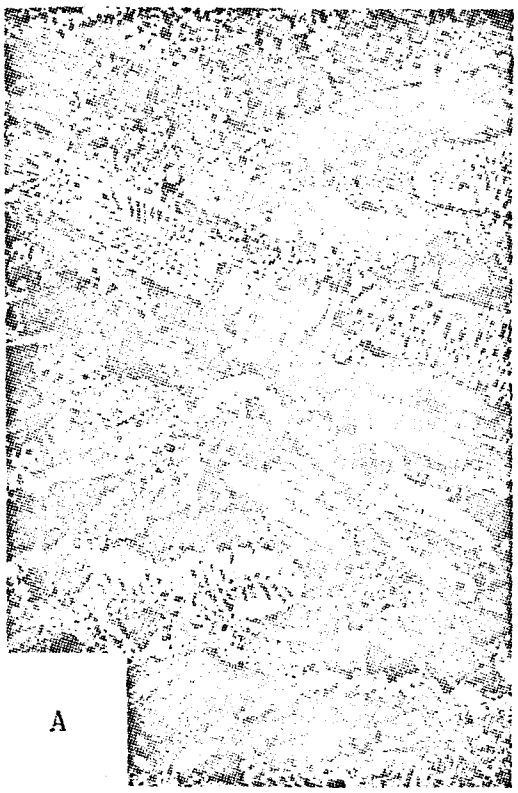
Typical facies of unit B. Illustrations are enlarged acetate peel-prints of core sections oriented with top of specimen toward top of page. (X 3.2)

A. Coarse fossil debris mixed with coarse, rounded, frosted sand grains (white and gray); sparry calcite is represented by dark-gray area. (No. 3 Lehman, at a depth of 3,298 feet)

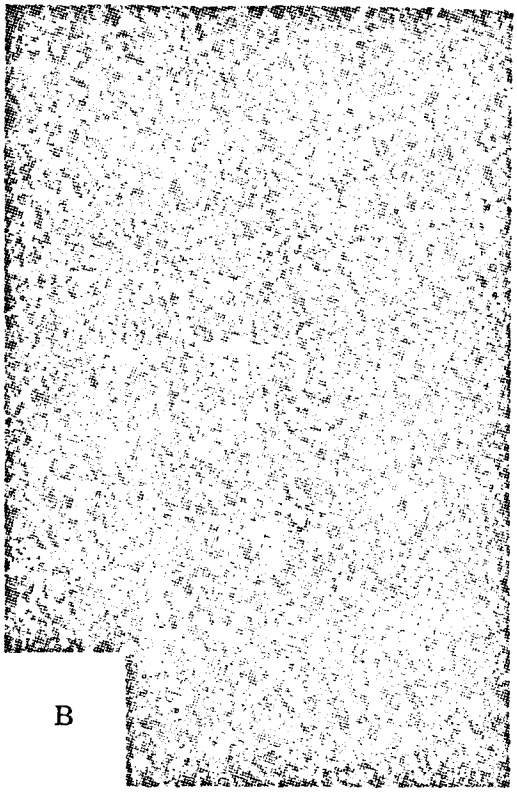
B. Light-gray areas represent dolomite; dark-gray areas are sparry calcite; light areas are quartz sand grains. (No. 2 Gehrt, at a depth of 1,531 feet)

C. Coarse fossil debris with many rounded crinoid fragments; very coarse quartz sand grains appear dark gray with white border; black areas are either sparry calcite or voids (No. 1 Lehman, at a depth of 3,291 feet)

D. Coarse fossil debris with scattered rounded, frosted sand grains (white and gray); black areas are sparry calcite note mixture of debris and sparry calcite inside corallite? chambers. (No. 1 Sperling, at a depth of 3,503 feet)

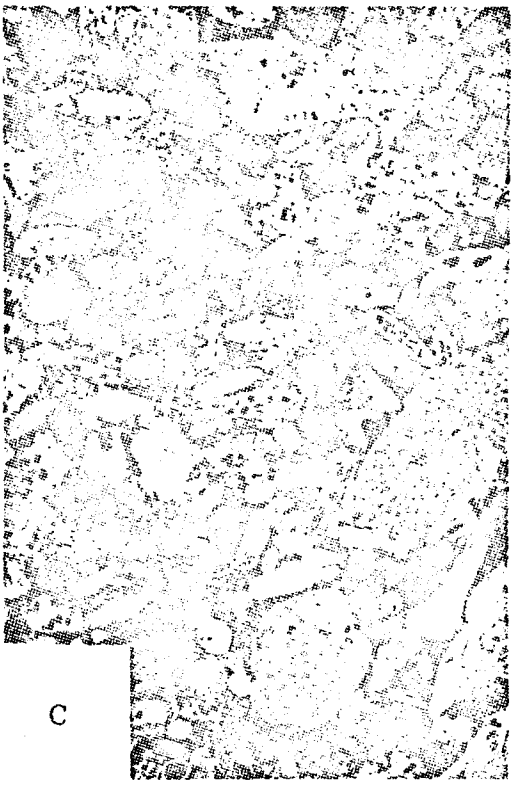


A

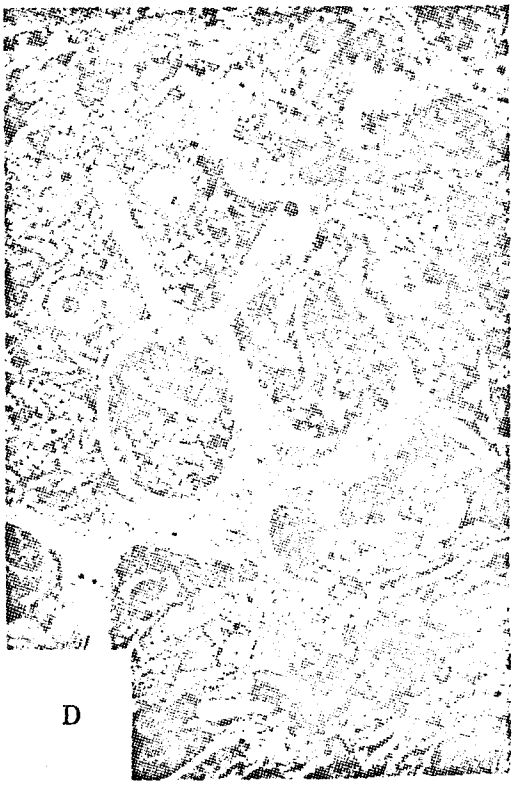


B

Plate II



C



D

Icriodus latericrescens latericrescens and Polygnathus varcus supports correlation of this unit with Givetian rocks.

Distribution

The inferred distribution of rock unit B is shown in Figure 10. Although the present distribution of this unit is considerably more restricted than underlying unit A, preservation of an outlier of unit B in Stafford County that rests unconformably on Ordovician rocks proves that the B unit must have overlapped unit A. This outlier further confirms that Givetian rocks overlapped the Ellis-Chautauqua Arch, but the southern and western limits remain unknown. Unit B rests unconformably on unit A, and its relationship to overlying rocks of unit C is inferred to be unconformable on the basis of lithologic and faunal evidence discussed later. In the No. 2 Koepsel well in Riley County, unit B is not recognized and unit C lies next above unit A. Because of the presence of brecciated and contorted beds at the contact (at a depth of 1,769 feet, 541 meters), the absence of unit B is assumed to be due to faulting rather than erosion. This well is located on the crest of the Nemaha Uplift and the presence of faults in the subsurface of the region is well documented in literature (Curtis, 1960; Merriam, 1963; Ireland, 1967b).

Unit B ranges in thickness from zero at its erosional margins to more than 200 feet in deeper portions of the North Kansas Basin. A core of equivalent beds taken in Sarpy County, Nebraska (Well No. 247), included Icriodus latericrescens

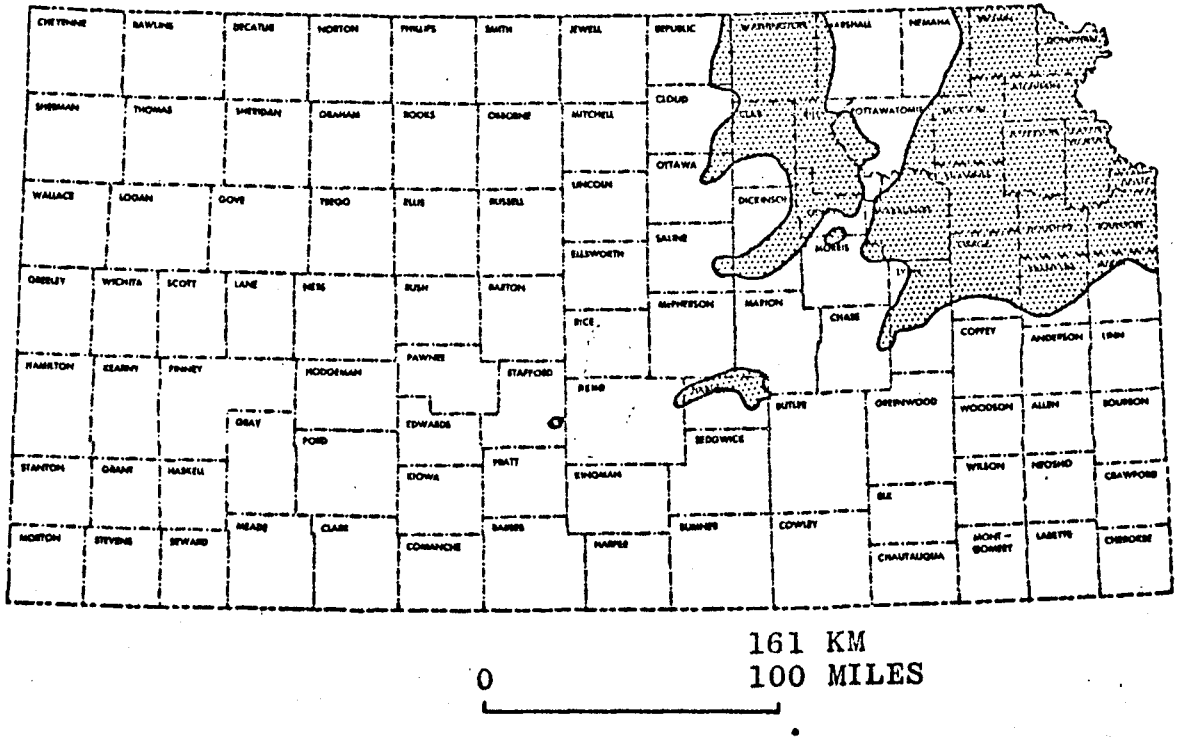


Figure 10. Inferred distribution of rock unit B. (stippled pattern)

latericrescens 285 feet below the top of the Cedar Valley formation.

Unit C

Lithology

Rocks of unit C are restricted to the North Kansas Basin and are characterized by gray to dark-gray dolomite. Sand grains are notably absent in contrast to lower units A and B. The dolomite is medium grained and dense, but locally fossil shell casts form highly porous zones saturated with oil. Some beds appear poorly laminated, but generally the unit is homogeneous. Chert is rare, but in porous zones isolated shell casts are filled with gray, translucent chert. In the No. 2 Davis Ranch core the dolomite is highly fractured. In this core most fractures and fossil shell casts are filled with pyrite. Acetate peel-prints of representative rocks of unit C are shown in Plate III.

Conodonts

Insoluble residues from four cores of this unit are characterized by the following conodont forms: Schmidtognathus wittekindti, Polygnathus cristatus, Icriodus cymbiformis, and Palmatolepis sp. Other genera recognized but not useful in correlation are: Hindeodella sp., Bryantodus sp., and Spathognathodus sp. The occurrence of Schmidtognathus wittekindti, Polygnathus cristatus, and Palmatolepis sp. supports correlation of this unit with rocks within the

EXPLANATION OF PLATE III

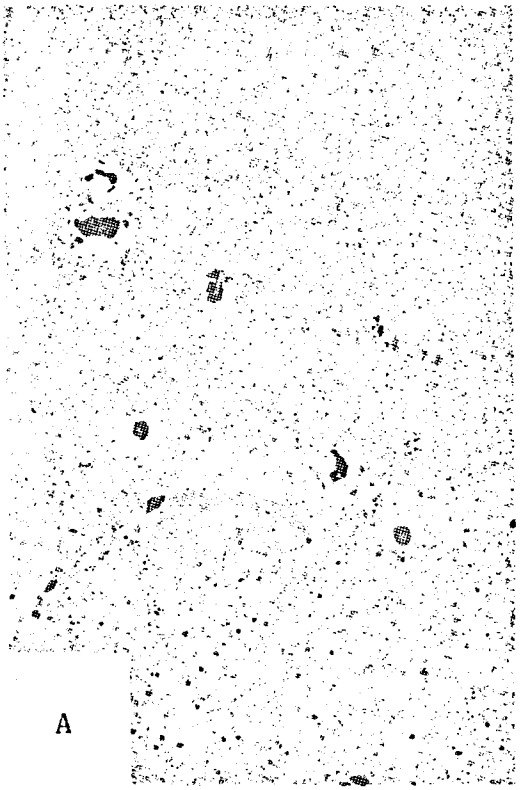
Typical facies of unit C. Illustrations are enlarged acetate peel-prints of core sections oriented with top of specimen toward top of page. (X 3:2)

A. Medium- to fine-grained dolomite; black areas are open voids; dark-gray "barb-like" feature is a portion of a shell fragment replaced by chert. (No. 2 Davis Ranch, at a depth of 2,981 feet)

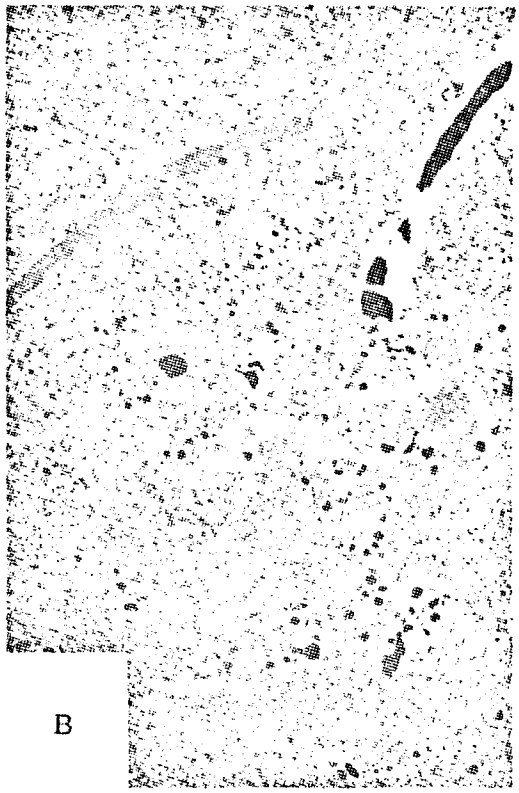
B. Dark-gray, medium-grained dolomite with numerous open voids appearing as black areas; dark-gray object is a shell fragment replaced by chert: note that an adjacent shell fragment is preserved as a cast coated with oil (whit rim). (No. 10 Strahm, at a depth of 2,832 feet)

C. Dark-gray, medium-grained nonporous dolomite; silicified fossil fragments are rare. (No. 2 Davis Ranch, at a depth of 2,980 feet)

D. Dense, medium- to fine-grained dolomite; irregular fossil casts rimmed with oil (white); white lines are scratches from polishing. (No. 2 Koepsel, at a depth of 1,664 feet)

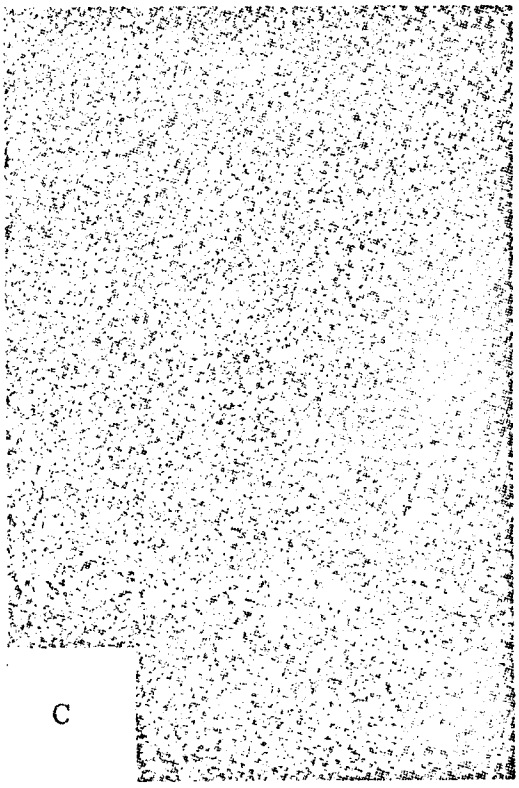


A

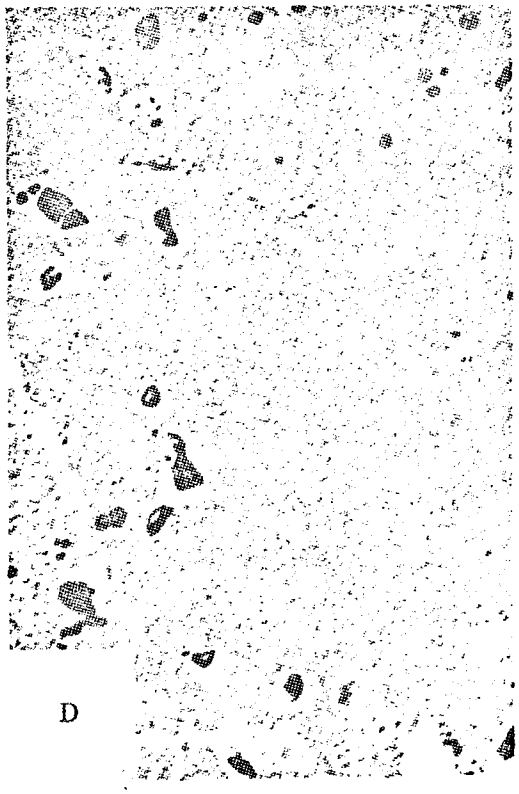


B

Plate III



C



D

Schmidtognathus hermanni-Polygnathus cristatus zone, the age of which is equivocal. In discussing this zone Orr and Klapper (1968) stated:

> The Schmidtognathus hermanni-Polygnathus cristatus zone (Ziegler, 1966) is found in Germany in beds lying between the Maenioceras terebratum zone below and the Pharciceras lunulicosta zone (Upper Devonian) above and thus is not fixed in terms of the Ammonoid chronology. The assignment of the S. hermanni-P. cristatus zone, especially of the part of the zone that carries P. cristatus Hinde, to either the Middle or the Upper Devonian must await the finding of diagnostic Ammonoids within it, unless agreement is reached to use some criterion other than Ammonoid evidence for the definition of the Middle-Upper Devonian boundary.

The zone is precisely correlative on a world-wide basis (Klapper, personal communication), but its classification remains debated. Within the context of this report, unit C is arbitrarily considered to be Upper Devonian because of the presence of Palmatolepis sp.

Distribution

The inferred distribution of rock unit C is shown on Figure 11. On the basis of cores studied, it does not extend beyond the limits of rock unit B although its present distribution is certainly a function of erosion. In a core taken at a depth of 2,832 feet in the No. 1 Strahm well, the underlying contact with unit B is preserved and judged to be unconformable. The contact is irregular and characterized by abundant quartz sand grains associated with pyrite and glauconite. Fragments of the underlying B unit are also included in this basal detrital facies.

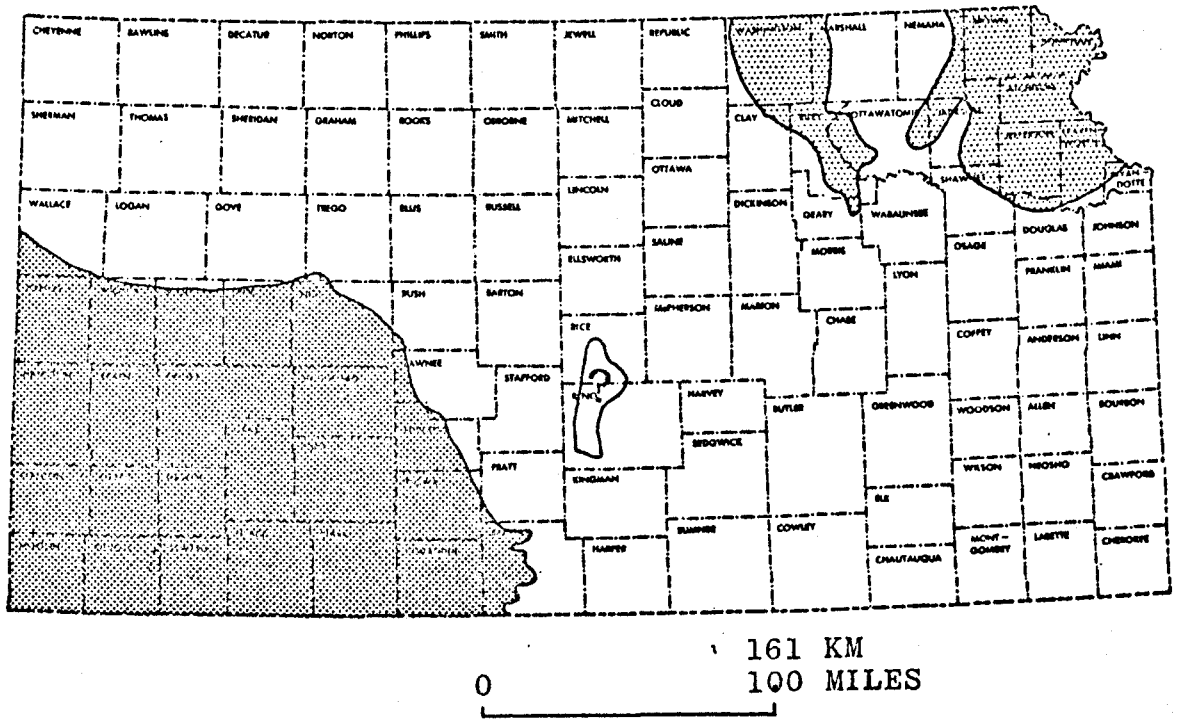


Figure 11. Inferred distribution of rock units C, D, and unassigned "Chattanooga limestone." (unit C - coarse stipple: unit D - fine stipple: "Chattanooga limestone" - ?)

Unit C is unconformably overlain by unit E of undoubted Late Devonian age. Unit C ranges in thickness from zero at the erosional margins to 5 feet at the Kansas-Nebraska border. In well No. 247, Sarpy County, Nebraska, it is more than 100 feet thick.

Unit D

Lithology

Rocks of unit D are characteristically gray to dark gray, fine to coarse, crystalline dolomite, locally containing gray, vitreous, nodular chert. The chert contains abundant black and amber specks which under magnification are revealed to be chitinozoans and other microscopic organisms.

Two types of dolomite are recognized within this unit. A coarser facies is composed of tightly interlocked grains of light and dark gray dolomite which gives a mottled appearance on its polished surface (Plate IV, A, D). A finer grained facies also contains dark and light grains but has a sandy appearance on a polished surface (Plate IV, B, D). Commonly, intraclasts of one facies are found within the other (Plate IV, A). Large open voids occur sporadically within unit D and are lined by transparent to translucent dolomite rhombs. In all cores of this interval, the dolomite is highly fractured, but this characteristic may not persist everywhere in the unit. The preservation of dolomitized crinoid columnals (especially in the coarser facies) confirms the view that the dolomite is secondary.

EXPLANATION OF PLATE IV

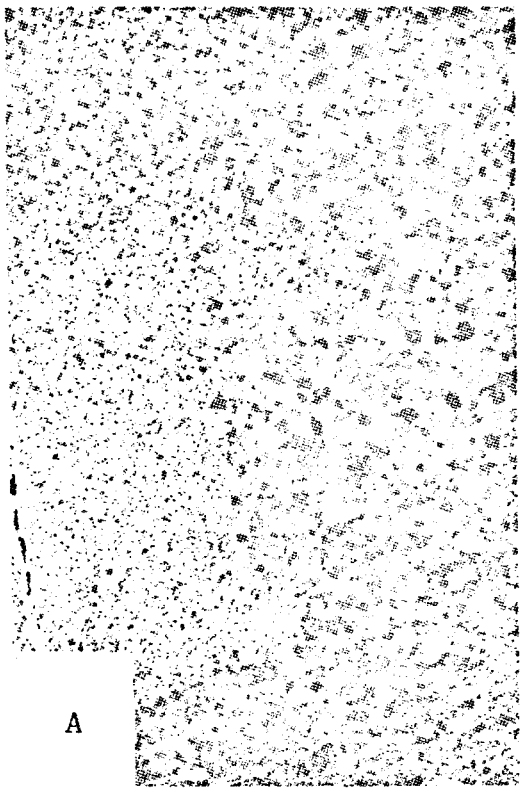
Typical facies of unit D. Illustrations are enlarged acetate peel-prints of core sections oriented with top of specimen toward top of page. (X 3.2)

A. Dark-gray, coarse-grained dolomite showing part of an intraclast of fine-grained dolomite at left; black area is an open fracture. (No. 1 Cunningham Estate, at a depth of 7,848 feet)

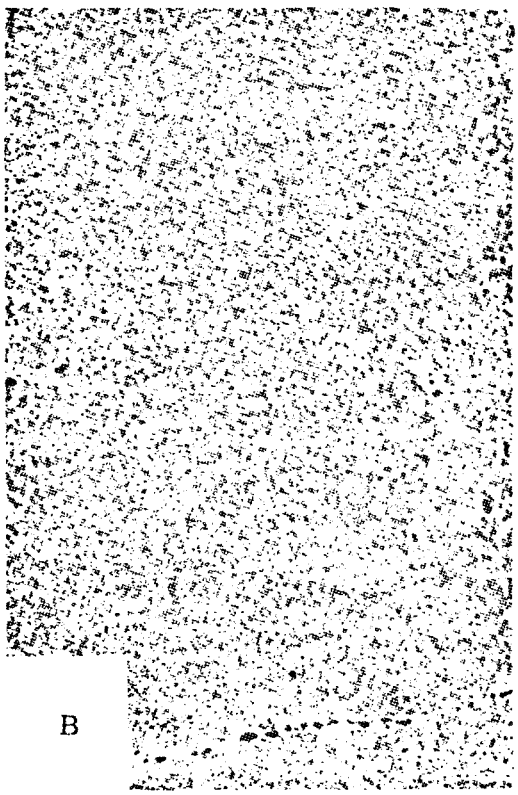
B. Light-gray, fine-grained dolomite displaying characteristic "sandy" texture; black areas represent voids along fracture. (No. 1 Elsea, at a depth of 4,968 feet)

C. Gray, coarse-grained dolomite showing characteristic interlocking grains and mottled texture. (No. 1 Cunningham Estate, at a depth of 7,854 feet)

D. Light-gray, fine-grained dolomite showing intersecting open fractures (black). (No. 1 Elsea, at a depth of 4,970 feet)

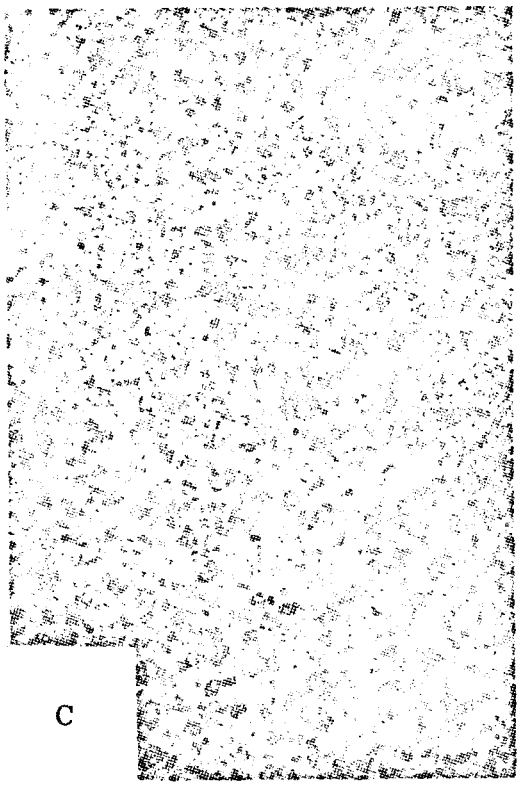


A

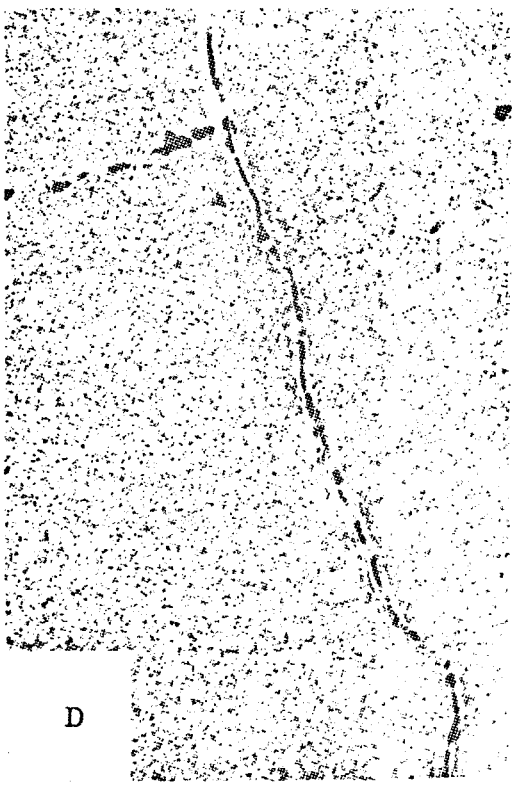


B

Plate IV



C



D

Conodonts

Insoluble residues from two cores of this unit are characterized by the following conodont forms: Ancyrognathus triangularis, Ancyrodella sp., Palmatolepis triangularis, P. quadrantinodosalobata, Polygnathus ordinatus, and P. cristatus. Other genera recognized but not useful in correlation include: Icriodus sp., Bryantodus sp., and Hindeodella sp. The occurrence of Ancyrognathus triangularis and Palmatolepis triangularis supports correlation of this unit with Frasnian rocks.

Distribution

The distribution of unit D (Fig. 11) is inferred largely on the basis of secondary information (sample logs and electric logs), for only two cores of this interval were available for study. The limestone outlier in Rice and Reno counties has not been assigned to any lettered unit in this report and its placement on Figure 11 is purely arbitrary. Further discussion of this anomalous outlier is included later in the text describing "Chattanooga limestone." To the writer's knowledge, undoubted Devonian carbonate rocks have never been reported anywhere in the Southwest Kansas Basin prior to this investigation, and rocks comprising unit D have been generally considered to be Viola Limestone (Middle Ordovician). Concurrent with the present investigation, Edwin D. Goebel (Kansas Geological Survey) and Walter C. Sweet (Ohio State University) were engaged in a similar study of Ordovician rocks in the

subsurface of western Kansas and two cores of unit D were originally assigned to that project for study. When their acid resiudes were examined, it became apparent that a Devonian fauna was present, and the core remnants and residues were transferred to the writer for consideration in this investigation. The significance of this fortuitous discovery is discussed later in this report (and in Goebel, Sweet and Hilpman, 1969).

In both cores, unit D rests unconformably on underlying Ordovician rocks. In the No. 1 Elsea well, there is little doubt that the underlying strata represent the Viola Limestone, but in the No. 1 Cunningham Estate well there is insufficient data at present to make such a judgment. Unit D is overlain unconformably by unit E and ranges in thickness from zero at the erosional margins to 191 feet in the No. 1 Cunningham Estate well.

Unit E

Lithology

The rocks of this unit encompass a wide variety of lithologies ranging from clean quartz sandstone to coarse pyritic conglomerates. The unit is of erratic distribution and commonly reflects the lithology of underlying beds from which it was derived. Locally, it is recognized only by thin concentration of sand grains at the base of an overlying unit, but in the No. 1 Cunningham Estate well, it is represented by more than 50 feet of sandstone and sandy shale. In

cores of more shaley facies, the unit shows marked bedding. Elsewhere, in sandy and conglomeratic facies, the rock ranges from poorly bedded to massive. None of the rocks of this unit lend themselves to peel techniques and accordingly, representative lithologies are not illustrated in this report.

Conodonts

Cores from nine wells contained rocks of unit E, and their insoluble residues contained a rich fauna of Devonian conodonts admixed with older forms. Indigenous conodonts recognized include the following forms: Ancyrodella sp., Ancyrognathus sp., Palmatolepis subrecta, P. tenuipunctata, P. triangularis, P. glabra, P. quadrantinodosalobata, P. serrata, Polylophodonta sp., Siphonodella sp., and Polygnathus communis. Pre-Devonian genera admixed with these forms include: Belodina sp., Cordylodus sp., Oistodus sp., Panderodus sp., Trichonodella sp. and Belodus sp. The indigenous fauna indicates considerable time transgression by this unit, ranging from earliest Late Devonian to Early Mississippian (Tournaisian) time.

Distribution

The inferred distribution of rock unit E corresponds to the distribution of units F, G, and H as shown in Figure 12. Unit E represents the basal detrital facies of units F through H and is important in defining sedimentary basins in Late Devonian-Early Mississippian time. The unit rests unconformably

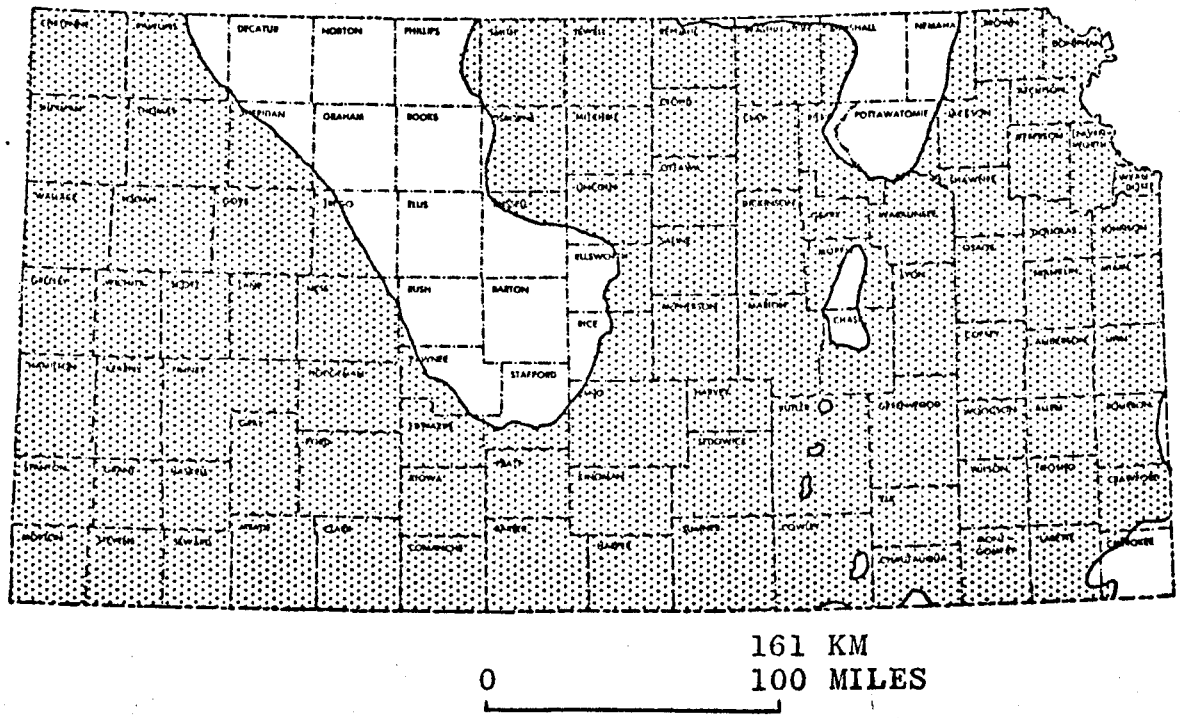


Figure 12. Inferred distribution of rock unit E. (stippled pattern)

on underlying rocks throughout its distribution. In Kansas, it overlaps rocks ranging in age from Ordovician to Late Devonian, and in southwestern Nebraska it overlies Cambrian rocks. Unit E grades upward into typical lithologies of respective overlying units F, G, and H.

The unit ranges in thickness from zero at the erosional margins to more than 50 feet in the No. 1 Cunningham Estate well.

Unit F

Lithology

Rocks of this unit are charactistically gray-black to black fissile shale, locally slightly silty, finely micaceous, and pyritic. Microscopic, amber-colored, disc-like bodies ("sporangites") are common in this unit. The abundance of these fossils has lithologic significance but their presence is often erroneously interpreted as indicating precise time significance. Further discussion of "sporangites" is included under the discussion of "Chattanooga limestone."

Conodonts

The shales of unit F are virtually insoluble in acetic acid and little success was experienced in breaking down the cores with either Quaternary "O" or Stoddard solution. A few conodonts were recovered by laboriously splitting cores along bedding planes and examining the surfaces under the microscope. In general, age relationships for this unit were based on conodonts recovered from underlying and overlying

units. Rocks of unit F do not permit the preparation of acetate peels suitable for printing and, accordingly, facies of this unit are not illustrated in this report.

Distribution

Inferred distribution of unit F is shown in Figure 13. Its lower boundary is transitional with the underlying detrital unit E. Where not truncated by post-Devonian erosion, unit F grades laterally and vertically into rocks of unit G. Traced west and north from southeast Kansas, unit F thins gradually as unit G thickens. The projected northwestern limit of this unit is based on the absence of black shale in cores and samples.

Unit G

Lithology

Rocks of this unit are characteristically light gray to gray, well laminated shale, locally silty or calcareous. Cores of unit G readily part along bedding planes that display an irregularly fluted surface. Truncation of laminae along the bedding surface suggests scour and fill structure. In contrast, other specimens show nearly parallel laminae. The darker laminae are attributed to the preservation of organic matter and lighter laminae appear to be composed of clay and very fine silt. "Sporangites" occur sporadically within this unit.

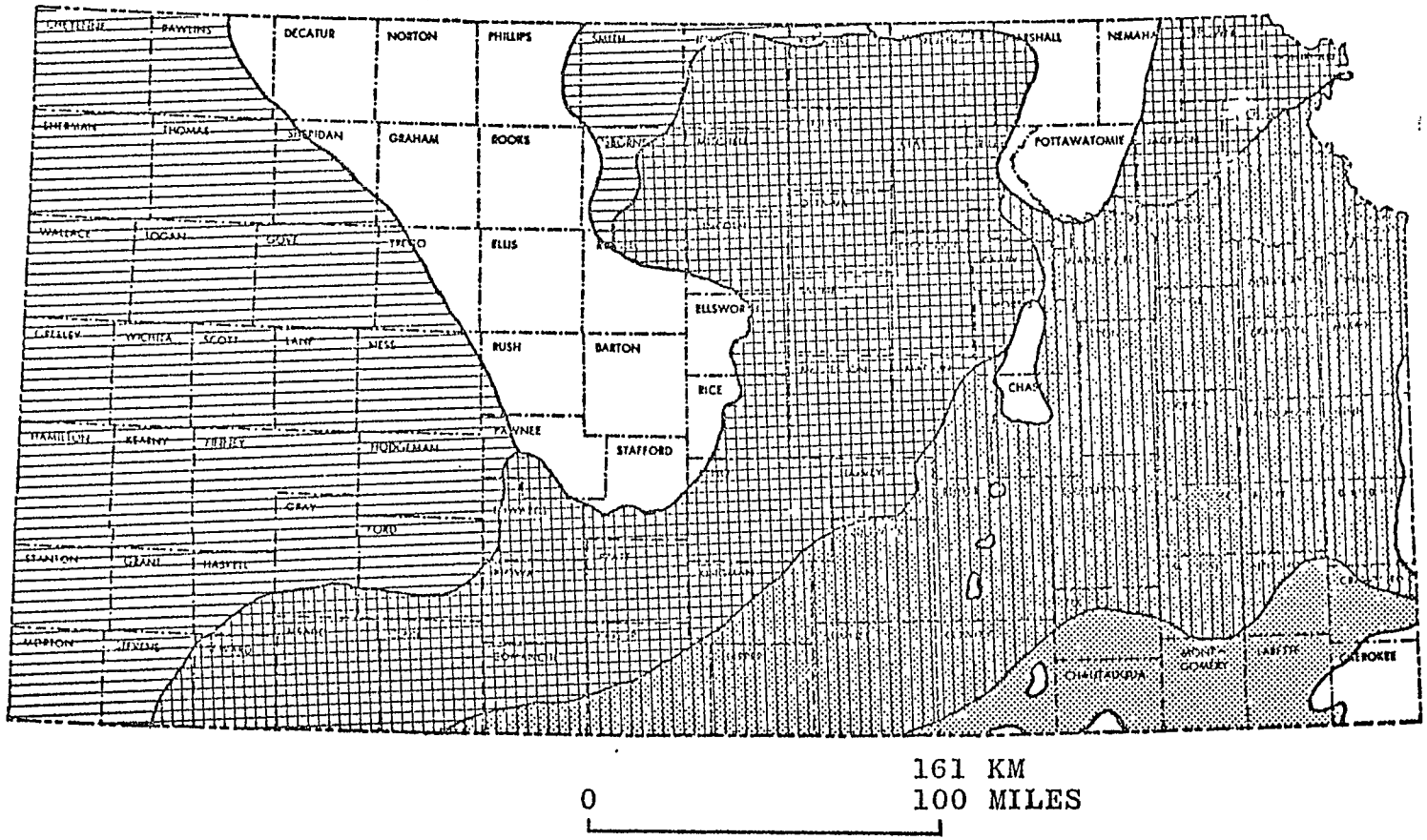


Figure 13. Inferred distribution of rock units F, G, and H. (unit F - stippled pattern: unit G - vertical lines: unit H - horizontal lines)

As with units E and F, unit G does not permit the preparation of acetate peels and accordingly representative facies are not illustrated in this report.

Conodonts

The seven cores of this unit proved only slightly soluble in acetic acid and no conodonts were recovered. Age relationships are based on stratigraphic relationships.

Distribution

The inferred distribution of rock unit G in relation to units F and H is shown in Figure 13. Southeastward it interfingers with black shales of unit F. The southernmost boundary is drawn along a line of wells in which light-gray shales are not recorded. As the unit is traced north and westward it becomes increasingly calcareous and interfingers with limestones of unit H (Fig. 14). The northwestern margin of unit G is projected along the line of wells in which limestones predominate.

The lower boundary of the unit is transitional with underlying unit E, and at the upper boundary the unit is unconformably overlain by Mississippian rocks (Osagian). The transitional margins of this unit with units F and H shift southeastward as the interval is traced from lowermost to uppermost beds. Accordingly, a well drilled in central Kansas is likely to encounter unit H, unit G, and unit F in descending order, as shown in schematic fashion in Figure 14.

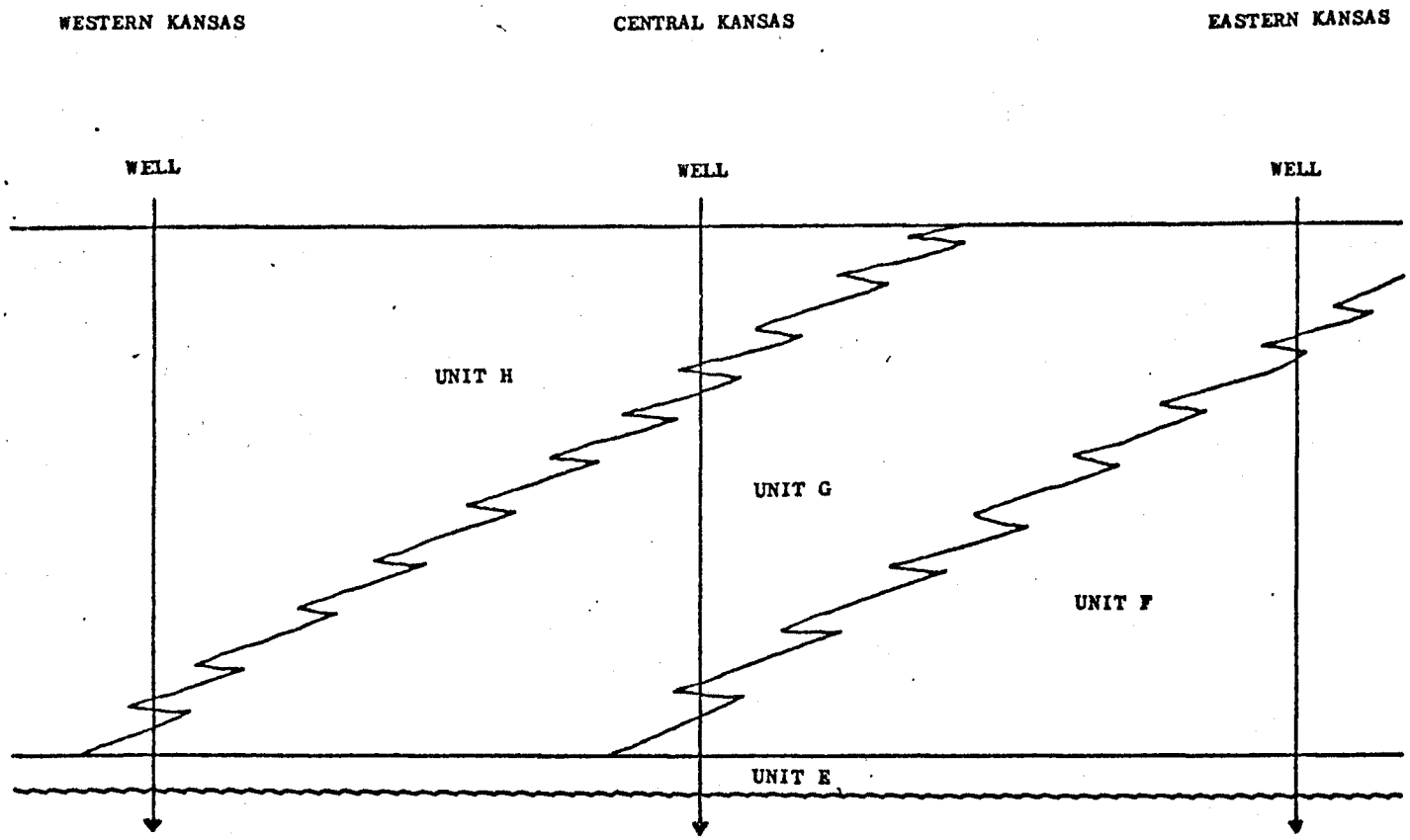


Figure 14. Schematic cross-section showing facies and time relationships between units F, G, and H.

Only regional studies of these units reveal that they are facies of one another, as depicted in this illustration.

The thickness of unit G ranges from zero at the erosional margins to 200 feet in McPherson County and more than 250 feet in Nemaha County.

Unit H

Lithology

Rocks of this unit are characteristically buff to gray, granular to oolitic limestones that contrast sharply with all other units reported in this investigation. Commonly, the rock is dominated by well-rounded fossil fragments, many of which resemble the associated oolites, sporadically scattered in the debris. Locally, the unit contains abundant oolites in a calcareous dolomite matrix. Detrital sand grains are uncommon except in the basal beds that grade downward into underlying unit E. In the No. 1 Mercer well, the lowermost beds are dark buff gray limestone. Chert occurs sporadically in the upper part of the unit. Acetate peel prints of representative lithologies of this unit are shown in Plate V.

Conodonts

Insoluble residues from three cores of this unit are characterized by the following conodont forms: Clydagnathus n. sp. b, Palmatolepis sp., Siphonodella sp., Polygnathus communis, and P. inornatus. Other genera recognized but not useful in correlation include: Ozarkodina sp.,

EXPLANATION OF PLATE V

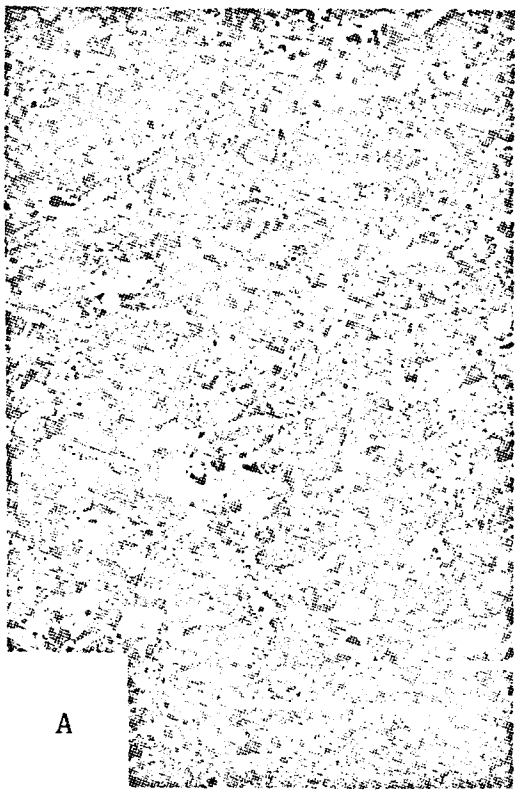
Typical facies of unit H. Illustrations are enlarged acetate peel-prints of core sections. Core specimens are not oriented with regard to top and bottom but peels were prepared on a polished surface oriented normal to bedding planes. (X 3.2)

A. Well-rounded skeletal fragments and scattered oolites; black areas represent sparry calcite and voids. (No. 1 Mercer, at a depth of 5,464 feet)

B. Admixture of rounded skeletal fragments and oolites in sparry calcite matrix; light and dark-gray areas represent fragments and oolites; black areas represent sparry calcite; black areas ringed with white represent voids. (No. 1 Smith, at a depth of 5,197 feet)

C. Dark-gray limestone composed of crinoid columnals and rounded fossil fragments; gray areas represent fossil fragments; dark-gray areas represent sparry calcite; black areas ringed with white represent voids. (No. 1 Smith, at a depth of 5,199 feet)

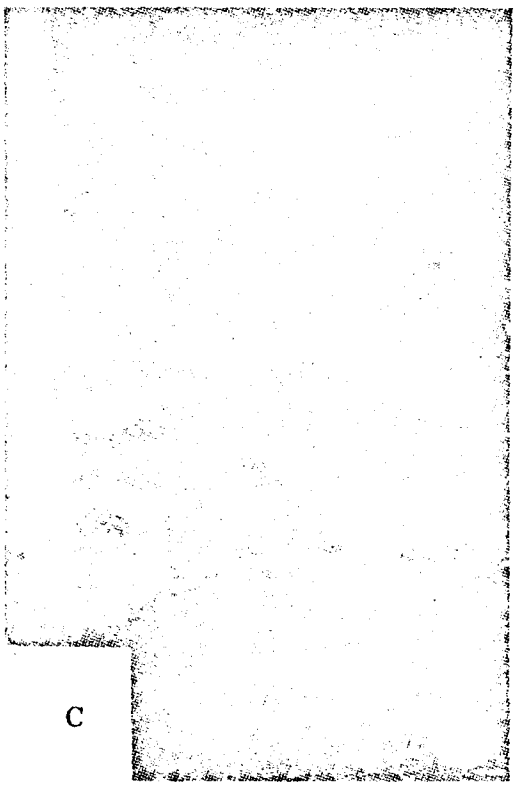
D. Admixture of well-rounded skeletal fragments and oolites; black areas represent sparry calcite and voids; white areas represent oil stains. (No. 1 Mercer, at a depth of 5,460 feet)



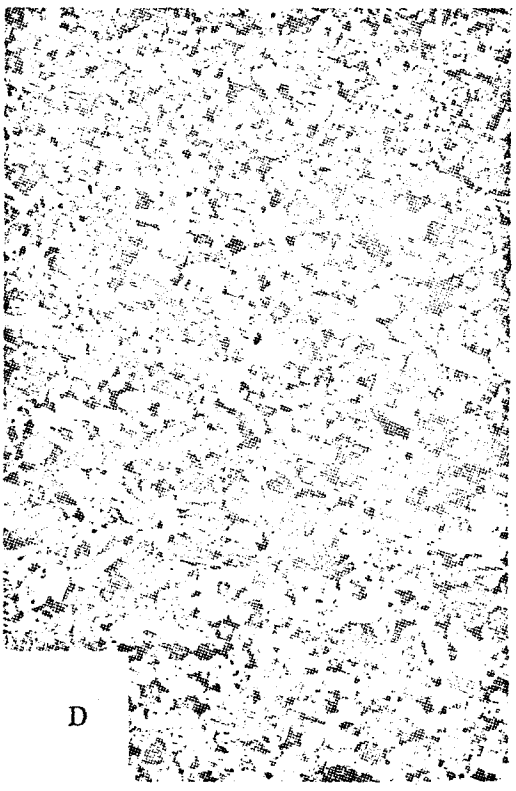
A

B

Plate V



C



D

Hindeodella sp., Spathognathodus sp. The occurrence of Clydagnathus n. sp. b, Polygnathus communis, Siphonodella sp., and Palmatolepis sp. support correlation of this unit with Upper Devonian (Famennian) and Lower Mississippian (Tournaisian) rocks.

Distribution

The inferred distribution of rock unit H is shown in Figure 13. Its lower boundary is gradational with underlying unit E, and the unit interfingers with green-gray shales of unit G (Fig. 14). At the upper boundary, unit H is unconformably overlain by Mississippian rocks (Osagian). Unit H ranges in thickness from zero at the erosional margins to more than 100 feet in southwestern Kansas. The extent of this unit in adjacent parts of Colorado is unknown but is presently under investigation.

"Chattanooga limestone"

Lithology

No cores of this unit were available for study and accordingly, description of its lithologic characteristics is based solely on well sample cuttings. Rocks of this unit consist of light-gray to buff, finely crystalline limestone. Sand grains and chert have not been observed in these rocks. Locally, the rocks are slightly argillaceous and Lee (1956) reported 5 to 10 feet of argillaceous, sucrose dolomite capping the unit in some areas.

Fossils

Because cores of this unit were unavailable for study, the writer hand-picked cuttings from five cable-tool wells penetrating the unit in an attempt to recover conodonts from the insoluble residues. Unfortunately, this effort proved unsuccessful and no reliable basis of correlation exists at present.

Lee (1956) interpreted this unit to be a limestone lentil within the Chattanooga Shale--primarily because of the occurrence of sporangites within the unit and within the underlying and overlying shales. The present writer recognizes the distinct possibility that the "Chattanooga limestone" is a lentil of unit H but considers the presence of sporangites within the unit a poor basis of correlation with any unit. Spore-like microfossils variously referred to in literature as Tasmanites, "sporangites" and spores are reported from the Sylvan Shale (Ordovician) of Oklahoma (Hedlund, 1960) and Niagaran rocks (Middle Silurian) in northeastern Illinois (Lowenstam, 1948). Clearly, these microfossils range from Late Ordovician to Late Devonian and have little stratigraphic significance when not properly identified (Marcia R. Winslow, University of Kansas, personal communication). Edson (1929) reported the unequivocal occurrence of "sporangites" in pre-Devonian rocks of the same area, but Lee may not have been aware of this earlier study.

Lee considered the shale beneath this lentil to be Chattanooga Shale. Conodonts uncovered in this investigation

indicate that the underlying shale is Maquoketa (Upper Ordovician) and that a thin bed of unit E lies immediately beneath the limestone outlier.

Distribution

The distribution of "Chattanooga limestone" is shown in Figure 11. It is assumed to rest conformably on unit E and interfinger laterally with unit G southeastward. To the west the unit is overlapped by Pennsylvanian basal conglomerates. The "Chattanooga limestone" ranges in thickness from zero at the erosional margins to more than 60 feet thick in southern Rice County.

NOMENCLATURE AND CORRELATION

The use of lettered (A through H) rock units in lieu of formal and informal names in common usage may appear a cumbersome and confusing plan to the reader. Accordingly, before discussing regional relationships and epeirogenic significance of these units, it would seem appropriate to substitute names for lettered units when sufficient evidence exists for doing so in accordance with the code of stratigraphic nomenclature (American Commission on Stratigraphic Nomenclature, 1961). In discussing nomenclatural problems created by correlation of surface and subsurface units, Article 13g of the code (op. cit.) states:

> It may be possible to correlate a named subsurface unit with a named surface unit. If the characteristics of both are so similar that two names are unnecessary, priority and usage should determine which is to be applied.

Strictly speaking, this section of the code does not apply in this case, for units designated by letters in this report have not been formally named and some of the rocks with which equivalence can be demonstrated are informally named. In keeping with the spirit of the code, however, names in common usage are substituted here (where justified) for lettered units in the remainder of this text. Units for which equivalence with a commonly named unit cannot be demonstrated retain their letter designation. Reasons for selecting either alternative for a given unit are as follows:

Unit A--occupies a stratigraphic position similar to that of the Wapsipinicon Formation but the latter differs lithologically in containing evaporite beds. No conodonts or diagnostic fossils have been found in the Wapsipinicon to facilitate correlation. The designation unit A is retained.

Unit B--occupies a stratigraphic position similar to that of the lower part of the Cedar Valley Formation and part of the Calloway Formation containing Icriodus latericrescens latericrescens but differs lithologically. The Fortune Formation of southwest Missouri also contains these same diagnostic conodonts but contrasts lithologically. Fraunfelter (1967) has recently introduced the name Cedar City Formation for the Calloway of Missouri and retained Calloway as a facies of his unit. Conodonts of the Calloway Formation have not been adequately studied and reliable correlation is not yet possible. The designation unit B is retained.

Unit C--occupies a stratigraphic position similar to that of the upper part of the Cedar Valley Formation and both contain a conodont fauna characteristic of the Schmidtognathus hermanni-Polygnathus cristatus zone. The units differ lithologically and the Rapid Member has not been adequately traced into the subsurface. The designation unit C is retained.

Unit D--has no recognized equivalents in Nebraska, Missouri, and Oklahoma. The unit is thought to be equivalent to unnamed Devonian rocks in the subsurface of Colorado. The designation unit D is retained.

Unit E--occupies the same stratigraphic position as sandstone units below black shales (Grassy Creek, Woodford, and Chattanooga formations) of Arkansas, Missouri, and Oklahoma. Unit E and all these basal sandstone units are transgressive from early Late Devonian into Early Mississippian time. Although informal, the term Misener sandstone is widely accepted for unit E throughout Kansas. The name Misener sandstone is, therefore, substituted.

Unit F--occupies the same stratigraphic position as the Woodford Shale of Oklahoma and the name Chattanooga Shale is widely accepted for this unit in Kansas. Both these units are characterized by black fissile shales ranging in age from Late Devonian to Early Mississippian. The name Chattanooga Shale is, therefore, substituted.

Unit G--occupies the same stratigraphic position as the Chattanooga Shale and is informally called "Kinderhook" shale

in Kansas. The unit contrasts lithologically with the Chattanooga. The term "Kinderhook" shale is inadvisable but persists in spite of attempts by stratigraphers to suppress it. The designation unit G is retained.

Unit H--occupies the same stratigraphic position as the Chattanooga Shale and unit G in Kansas and the Hampton Group and Gilmore City Limestone of Nebraska. The names Sedalia Dolomite and Gilmore City Limestone are presently applied to this unit by stratigraphers in Kansas. Prior to this study, the Sedalia and Gilmore City have not been recognized as including Devonian rocks and are presently assigned a Kinderhookian age. The name Sedalia Dolomite is substituted for the lower, dark buff-gray strata of unit H and the name Gilmore City Limestone is substituted for the overlying gray, granular to oolitic beds of unit H.

REGIONAL RELATIONSHIPS AND EPEIROGENIC SIGNIFICANCE

The character and distribution of Late Cambrian, Ordovician, and Silurian strata in Kansas indicates that shallow seas covered the region and a sequence of marine sandstones, shales, and carbonates was deposited during pre-Devonian time. Area-wide unconformities are present within the sequence, but marked development of basins and intervening uplifts is not indicated. In Late Silurian time the entire area became emergent and widespread erosion ensued. This erosion continued through Early Devonian time, although transgressive seas occupied slowly subsiding basins in

adjacent states (Iowa and Oklahoma). There is little evidence to suggest that the structural provinces depicted in Figure 5 had as yet developed. By early Middle Devonian time, the North Kansas Basin was downwarped and merged with the Central Iowa Basin; epeirogenic differentiation in Kansas was initiated. Seas that transgressed into Kansas from the northeast deposited sandy dolomites of unit A and, subsequently, fossiliferous limestones of units B and C. The outlier of unit B in Stafford County (Fig. 10), and the similar outlier of the Fortune Formation in southwestern Missouri are of equivalent age. The location of these outliers along the Ozark Uplift-Chautauqua Arch-Ellis Arch axis suggests that maximum transgression occurred during the time these rocks were deposited. The unconformities above and below unit B are not everywhere present within the North Kansas-Central Iowa Basin area and are interpreted to represent marginal withdrawals of Middle Devonian seas from Kansas. Rocks of this epoch are unknown elsewhere in the state, and erosion is assumed to have continued south and west of the North Kansas Basin. There is little reason to suspect that the eroded areas were marked by significant relief, for detrital clastics are insignificant in basinal deposits of this time.

In earliest Late Devonian time (post-S. hermanni-P. cristatus zone) the area was subject to epeirogenic differentiation that resulted in the formation of the Southwest Kansas Basin (Fig. 5). Through gentle downwarping of southwestern Kansas and a seemingly compensating uplift in the North Kansas

Basin, Middle Devonian areas of erosion and deposition were transposed. The axis of the tilting conforms with the common axis of the Ellis and Chautauqua arches.

With submergence of the Southwest Kansas Basin, seas from south and west invaded Kansas through the Colorado Sag (Fig. 2). Sediments deposited by these seas are presently more than 7,000 feet beneath the surface in extreme southwestern Kansas and are even more deeply buried in the Panhandle area of Oklahoma. Few wells in Kansas, Oklahoma, and Colorado have penetrated this interval, and additional information about unit D and the basin in which it was deposited is not likely to be generated rapidly. Cores thought to include this interval have recently been received by the Kansas Geological Survey but could not be processed in time for inclusion in this report.

By Middle Senecan (Frasnian) time, the sea withdrew in response to general emergence in the area and erosion became widespread throughout the state except in extreme southeastern Kansas. In this area, rocks correlative with the Misener sandstone (Sylamore Sandstone of Oklahoma and Arkansas) and the overlying black Chattanooga Shale (Woodford Shale) were being deposited by a transgressive sea from the southeast. No cores from extreme southeastern Kansas were studied during the present investigation, but workers in Oklahoma (Hass and Huddle, 1965) and in Arkansas (Freeman and Schumacher, manuscript in press) indicate that seas depositing black shale entered the southeast Kansas area before the demise

of the Southwest Kansas Basin. If this interpretation is correct, it follows that downwarping of the southern end of the Ellis-Chautauqua axis accompanied the tilting that formed the Southwest Kansas Basin. Conodonts recovered from Misener sandstone (unit E) and Chattanooga Shale (unit F) in eastern and south-central Kansas are younger than the fauna of unit D and support interpretation of gradual time transgression northwestward. In the No. 1 Elsea well (Barber County, Kansas), the Misener sandstone (unit E) and a thin interval of Chattanooga Shale (unit F) unconformably overlie unit D.

By Late Senecan (Frasnian) time, the sea from the southeast merged with a sea from the northwest which presumably crossed the Transcontinental Arch in western Nebraska and northeastern Colorado. The two seas not only contrasted in direction of transgression but also in the character of sediments deposited within them. The northern sea was characterized by carbonates of the Sedalia Dolomite and Gilmore City Limestone (unit H) and the southern sea deposited the black shales of the Chattanooga (unit F). The green-gray shales of unit G are believed to be transitional between these contrasting lithologies for the unit is found to interfinger laterally with both types of rock. The Misener sandstone (unit E) occupies a basal position with respect to all three rock types.

As regional subsidence continued through Late Devonian and Kinderhookian time, the Misener sand and overlying facies transgressed successively older units northward onto

the flanks of the Transcontinental Arch. The entire western Midcontinent area was probably inundated in Kinderhookian time. In western Nebraska (No. 1 Hogsett well), Gilmore City Limestone (unit H) containing late Devonian conodonts rests unconformably on Cambrian rocks.

The sequence of rocks above the Misener sandstone (unit E) represents essentially continuous deposition from Late Devonian time through Early Mississippian time. The continuity is terminated by a prominent pre-Osagian unconformity of wide distribution in the Central Interior. Ham and Wilson (1967) reported this unconformity in Illinois, Iowa, Nebraska, Kansas, Missouri, Oklahoma and Arkansas.

A summary of the foregoing interpretations follows: (1) Widespread erosion during Early and Middle Devonian time in all areas except the North Kansas Basin. Early Devonian rocks are not reported anywhere in the state and Middle Devonian rocks are restricted to and roughly define the North Kansas Basin. (2) In early Late Devonian time the region was tilted along a northwest-southeast axis, creating the Southwest Kansas Basin to the south and initiating erosion in the north. Early Late Devonian (Frasnian) carbonates are restricted to and generally define the Southwest Kansas Basin. (3) By middle Late Devonian time, differentiation ceased in Kansas and the region slowly subsided as a unit through the remainder of the epoch and most of Kinderhookian time. (4) A widespread pre-Osagian unconformity in Kansas indicates Late Kinderhookian emergence.

(5) The Ellis-Chautauqua Arch trend was never a dominant positive element--merely an axis of relative stability during episodes of epeirogenic differentiation.

STRATIGRAPHIC SEQUENCES

Generalized epeirogenic interpretations for the Central Stable Interior have been put forth by Sloss (1960, 1963, 1964, 1966), Wheeler (1963, 1964), and Ham and Wilson (1967). The interpretations of these workers are not in agreement with one another in regard to the Devonian history of Kansas, and it is appropriate to discuss their views in light of information generated by this investigation.

The interpretations of Sloss depict Kansas as the scene of a single marine transgression, beginning in early Middle Devonian time (pre-unit A) and terminating in Late Mississippian time (Chesteran). Sediments deposited during this time interval comprise the Kaskaskia Sequence and are inferred to represent essentially continuous deposition.

Wheeler divided the Kaskaskia into two sequences (Piankasha and Tamaroa) separated by an early Late Devonian (pre-Misener) interregional unconformity.

While not specifically endorsing the concept of stratigraphic sequences, Ham and Wilson recognized three area-wide unconformities between the bounding unconformities of the Kaskaskia Sequence.

In spite of obvious differences, several similarities exist in these interpretations. First, all recognize the

area-wide extent of unconformities bounding Sloss' Kaskaskia Sequence. Second, none of the authors had firsthand knowledge of Devonian stratigraphy in Kansas and all drew heavily from lithostratigraphic interpretations of other workers in the area. Both Sloss and Wheeler admit "that the best answer to this problem will be provided by those who possess more critical data and who can view it through less prejudiced eyes" (Sloss, 1954, p. 123).

It is felt that interpretations presented in this report are based on "more critical data" and do not fully support any of the aforementioned interpretations.

Sloss (1966) presented a detailed account of the Kaskaskia Sequence (see Appendix B) in describing his epeirogenic sequence model (Fig. 15). Only his stages 1 through 3 involve rocks studied during this investigation and, accordingly, stages 4 and 5 will not be discussed in detail.

Stage 1 is characterized by widespread erosion with the entire craton well above base level and with little or no epeirogenic differentiation. Deposition is initiated in latest Early Devonian and early Middle Devonian time. The complete absence of Stage 1 deposits in Kansas is not in conflict with Sloss' interpretation, for Kansas is located on the portion of the craton not reached by these early seas. The LaPorte City Formation in the Central Iowa Basin is interpreted here to represent Stage 1 sedimentation.

In Stage 2, which includes Middle Devonian and early Late Devonian sedimentation, cratonic differentiation is accelerated

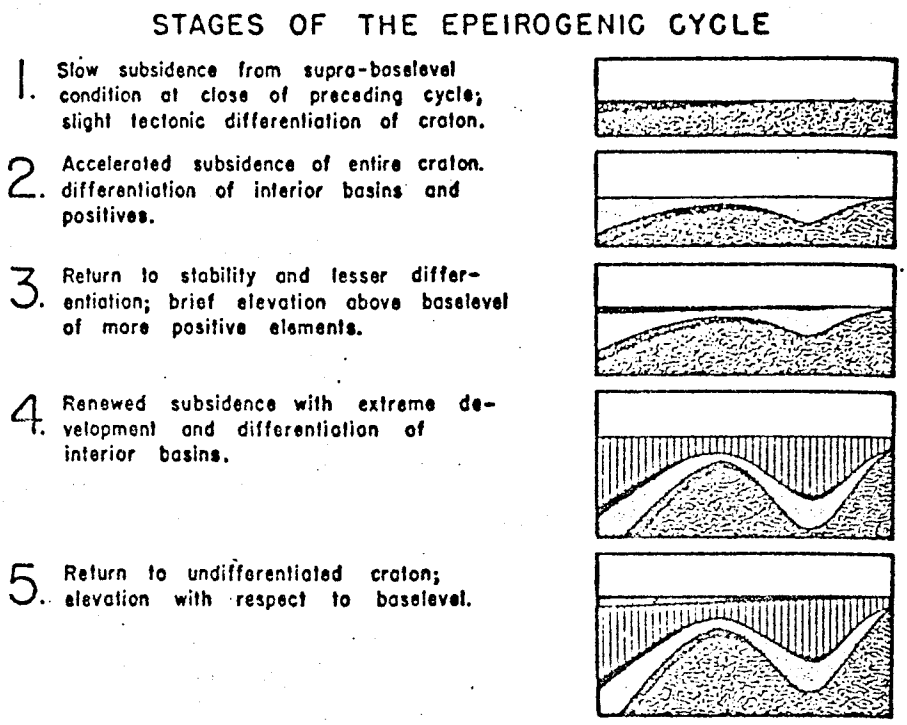


Figure 15. Stages of the epeirogenic sequence model. (Sloss, 1966)

and most of the Central Stable Interior is inundated. Stratigraphic relationships in Kansas largely conform to this plan (rock units A, B, C, and D). The development of epeirogenic differentiation in Kansas (North Kansas Basin, Southwest Kansas Basin, and Ellis-Chautauqua Arch trend) during Middle Devonian time is also in agreement with Sloss' views.

Sloss' third stage is marked by continued onlap interrupted by minor, local regressive phases of supra-base level emergence and climaxed in latest Devonian and earliest Mississippian time by deposition of Chattanooga Shale and equivalent strata. Application of the epeirogenic sequence model to Kansas stratigraphy breaks down at this point in precise agreement with interpretations presented by Wheeler and Ham and Wilson. In Kansas, the Misener sandstone rests unconformably on deeply eroded older Devonian rocks and pre-Devonian strata as old as the Early Ordovician Arbuckle Group. In surrounding states the Misener sandstone and its equivalent Sylamore Sandstone display similar relationships. Sloss acknowledges "minor regressive phases" within this stage, but it is difficult to accept emergence of northern Oklahoma, Arkansas, eastern Colorado, Kansas, Missouri, Nebraska and southern Illinois as a local regression. Conodont evidence uncovered in this and other investigations indicates considerable time transgression by the Misener sandstone, further supporting the presence of an important hiatus. Wheeler (1963) subdivided Sloss' Kaskaskia Sequence into the Piankasha (older) and Tamaroa (younger) sequences on the basis of this

unconformity. Ham and Wilson (1967, p. 365) considered this unconformity "one of the most conspicuous of all Paleozoic unconformitiès in the southern and central regions of this great interior province." The interpretations presented here support the views of Wheeler, and Ham and Wilson on this point. Data uncovered in this investigation do not, however, support Ham and Wilson in their interpretation of a major pre-Kinderhookian unconformity in the subsurface of the western Mid-continent. In describing this unconformity, Ham and Wilson pointed out that rocks above the unconformity are generally carbonates of Kinderhookian age--Hampton Group in central and western Nebraska and Gilmore City Limestone and Sedalia Dolomite (unit H) in western Kansas. Cores of these rock units in western Kansas and western Nebraska were examined as part of this investigation (No. 1 Mercer, No. 1 Hogsett, and No. 1 Smith wells). Both lithologic and paleontɔlogic data indicate continuous deposition from Late Devonian into Kinderhookian time for these strata (unit H). The same age relationships are also indicated for the Chattanooga Shale (unit F) and unit G--lateral equivalents of these rocks.

In southeastern Nebraska and northeastern Kansas, the Boice Shale of Kinderhookian age rests unconformably on the Chattanooga Shale and unit G. Evidence for a pre-Kinderhookian unconformity is unquestioned in this area. The Boice Shale (Fig. 16) is restricted geographically, however, and is associated with sporadic emergence along the Southeast Nebraska Arch (ancestral Nemaha Uplift). An uplift in this

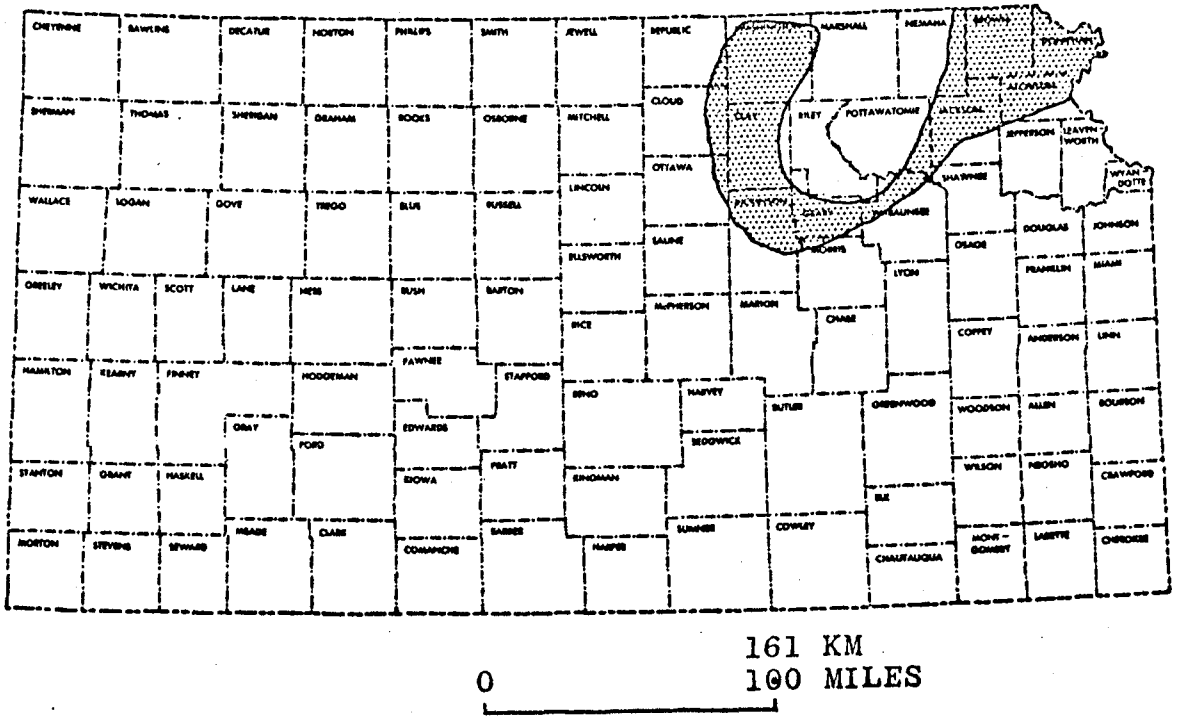


Figure 16. Inferred distribution of the Boice Shale. (stippled pattern)

area during Middle Ordovician time removed Arbuckle rocks from the Southeast Nebraska Arch in similar fashion (Lee, 1956, panel 1, Plate 1; Merriam, 1963, Figure 82). The arch was active again in Late Pennsylvanian time and tongues of arkose, developed by erosion on its crest, have been observed within rocks of the Kansas City Group (Missourian Stage). In short, the Southeast Nebraska Arch-Nemaha Anticline trend is an outstanding example of resurgent tectonics in the Midcontinent region, and the unconformities associated with its emergence have never been of more than local significance. Accordingly, a pre-Kinderhookian unconformity of regional extent has not been demonstrated for Kansas.

Stage 4 of Sloss' epeirogenic model occupies the remainder of Early Mississippian and most of Middle Mississippian time. It represents a return to conditions very much like those of Stage 2. Because Wheeler (1963) considered Sloss' omission of the pre-Misener unconformity as the "only glaring disparity" between their two interpretations, one can safely assume that he supported continuous deposition during this interval as well. In contrast, Goebel (1968), Ham and Wilson (1967), and Carlson (1963) cited considerable evidence for the existence of an area-wide pre-Osagian unconformity. This investigation did not include study of rocks from this interval and mention of the unconformity serves only as a terminal point for the discussion of epeirogenic sequences.

In summary, findings of this investigation support the presence of an important area-wide unconformity upon which

the Misener sandstone (unit E) was deposited throughout Kansas, but the presence of a pre-Kinderhookian unconformity of the same magnitude is not indicated.

CONCLUSIONS

(1) In Early Devonian time, Kansas was characterized by erosion rather than deposition.

(2) Middle Devonian strata are restricted to the North Kansas Basin and extended as far west as Stafford County.

(3) Early Late Devonian carbonates are widespread in the Southwest Kansas Basin and have been erroneously identified as Ordovician rocks.

(4) The Chattanooga Shale, unit G ("Kinderhook" shale), Sedalia Dolomite, and Gilmore City Limestone (unit H) represent lateral facies of one another and include rocks of Late Devonian and Early Mississippian age. The term "Kinderhook" shale should be discarded.

(5) The North Kansas Basin, Southwest Kansas Basin, Ellis Arch, and Chautauqua Arch are seemingly Devonian features and were of little epeirogenic significance in other Paleozoic periods.

(6) As defined, the Kaskaskia Sequence does not apply in the western Midcontinent.

(7) Devonian rocks in Kansas can be subdivided into eight distinct lithostratigraphic units. Conodonts provide a satisfactory basis for correlating these units with distant outcrops in surrounding states.

(8) The Ellis and Chautauqua arches are more realistically characterized as a stable area between subsiding basins.

(9) The North Kansas Basin was prominent only in Middle Devonian time.

(10) The Southwest Kansas Basin was prominent in early Late Devonian time.

(11) Middle Devonian rocks in Kansas were deposited by seas transgressing from the Central Iowa Basin.

(12) Early late Devonian rocks were deposited by seas transgressing northeastward from the Colorado Sag.

(13) Latest Devonian and Early Mississippian rocks were deposited in a sea formed by merging of a northwestern sea depositing carbonates and a southeastern sea depositing black shale.

(14) Use of the term "Hunton" should be discouraged in reference to Devonian rocks in Kansas, although it aptly applies to Silurian strata.

(15) In this investigation, cores of rocks previously interpreted as Ordovician or Mississippian in age have been found to contain indigenous Devonian conodonts. Clearly, currently accepted stratigraphic interpretations of pre-Pennsylvanian rocks in the subsurface of Kansas contain serious errors. Both paleontological and physical criteria must be evaluated if such misinterpretations are to be avoided in the future.

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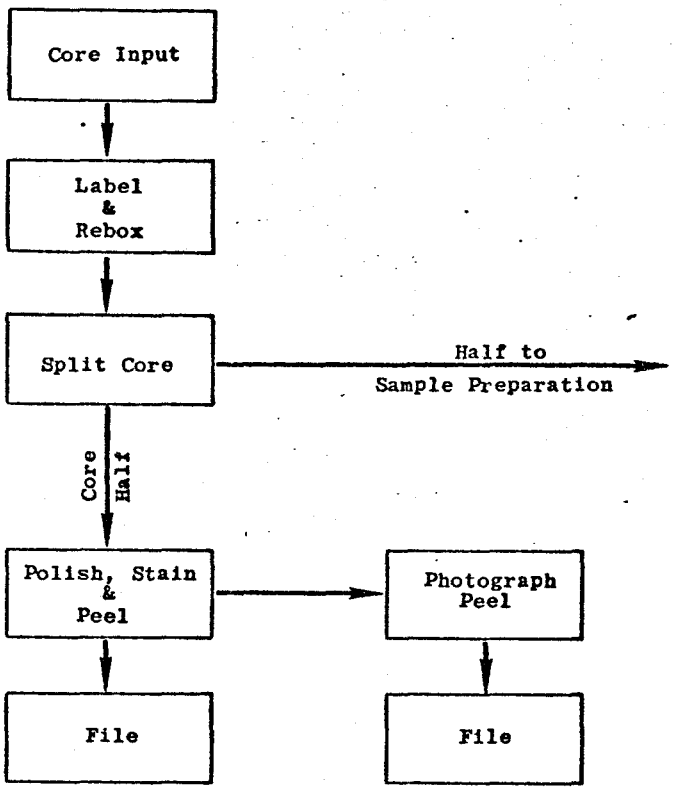
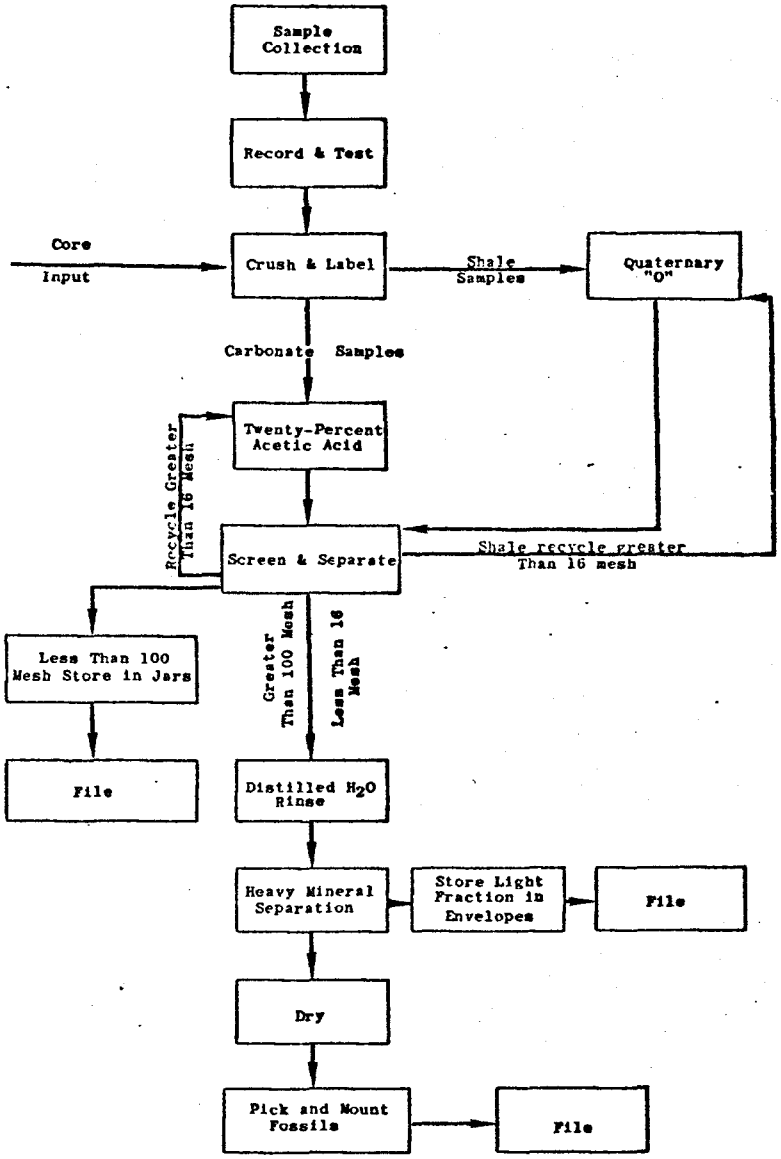
APPENDIX A

Flow diagram of major core preparation steps.



Flow diagram of major sample preparation steps.



APPENDIX B

"*The Epeirogenic Sequence Model.* Five stages are discernible in the tectonic behavior of the craton during the deposition of an epeirogenic sequence. These stages are illustrated diagrammatically in FIGURE 2 and may be clarified by brief discussion, using the Kaskaskia Sequence as an exemplar:

"*Stage 1* opens with the entire craton well above baselevel and with large areas suffering erosion as indicated by the profundity of the unconformity at the base of the sequence. Deposition is initiated in latest Early Devonian and early Middle Devonian time with the spread of blanket sandstones (Oriskany, Sylvania) and carbonates (Clear Creek, Onondaga, Bois Blanc) from the cratonic margins toward the interior without significant isopach or facies reflection of basins and other tectonic elements.

"In *Stage 2,* which includes much of the Middle Devonian and early Late Devonian, subsidence is accelerated and there is progressive onlap beyond the Stage 1 deposits to cover large cratonic-interior areas. Thicknesses and facies reflect differentiation of the craton; interior basins accumulate thick successions of salt (Elk Point, Detroit River) or carbonates (Grand Tower, Wapsipinicon).

"*Stage 3* (the remainder of Late Devonian and most of Kinderhookian) is marked by continued onlap interrupted by minor regressive phases and local supra-baselevel emergence; there is much less differentiation of basins from surrounding shelves and positives. The climax of the stage is in the latest Devonian and earliest Mississippian and is represented by thin sheetlike strata (Chattanooga, upper Three Forks, Baaken) of great extent and little systematic change in thickness of facies.

"*Stage 4* occupies the remainder of Early Mississippian and most of Middle Mississippian time and represents a return to conditions very much like those of stage [*sic*] 2. Onlap is renewed at a vigorous pace beyond the limits of Stage 2 and Stage 3 units to cover much of the cratonic interior early in the stage. By Meramec time, differentiation of the interior basins is re-established to a maximum degree and thick basinal carbonates (Salem), salts (lower Charles, Michigan), and shales (Caney, Barnett) are deposited.

"*Stage 5,* confined to the Late Mississippian, in [*sic*] characterized by gradual cessation of the differential subsidence of basins, combined with regression and offlap. In the cratonic interior, regressive clastic sediments (Elvira, upper Big Snowy) replace the dominant carbonates and evaporites of Stage 4. By the end of the stage, the entire craton is above baselevel, leading to the development of the sub-Absaroka unconformity." (Sloss, 1966, p. 583-585)