PENNSYLVANIAN STRATIGRAPHY OF THE NORTHERN SHELF AND EASTERN PART OF THE ANADARKO BASIN OF OKLAHOMA AND KANSAS

by

JOHN B. BUTLER

B. S., Oklahoma State University, 1959

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

TABLE OF CONTENTS

INTRODUCTION

This investigation is a subsurface study of Pennsylvanian stratigraphy on the eastern flank of the Anadarko Basin of Oklahoma, and the shelf area of North Central Oklahoma and South Central Kansas.

On the shelf of the Anakarko Basin of Northern Oklahoma and in the Sedgwick Basin of South Central Kansas, Pennsylvanian stratigraphic units are easily differentiated. That is, owing to the presence of excellent stratigraphic markers, accurate correlation of individual formations is possible. The limestones provide the best markers for the purpose of correlation in the area.

South of the shelf area, in the deeper parts of the basin, the probability of accurate correlation is lessened considerably. Correlation of the designated northern and southern stratigraphic units is hindered by the absence of fossils and good regional markers in the southern area. Rapid facies changes and variations of the stratigraphic column in different pools also tend to complicate the problem. In the central part of the Anadarko Basin individual formations were rarely correlated, and even the correlation of groups presented many problems.

Therefore, some of the sedimentary rock units of Kansas can be traced into North Central and Central Oklahoma, but few can be carried the length of the cross sections (Plates I and II).

Purpose of Investigation

The primary purpose of this investigation was to correlate the Upper Pennsylvanian limestones and shales on the shelf with the coarse clastics of the central Anadarko Basin of South Central and Central Oklahoma where a complete Pennsylvanian section, from Springeran to Virgilian, is present (see Figure 1).

A secondary purpose was to present a description of tectonic and depositional conditions, which prevailed during Pennsylvanian time and formed the Anadarko Basin, as revealed from the stratigraphic data gained. A brief description of geologic conditions previous to Pennsylvanian time is also included.

Location of Cross Sections

The area traversed by the cross sections is in South Central Kansas and North Central, Central, and South Central Oklahoma (see Figure 2). The cross sections are sub-parallel to the southern part of the Nemaha Anticline in Oklahoma and Kansas.

Cross section AB (Plate 1) consists of fifteen correlated electric logs extending from well No. 1 in the NE¼ SW¼ SW¼, Sec. 31, T. 20 S., R. 3 E., Marion County, Kansas, to well No. 15 in the NW¼ NW¼ NW¼, Sec. 8, T. 23 N., R. 3 W., Garfield County, Oklahoma. Well No. 15 of cross section AB is also well No. 15 of cross section BC.

Cross section BC (Plate II) consists of twelve correlated electric logs extending from well No. 15 in the NW¼ NW¼ NW¼,

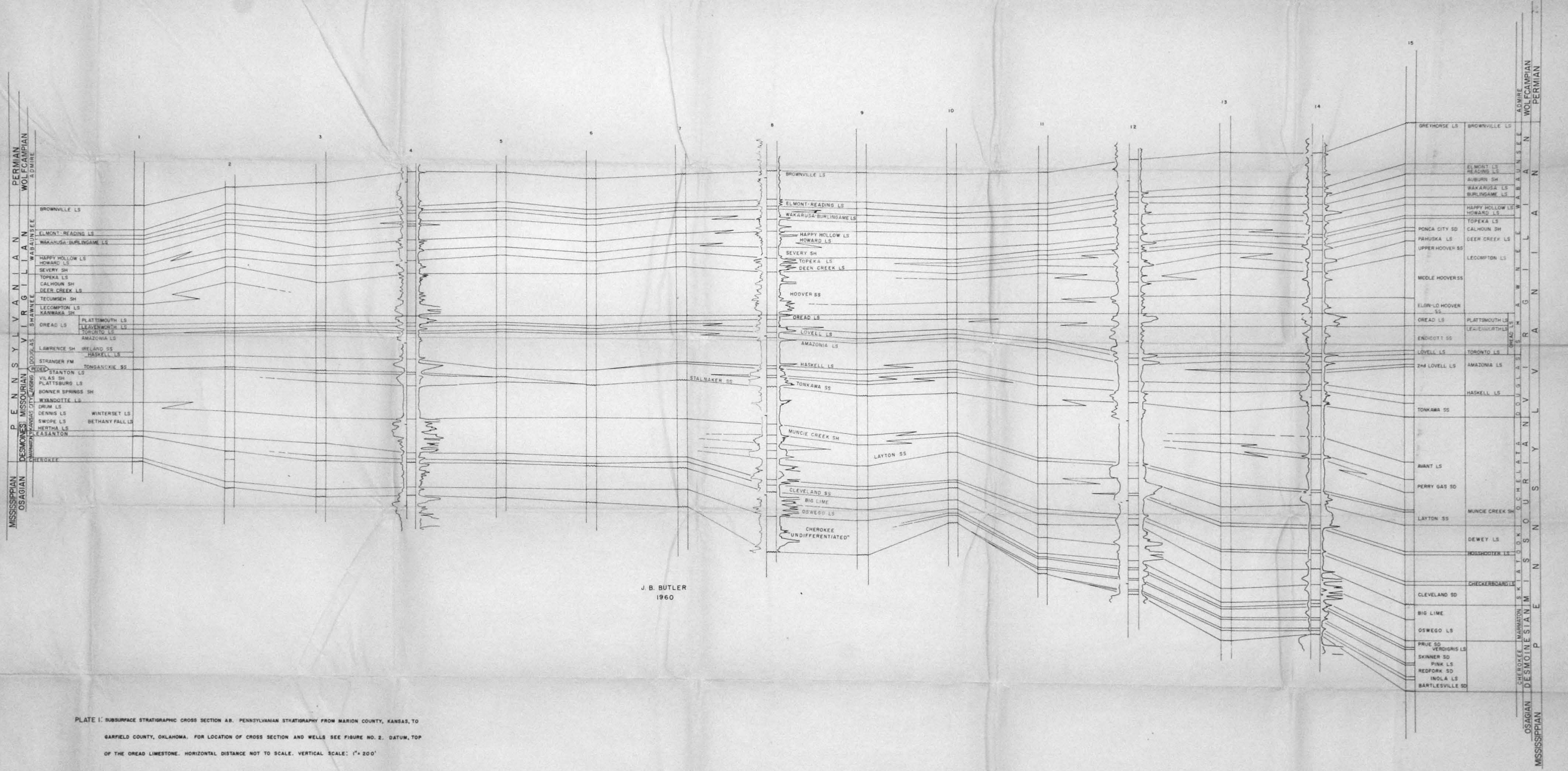

PLATE I: SUBSURFACE STRATIGRAPHIC CROSS SECTION AB. PENNSYLVANIAN STRATIGRAPHY FROM MARION COUNTY, KANSAS, TO GARFIELD COUNTY, OKLAHOMA. FOR LOCATION OF CROSS SECTION AND WELLS SEE FIGURE NO. 2. DATUM, TOP OF THE OREAD LIMESTONE. HORIZONTAL DISTANCE NOT TO SCALE. VERTICAL SCALE: 1"= 200'

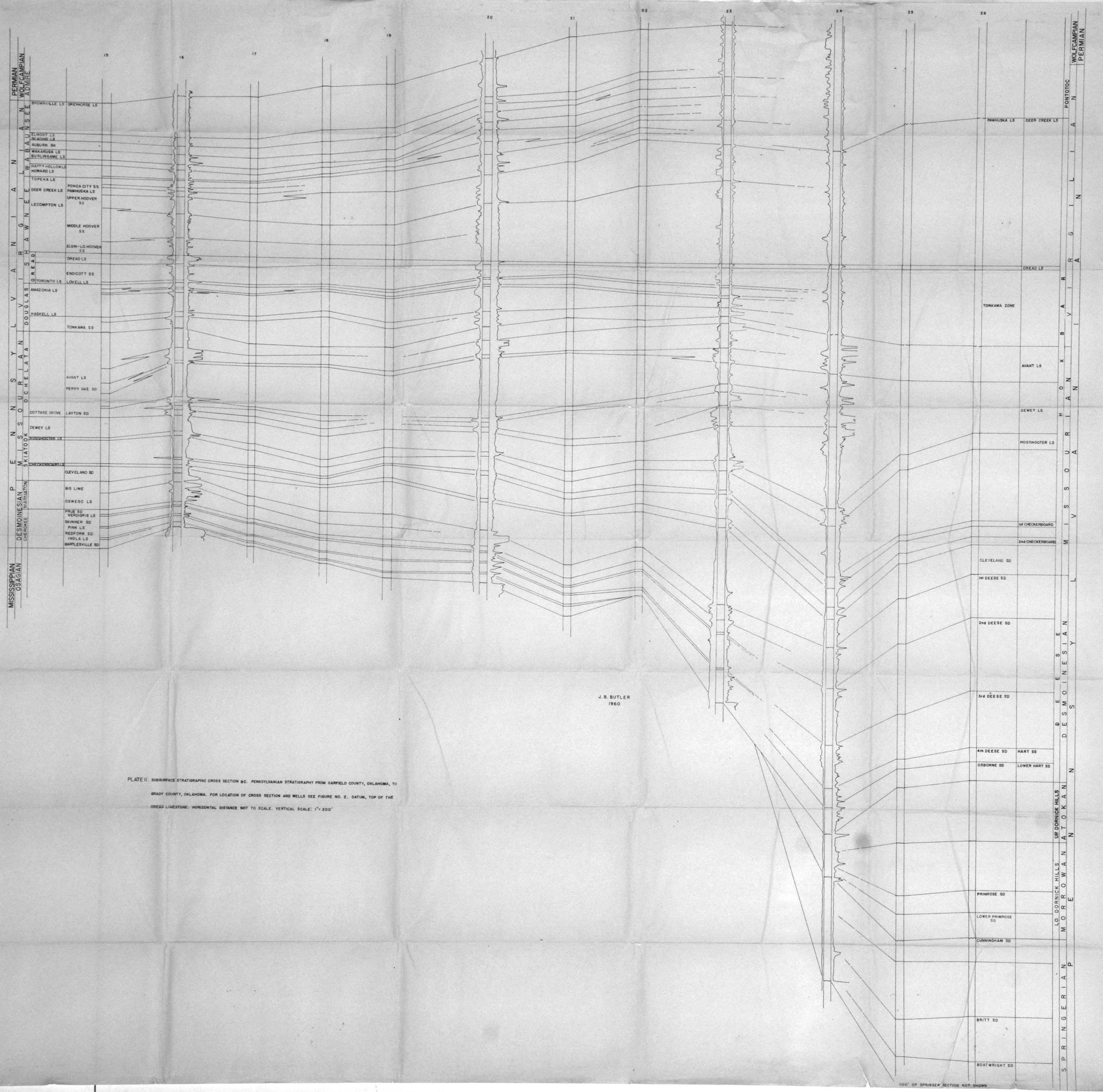

PLATE II. SUBSURFACE STRATIGRAPHIC CROSS SECTION BC. PENNSYLVANIAN STRATIGRAPHY FROM GARFIELD COUNTY, OKLAHOMA, TO GRADY COUNTY, OKLAHOMA. FOR LOCATION OF CROSS SECTION AND WELLS SEE FIGURE NO. 2. DATUM, TOP OF THE OREAD LIMESTONE. HORIZONTAL DISTANCE NOT TO SCALE. VERTICAL SCALE: 1" = 200'

SYSTEM	SERIES	SO. CENTRAL KANSAS & NO. CENTRAL OKLAHOMA		CENTRAL OKLAHOMA		SO. CENTRAL OKLAHOMA	
PERMIAN		Admire				Pontotoc	
PENNSYLVANIAN	VIRGILIAN	Wabaunsee	Brownville ls Elmont-Reading ls Wakarusa-Burlingame ls Happy Hollow-Howard ls	Wabaunsee	Grayhorse ls Stonebreaker ls Cryptozoan ls Happy Hollow-Howard	Pontotoc	
PENNSYLVANIAN	VIRGILIAN	Shawnee	Topeka ls Calhoun sh Deer Creek ls Kanwaka sh	Shawnee	Pawhuska ls Hooverss fm	--	Pawhuska ls
PENNSYLVANIAN	VIRGILIAN	Douglas	Oread ls Lawrence sh Stranger fm	Douglas	Cread ls Lovell ls Stalnaker ss	Hoxbar	Cread ls Tonkawa ss fm
PENNSYLVANIAN	MISSOURIAN	Lansing	Stanton ls Plattsburg ls Wyandotte ls	Ochelata	Avant ls Perry Gas sd Layton ss Dewey ls	Hoxbar	Avant ls Dewey ls
PENNSYLVANIAN	MISSOURIAN	Kansas City	Drum ls Dennis ls Swope ls Hertha ls	Skiatook	Hogshooter ls 1st Checkerboard ls 2nd Checkerboard ls Cleveland ss fm	Hoxbar	Hogshooter ls 1st Checkerboard ls 2nd Checkerboard ls
PENNSYLVANIAN	MISSOURIAN	Pleas-anton	"undifferentiated"	Skiatook		Hoxbar	
PENNSYLVANIAN	DESMOINESIAN	Marmaton	Big Lime ls Oswego ls	Deese	1st Deese sd 2nd Deese sd	Deese	1st Deese sd 2nd Deese sd
PENNSYLVANIAN	DESMOINESIAN	Cherokee	Prue sd Verdigris ls Skinner sd Pink ls Red Fork sd Inola ls Bartlesville sd	Deese	3rd Deese sd 4th Deese sd 5th Deese sd	Deese	Gibson sd Hart sd Lower Hart sd
PENNSYLVANIAN	ATOKAN	"absent"		Dornick Hills		Upper Dornick Hills	
PENNSYLVANIAN	MORROWAN	"absent"		Dornick Hills		Lower Dornick Hills	
PENNSYLVANIAN	SPRINGERAN	"absent"		"absent"		Cunningham sd Britt sd Spiers sd Boatwright sd Goddard sh	
MISSISSIPPIAN		OSAGIAN		KINDERHOOKIAN		KINDERHOOKIAN	

Fig. 1. Stratigraphic correlation chart of the Pennsylvanian system.

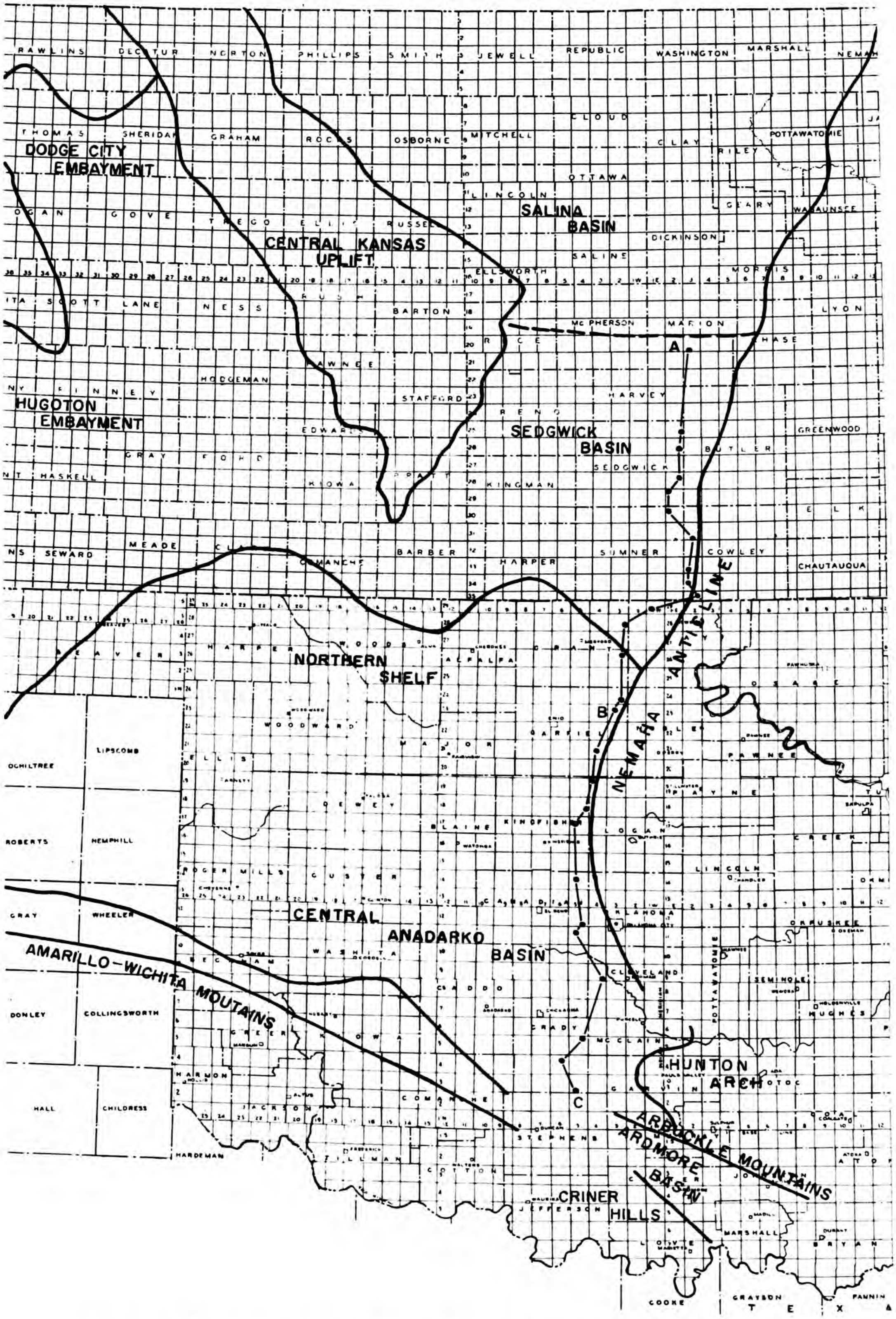

Fig. 2. Location map of stratigraphic cross sections and tectonic features.

Sec. 8, T. 23 N., R. 3 W., Garfield County, Oklahoma, to well No. 26 in the NW¼ NW¼ SE¼, Sec. 32, T. 3 N., R. 5 W., Grady County, Oklahoma.

Data on the wells used in the stratigraphic cross sections is given in Table 1.

Procedure

The stratigraphic cross sections were correlated by means of electric log examination and microscopic study of rotary well cuttings, supplemented by previous work of other geologists.

Rotary well cuttings were studied from all of the wells in the cross sections to determine the lithology of the sediments, and to corroborate correlations based on electric log data. Supplementary study of well samples from well near the line of the cross sections was also made to support stratigraphic correlation within the area of the cross sections.

As stratigraphy was the primary concern of the investigation, the wells in the cross sections are aligned vertically so that the top of the Oread limestone forms a horizontal plane or datum.

Isopach maps incorporated into the paper were adapted from work presented by Huffman (1959), and are used to illustrate the horizontal and vertical extent of sediments within the Anadarko Basin.

Scout tickets and electric logs of the Gulf Oil Company were used extensively. Samples from the various wells were obtained from the Shawnee Sample Cut, Shawnee, Oklahoma, and the

Table 1. Location of wells used in stratigraphic cross sections.

No.	Operator	Farm Name	Well No.	Location				County	Surface Elev.	Depth Drilled
				KANSAS						
1.	The Texas Co.	Schmidt	1	NE SW SW	Sec. 31,	T. 20 S.,	R. 3 E.	Marion	1,443	3,150
2.	The Texas Co.	Blackford	1	NE NE NE	24	25	2	Sedgwick	1,355	3,375
3.	J. P. Gaty	Stollei	1	SW SE SW	22	26	2	Sedgwick	1,400	2,909
4.	The Texas Co.	Devine	1	NE NE SE	11	28	2	Sedgwick	1,340	3,350
5.	Beech Aircraft	McClellan	1	S Ec NE	6	29	2	Sedgwick	1,300	3,515
6.	R. L. Carnahan	Parker	1	NE NE SE	7	30	2	Sumner	1,216	3,650
7.	Barnett Oil Co.	Wilson	8	SE SE SW	33	31	3	Cowley	1,186	3,309
8.	Beaumont Petr.	Hansen	1	SW SW SE	29	33	3	Cowley	1,103	3,377
9.	Ingling	Shurtz	1	SW SE SE	20	34	3	Cowley	1,140	3,393
10.	The Texas Co.	Anderson	1	SW SW NE	11	35	2	Sumner	1,195	3,573
				OKLAHOMA						
11.	Shell Oil Co.	McCormick	B-4	NW SW SE	21	29 N.	1 W.	Kay	1,125	3,470
12.	Barnsdall Oil Co.	Balderson	1	NE SW SE	24	28	3	Grant	1,149	6,781
13.	Gulf Oil Corp.	Newkirk	1	NE NE NW	10	26	3	Grant	1,110	4,687
14.	Dirickson & Lewis Oil Co.	Price Estate	1	SE SE NE	26	24	3	Garfield	1,010	5,055
15.	Helmerich & Payne, Inc.	La Grange	1	NW NW NW	8	23	3	Garfield	1,059	5,487
16.	Powell Briscoe, Inc.	Boepple	1	SW SW NE	21	21	4	Garfield	1,105	6,781
17.	The Texas Co.	Cromer	1	NW SW SE	6	19	4	Logan	1,047	6,738
18.	Tenn. Gas Tran.	Oltmanns	1	NE SW NE	24	18	5	Kingfisher	1,083	6,182
19.	The Texas Co.	Ash	1	SE NW NE	19	17	5	Kingfisher	1,018	8,519
20.	Jones Shelburne & Pellow Oil Co.	Simpson	1	C NE SW	16	14	5	Canadian	1,204	8,326
21.	Kingwood Oil Co.	Rutty	1	NE NE	35	12	5	Canadian	1,247	7,970
22.	Woodward & Co.	Sterrett	1	SW SW	9	11	5	Canadian	1,310	9,244
23.	Gulf Oil Corp.	Bass	1	SW NE	36	9	4	McClain	1,213	10,775
24.	Superior Oil Co.	State	1	C SE SE	2	5	5	Grady	1,157	14,124
25.	The Pure Oil Co.	Parks Unit	1	C NE NE	10	4	6	Grady	1,137	12,903
26.	Brit. Amer. Oil	Hayes	1	NW NW SE	32	3	5	Grady	1,220	16,820

Oklahoma Geological Survey, Norman, Oklahoma.

Data on wells in Kansas was obtained from Herndon maps and the Kansas Geological Survey, Lawrence, Kansas.

STRATIGRAPHY OF THE UPPER PENNSYLVANIAN SERIES

The sedimentary rocks that comprise the Pennsylvanian system in Kansas and Northern Oklahoma are sub-divided, in descending order, into three principal series: The Virgilian, the Missourian, and the Desmoinesian. Pennsylvanian rocks, ranging in thickness from 1600 feet in Central Kansas to 3500 feet near the southern border, consist of interbedded limestones, shales, and lenticular sandstones (Plate I).

The Pennsylvanian rocks in the central part of the basin have been sub-divided, in descending order, into six principal series: The Virgilian, the Missourian, the Desmoinesian, the Atokan, the Morrowan, and the Springeran. The Pennsylvanian rocks in this area consist of 5,000 to 10,000 feet (Plate II) of sandy limestones, arkosic sandstones, shales, and conglomerates. The terminology applied to designate the Upper Pennsylvanian formations has been adapted from areas in Northern Oklahoma and Kansas, whereas terminology applied to the Lower Pennsylvanian formations has been adapted from areas in Southern Oklahoma (see Figure 1).

Virgilian Series

The Virgilian series comprise the youngest Pennsylvanian rocks within the basin. In Southern Kansas and Northern

Oklahoma this series is sub-divided, in descending order, into three groups: The Wabaunsee, the Shawnee, and the Douglas (see Figure 1). However, in South Central and Southern Oklahoma, this series is divided into only two groups: The Lower Pontotoc (Lower Wolfcampian-Upper Virgilian) and the Upper Hoxbar (Virgilian) (see Figure 1). On the electric log of well No. 2 (Plate I), the Virgilian is 1,000 feet thick, increasing to approximately 2,200 feet on the electric log of well No. 24 (Plate II).

Wabaunsee Group. The Wabaunsee group in Kansas and North Central Oklahoma includes rocks of uppermost Virgilian age, which are predominantly limestones and shales. In this area the upper boundary of the group is the unconformable Pennsylvanian-Permian contact, and the lower boundary is the top of the Topeka limestone of the Shawnee group.

In Southern Oklahoma, the Wabaunsee group is probably equivalent to the shales, arkosic sandstones, and conglomerates of the lower Pontotoc (Lower Wolfcampian-Upper Virgilian) group. The upper boundary, which is the Pennsylvanian-Permian contact, cannot be established by the use of lithologic variation and faunal evidence. The lower boundary is placed at the top of the Pawhuska limestone of the Hoxbar group, and it is the first marine limestone below 5,000 to 6,000 feet of Permian and Pennsylvanian red beds.

Brownville Limestone. The upper limit of the Wabaunsee group in Kansas and Northern Oklahoma is marked by the top of the Brownville limestone, which is characterized by a relatively consistent resistivity deflection on most electric logs (Plates I and II).

R. C. Moore has stated ".... in most places the limestone mapped as Grayhorse in Oklahoma is really Brownville". Therefore, these terms will be considered as synonymous (Moore, 1949).

Examination of well cuttings indicated that the Brownville limestone is a gray to brown, fine to medium crystalline, very fossiliferous limestone in Northern Oklahoma and Southern Kansas, which grades southward into a thin, sandy limestone. In South Central Oklahoma, the Brownville limestone is lost in a series of red beds.

Elmont-Reading Limestone. Lying 100 to 200 feet below the base of the Brownville is the Elmont-Reading limestone, which is correlative to the Stonebreaker limestone of Oklahoma (Lukert, 1949). This limestone is gray, crystalline, and fossiliferous in the shelf area, but changes to a sandy limestone in well No. 20, and is low in a sequence of shales in South Central Oklahoma.

Wakarusa-Burlingame Limestone. The Wakarusa and Burlingame limestones are somewhat similar in lithology and have been combined as one unit for the purpose of correlation. In Oklahoma this unit has also been designated as the "Cryptozoan" limestones (Lukert, 1949).

The Wakarusa-Burlingame is the first massive limestone encountered by the drill in the Pennsylvanian. It is 40 to 60 feet thick and is distinguishable from the limestones above and below by the presence of a thin shale in the center, which thickens southward as the limestones disappear. On the shelf, Wakarusa-Burlingame limestone is white to gray, fine to medium crystalline limestone, which changes to a shale as it is traced into the basin.

Happy Hollow-Howard Limestone. Owing to lithologic similarities, these two limestones have also been combined to form one unit, and are separated from the Wakarusa-Burlingame limestone unit by 70 to 100 feet of unnamed shale. In well No. 4, the Happy Hollow-Howard limestone is a gray to white, finely crystalline, very fossiliferous limestone, whereas in well No. 20, examination of well cuttings indicated a sandy limestone which in wells farther south was not recognizable.

Shawnee Group. In Kansas, the Shawnee group consists of 350 to 400 feet of interbedded limestones and shales. The upper limit of the group is placed at the top of the Topeka limestone, and the lower boundary has been placed at the base of the Toronto limestone member of the Oread limestone (Moore, 1949). The limestones of this group are particularly useful as markers in subsurface correlations because they are present as far south as well No. 20, in Canadian County, Oklahoma. Most of the members of the Shawnee group cannot be traced the length of the cross section, however, because they become discontinuous, replaced by sandstones, or are so thin that they cannot be identified in rotary well samples.

In South Central and Central Oklahoma, the Shawnee group is correlative with the upper part of the Upper Hoxbar group, which is bounded at the top by the Pawhuska or Deer Creek limestone and at the bottom by the base of the Oread limestone. The top of the Pawhuska limestone in this area is also used as the upper boundary of the Pennsylvanian because the true Pennsylvanian-Permian contact cannot be established by the use of lithologic variation and fossil evidence. The part of the Upper Hoxbar group, which is probably equivalent to the Shawnee group, consists of approximately 1,100 feet of shales, calcareous sandstones, and a few dense limestones.

Topeka Limestone. The Topeka limestone in Kansas is a well defined fossiliferous limestone, which is equivalent to the upper part of the Pawhuska limestone of Oklahoma. In well No. 20, it is a thin, light tan, medium to finely crystalline limestone, which grades into a light tan, medium grained, slightly calcareous sandstone as it dips into the basin. In the central part of the basin it is probably equivalent to one of the numerous sandstones of the Hoxbar group.

Calhoun Shale. The Calhoun shale lies between the base of the Topeka limestone and the top of the Deer Creek limestone. It consists of 40 to 50 feet of silty to sandy shale, which diminishes in thickness southward from well No. 2, until it is absent in well No. 8. In well No. 10, the Ponca City sand occurs at the same stratigraphic interval, and is probably equivalent in part to the Calhoun shale. The shales and sandstones, other than the Ponca City sand, separating the Topeka limestone and the Deer Creek limestones are unnamed in Northern Oklahoma.

Deer Creek Limestone. According to Lukert (1949), the Deer Creek limestone of Kansas and the Pawhuska limestone of Oklahoma are considered to be equivalent. The Deer Creek limestone grades from a white, finely crystalline limestone in well No. 4, to a soft limestone in well No. 16. Southward into the basin it is a sandy limestone, and the top of the Deer Creek or Pawhuska limestone is the upper limit of the Hoxbar group.

Hoover Sandstone Formation. This formation consists of upper, middle, and lower members. The lower member is referred to by Oklahoma geologists as the Elgin sandstone, which is equivalent to the Kanwaka shale of Kansas.

The upper and middle members are separated by the thin, mottled, white and dark brown, finely crystalline, Lecompton limestone which can be traced from well No. 1, to well No. 23, in the cross section. The Hoover formation is a sequence of dark gray and black, blocky shales, very thin, tan, finely crystalline, slightly porous limestones, and lenticular sandstones.

In places where the lenticular sand bodies occur, they are white to green in color, angular to sub-rounded, fine to medium grained, and slightly calcareous.

Oread Limestone. The top of the Oread limestone was used as the datum for the stratigraphic cross sections because of its persistency throughout the area (Plates I and II).

The Plattsmouth limestone member of the Oread limestone in

Kansas is referred to as the Oread limestone in Oklahoma. several other members of the Oread limestone, for example the Leavenworth and Toronto limestones, have been identified and traced from well No. 1, in Marion County, Kansas, to well No. 19, in Canadian County, Oklahoma.

Plattsmouth limestone member. This limestone may be identified throughout the entire area of the cross sections. It grades from a well defined, firmly crystalline limestone in well No. 4, to a brown, medium crystalline, slightly dolomitic, slightly arenaceous, soft limestone in well No. 21. Southward from well No. 21, it is recognized as a very calcareous sandstone.

Leavenworth limestone member. In well No. 4, this member is a well defined, crystalline limestone which grades to a sandy limestone in well No. 14, and is absent in Central Oklahoma.

Endicott sandstone member. This member of the Oread limestone is a lenticular, medium to fine grained, sub-angular to rounded sandstone.

Toronto limestone member. The Toronto limestone was correlated by Lukert (1949) as the equivalent of the Lovell limestone of Central Oklahoma. It is approximately 20 to 40 feet thick and is white, medium crystalline, and slightly dolomitic. In South Central Oklahoma, the Lovell limestone is replaced by a white, fine to medium grained, calcareous sandstone, which is designated as the Lovell sandstone.

Douglas Group. The Douglas group in Kansas and Northern Oklahoma comprises those sedimentary rocks from the base of the Toronto limestone to the base of the Virgilian series. Thickness of the group varies from 200 feet in Marion County, Kansas, to 500 feet in well No. 14, in Northern Garfield County, Oklahoma (Plate I). The group consists of vari-colored shales, thin limestones, and prominent sandstones in the lower part.

In Central and South Central Oklahoma, the Douglas group is correlative with the lower part of the Upper Hoxbar group. This part of the Hoxbar group, designated as the Tonkawa sandstone on the cross sections, contains those rocks from the base of the Oread limestone to the top of the Avant limestone, and whose thickness ranges from 500 to 600 feet.

Amazonia Limestone. Throughout the area between well No. 1, and well No. 22, a thin, persistent, crystalline limestone, lying approximately 40 feet below the Toronto limestone, was encountered. This limestone occupies the position of the Amazonia limestone on the surface (Lukert, 1949), and they have been questionably correlated. The limestone is replaced by shale in Central Oklahoma.

Ireland Sandstone. In the shale sequence underlying the Amazonia limestone, a lenticular sandstone is present in the first four wells of cross section AB. This sandstone is considered to be correlative with the Ireland sandstone of the surface section. Moore (1951) considers this interval, from the top of the Amazonia limestone to the base of the Ireland sandstone, to be equivalent to the Lawrence shale which occurs in exposed Pennsylvanian rocks in Kansas.

Stranger Formation. The sedimentary rocks from the base of the Ireland sandstone to the base of the Tonganoxie sandstone are classified as the Stranger formation. (Moore, 1951.)

Haskell limestone member. The Haskell limestone is a persistent, sandy limestone from well No. 1, in Marion County, Kansas, to well No. 16 in Garfield County, Oklahoma. In Central Oklahoma, it has not been identified on electric logs or in the rotary well samples.

Tonganoxie sandstone member. This sandstone is the basal member of the Douglas group in Kansas. Lukert (1949) has stated "....Stalnaker sandstone is Virgilian in age and in part equivalent to beds occupying the position of the Tonganoxie sandstone." In this area, the sandstone is tan, fine to medium grained, angular to sub-rounded, and calcareous.

Farther south in Oklahoma, the Stalnaker sandstone is correlative with the Tonkawa sandstone. The Tonkawa, the base of which marks the disconformity between the Virgilian and Missourian series, consists of 250 to 300 feet of interbedded shales and sandstones throughout the southern part of the cross section.

Missourian Series

In Kansas, the Missourian series has been divided into four groups. They are, in descending order, the Pedee, Lansing, Kansas City, and Pleasanton. In the Central Kansas area of the cross section, it has not been possible to distinguish rocks of the Pedee group.

The Lansing-Kansas City groups are best defined from well No. 1, to well No. 6, in Kansas. These groups consist of limestones and interbedded shales from the top of the Stanton limestone to the base of the Hertha limestone. This predominantly limetone sequence changes to shale, and then to shales and sandstones as it is traced southward into Southern Kansas. The facies changes occur first in the Lansing group, and then in the Kansas City group as they are traced from Marion County, Kansas into Southern Kansas (Lukert, 1949).

The Pleasanton group can be traced from well No. 1, to well No. 7, where the limestones are replaced by shales.

Owing to the rapid facies changes within these groups, the Kansas terminology becomes less applicable in Southern Kansas and Northern Oklahoma, and in this area a two-fold division of the Missourian series is used. In this area rocks of the Missourian series are divided, in descending order, into the Ochelata and Skiatook groups, which in Central and South Central Oklahoma are the equivalent of the Lower Hoxbar group (see Figure 1). This classification has been recommended by R. C. Moore (1951), and is used by the Oklahoma Geological Survey.

Ochelata Group. The Ochelata group consists of rocks from the base of the Tonkawa sandstone to the base of the Layton sandstone, and varies in thickness from 650 to 800 feet.

Avant Limestone. Below the Tonkawa sandstone, and separated from it by 40 to 100 feet of unnamed, gray, blocky shales, is the Avant limestone. On the shelf, the Avant varies from 50 to 75 feet in thickness, and grades from a buff to white, fine to medium crystalline, oolitic, sandy limestone in Central Oklahoma.

In the southern area of cross section BC, where the Avant is 80 to 100 feet thick, it is difficult to determine boundaries of this rock unit owing to the addition of more limestone beds. In this area it is referred to as the Tonkawa limestone, and varies from an off-white to tan, hard, dense limestone to a gray to tan, finely crystalline limestone.

Perry Gas Sand. The Perry Gas sand is separated from the Avant limestone by a thin, unnamed shale, and is 10 to 40 feet thick. In the area of well No. 16, the Perry Gas sand is well defined, and is a white to glassy, fine to medium, angular to sub-rounded sandstone. Southward from well No. 16, it becomes more calcareous and is replaced by a sandy limestone in well No. 23.

Layton Sandstone Formation. Between 100 to 200 feet below the Perry Gas sand is the Layton sandstone formation consisting of lenticular sandstones in dark shales. This formation can be traced from well No. 8, southward to well No. 23, and has also been referred to as the Cottage Grove sandstone formation.

The Layton or Cottage Grove sandstone formation consists of 150 to 200 feet of sandstones, shales, and thin limestones that change facies over the area. The sandstone bodies attain a maximum thickness of around 35 to 40 feet and are composed of gray, fine to medium grained, micaceous sandstones.

Skiatook Group. This group includes the rocks from the base of the Layton sandstone formation to the top of the Oolagah, or "Big Lime" limestone. It varies in thickness from 150 feet in well No. 12, to 1700 feet in well No. 24, where it is equivalent to the lower part of the Hoxbar group. Several correlative limestone beds occur within this group, of which the Hogshooter and Checkerboard limestones are the most important.

Dewey Limestone. From well No. 12, through well No. 18, a very prominent limestone, the Dewey limestone, is the top bed in the Skiatook group. Southward from well No. 18, in the deeper parts of the basin, this limestone is replaced by a sequence of massive limestones, thin bedded shales, and lenticular sandstones. In Kansas, the Drum limestone is generally considered to be equivalent to the Dewey limestone. (Lukert, 1949.)

In the area of well No. 14, the Dewey limestone is recognized as 60 to 70 feet of brown, finely crystalline, hard limestone, which changes to a tan to gray, soft limestone in well No. 16.

In the southern area of the cross section BC, the Dewey is a buff to gray, hard, finely crystalline limestone underlain by

60 to 100 feet of white to tan, glassy, fine grained, calcareous sandstone, and 400 feet of gray to black, blocky shales.

Hogshooter Limestone. Below the Dewey limestone in well No. 12, is the Hogshooter limestone, which is an excellent stratigraphic marker throughout the basin area. The Hogshooter limestone in this area is correlative with the County Line limestone of Southern Oklahoma.

In the area of well No. 12, the Hogshooter is a thin, gray to brown, coarsely crystalline, sandy and oolitic limestone, changing facies basinward to a massive, white to tan, dense to sucrosic, soft limestone isolated in the section by a 400 foot shale interval above and a 450 foot shale interval below. In the southern area of the cross section, the Hogshooter limestone varies in lithology from well to well as do most of the Lower Hoxbar members.

First Checkerboard Limestone. The First of "Oklahoma City" Checkerboard limestone is well defined throughout cross section BC. It consists of 20 to 100 feet of brown, coarsely crystalline, detrital limestone at the top, grading downward into a white to buff, dense limestone. A shale member, 20 to 30 feet thick, is present in the central portion of the formation giving a duplicated high resistivity reflection on the electric log. (Plate II.)

Second Checkerboard Limestone. The Second or "True" Checkerboard limestone occurs 60 to 100 feet below the First Checkerboard limestone.

Lukert (1947) believes the Second Checkerboard to be correlative to the Hertha limestone of the Kansas City Group, whereas Oakes and Jewett, as cited by Lukert (1947), traced the Checkerboard on the surface from Oklahoma into Kansas, contend "....Checkerboard limestone is correlative to a limestone above the Hepler sandstone in the Pleasanton group".

As shown in the cross sections, the writer has correlated the Checkerboard to the upper part of the Pleasanton group.

The Second Checkerboard varies from 10 to 20 feet in thickness in Kansas, whereas in Oklahoma it is more than 100 feet thick in the central basin area. In the northern area of the cross sections, the Checkerboard is a blue gray to brown, medium to coarsely crystalline, dolomitic limestone. As it is traced into the basin, it becomes slightly arenaceous, and in well No. 24, it is a sandy limestone having a pseudo-oolitic appearance. The sand grains are frequently sub-rounded and frosted, and the limestone is tan to gray, and consists of large fragments of white, hard limestone interbedded in a brown, calcareous matrix.

Cleveland Sandstone Formation. The Cleveland sandstone formation, of Seminole formation, contains the Cleveland sandstones. The base of the formation marks the lower limit of the Missourian series, which lies unconformably on rocks of Desmoinesian age. The formation is correlative with the lower part of the Pleasanton group of Kansas.

The Cleveland sandstone formation consists of 70 to 600 feet of gray, blocky shales, thin limestone stringers, and lenticular sandstones. In areas where they are present, the sandstones are gray to tan, fine to medium grained, fossiliferous, and shaly.

Desmoinesian Series

The Desmoinesian series of Kansas and Northern Oklahoma is divided, in desdending order, into two groups: The Marmaton, and the Cherokee. In Southern Oklahoma, the Deese group is equivalent in age to both the Marmaton and Cherokee groups.

Correlation between the Northern and Southern Oklahoma stratigraphic units is impossible. Therefore, the two provinces will be discussed separately in this paper.

The Marmaton and Cherokee groups include rocks from the disconformity at the base of the Missourian series to the unconformity at the base of the Pennsylvanian and top of the Mississippian (Osagian).

The Deese group of Southern Oklahoma include rocks from the disconformity at the base of the Missourian series to the disconformity at the base of the Desmoinesian and top of the Atokan series.

Marmaton Group. This group contains the Oolagah and Fort Scott limestone defined in surface exposures. In the subsurface, the terms are changed to the "Big Lime" and the Oswego, respectively. The Marmaton is difficult to sub-divide north of well No. 8 in Kansas because of the lateral and vertical variations of the "Big Lime" limestone. However, the complete unit is a very good correlative limestone, which has distinctive electric log characteristics, particularly in the lower or Oswego limestone part.

"Big Lime" Limestone. In areas where the Marmaton can be divided, the "Big Lime" consists of gray, fine to medium crystalline, sucrosic, dolomitic limestone ranging in thickness from 10 to 100 feet. In most places, a shale member 5 to 10 feet thick separates the "Big Lime" limestone from the underlying Oswego limestone. In the central basin area the "Big Lime" limestone is absent.

Oswego Limestone. The Oswego limestone is an excellent marker bed, both in well samples and in the distinctive resistivity curve on the electric log. It is a tan to light brown, somewhat porous, dolomitic limestone, which in Northern Oklahoma becomes arenaceous in the lower part. Traced basinward, it becomes a calcareous sandstone and is probably equivalent to one of the Upper Deese sandstones.

Cherokee Group. The Cherokee group consists of rocks from the base of the Oswego limestone to the base of the Pennsylvanian, in places where rocks of Morrowan and Atokan age are absent. The thickness of the group varies considerably over the area of the cross sections owing to the topographic variability of the underlying Mississippian surface. The group is composed of a sequence of dark gray, blocky shales and alternating beds of sandstones and limestones.

Prue Sand. The Prue sand is gray to green, fine grained, and micaceous. It is approximately 40 to 60 feet thick over areas where it is present. In some areas, it is replaced by gray, blocky shales.

Verdigris Limestone. The Verdigris is a persistent, buff colored, dolomitic limestone, which lies directly below the Prue sand, and is designated as the "First" Verdigris. It is 10 to 15 feet thick throughout the area of the cross section, but thickens slightly as it dips westward from the Nemaha Anticline.

Skinner Sand. Below the First Verdigris limestone lies a sequence of tan to black, fine grained, micaceous sandstone, referred to as the Upper Skinner sandstone. This sandstone has a thickness of approximately 40 feet.

Below the Upper Skinner sandstone, another thin, but persistent, limestone occurs in the central part of the Skinner sandstone dividing it into two parts. This limestone is referred to as the "Second"Verdigris limestone and is tan, fine to medium crystalline, and fossiliferous.

The Lower Skinner sandstone lies below the Second Verdigris limestone and consists of 30 to 40 feet of tan, medium grained, micaceous sandstone. Lithologically, it is similar to the Upper Skinner sandstone, and for the purpose of correlation they were treated as one unit.

In well No. 10, where the Cherokee group onlaps the Nemaha Anticline, the Skinner sandstone is the lowest member of the Cherokee group present.

Pink Limestone. The Pink limestone lies below the Lower Skinner sandstone. It is a thin, but persistent bed some 10 feet thick, consisting of coarsely crystalline, shaly, sandy limestone.

Red Fork Sandstone. The Red Fork sandstone is a tan to white, fine to medium grained, angular, micaceous sandstone. It maintains a thickness of 80 feet in the area of the cross section, and in areas where the underlying Bartlesville sand has been omitted by onlap, the Red Fork has been erroneously referred to as the Bartlesville.

Inola Limestone. The Inola is a thin, persistent limestone, which separates the Red Fork and Bartlesville sands. Lithologically, it is a gray to tan, finely crystalline, dolomitic limestone.

Bartlesville Sand. The Bartlesville sand is porous, tan to brown, fine to medium grained, and varies in thickness from 0 to 35 feet. It occurs as lenticular bodies of relatively clean sand in a sequence of Lower Cherokee shales; these sand bodies may have been low sand bars in the shallow Cherokee seas.

<u>Deese Group</u>. The Deese group of Southern Oklahoma is equivalent to the Marmaton and Cherokee groups of Kansas and Northern Oklahoma. In the southern area of the cross section, the top of the Deese is customarily placed at the base of the Cleveland sandstone, where recognizable, or at the base of the Checkerboard limestone. The lower contact of the Deese group is the top of the Upper Dornick Hills (Atokan) group.

It would be misleading to describe the Deese group as if it were a continuous uniform body, because a rapid facies change occurs in this group across the area and even between wells. This is due to the uplift of the Wichita Mountains and the corresponding fluctuation of the Deese seas.

In general, the upper one-third of the Deese sedimentary section is calcareous, gray, micaceous shale containing a few sandstone bodies, whereas the lower two-thirds is a sequence of sandstones, shales, and a few thin limestones. In the wells of cross section BC, the Deese ranges from 1,500 to 2,600 feet in thickness, as compared to the 6,500 feet of sediments assigned to the Deese by Tomlinson (1929) in the Ardmore Basin.

First Deese Sand. The First Deese sand is a typically light gray, micaceous, calcareous siltstone, which changes to a very fine, micaceous sandstone in some wells near the cross section.

Second Deese Sand. In places where it is present, this sandstone is light gray, very fine grained, and micaceous.

Third Deese Sand. The Third Deese or Gibson sandstone is not well defined over most of the area. In well No. 25, it is overlain by 15 feet of fine grained, clean, calcareous sandstone containing many grains of siderite. The Gibson in the well is a white to green, fine grained, micaceous sandstone containing some glauconite.

Fourth Deese Sand. The Fourth Deese sand is also referred to as the Hart sandstone. In well No. 26, the Fourth Deese is encountered about 200 feet below the Third Deese, and is a white, medium to coarse grained, well-sorted sandstone.

Osborne Sand. The Osborne sandstone is also referred to as the Fifth Deese or Lower Hart sand. It occurs about 30 feet below the Fourth Deese in well No. 24, and, except for being poorer sorted, is similar in lithology.

STRATIGRAPHY OF THE LOWER PENNSYLVANIAN SERIES

Rocks of the Lower Pennsylvanian in the Anadarko Basin are confined to the central basin area (see Figures 7, 8, and 9), and are not present on the north flank or shelf area.

Lower Pennsylvanian sediments are represented in wells No. 23, 24, 25, and 26 of cross section BC, and they have subdivided, indescending order, into the Atokan, Morrowan, and Springeran series. Rocks within these series, particularly the Springeran sediments, are absent over most of Kansas (Moore, 1949).

Atokan Series

Upper Dornick Hills Group. Lying below the Seese group is the Upper Dornick Hills group. The top of the group is placed at the base of the Hart sandstone and below a brown, hard, dense limestone. The limestone is an exceptionally good stratigraphic marker in the area and is easily recognized on the resistivity curve of the electric log. (Plate II.)

The Upper Dornick Hills group is a dark gray shale containing a few thin, limestone beds. It ranges from 300 to 500 feet in thickness, becoming much thinner to the north and east as the result of truncation and onlap.

Near the base of the group is a green chert conglomerate, which is probably equivalent to the Bostwick conglomerate of the Ardmore Basin. This conglomerate marks the top of the major Lower Dornick Hills (Morrowan)-Upper Dornick Hills (Atokan) unconformity, which reflects the first uplift of the Wichita Mountains (Tomlinson, 1929).

Morrowan Series

Lower Dornick Hills Group. Below the conglomerate at the base of the Upper Dornick Hills group lies the Lower Dornick Hills group. This group consists of dark gray shales, a few thin limestones, and a sandstone at the base. The thickness of the group in well No. 25, and well No. 26, is approximately 750 feet.

Primrose Sandstone. This sandstone was originally classified as Upper Springeran in age by Tomlinson (1929) in the Ardmore Basin. However, because of its drastic lithologic difference, indicating a source different from the underlying Springer, it is now placed in the Lower Dornick Hills group.

The Primrose sandstone is also fossiliferous, whereas the underlying Springeran sediments contain few, if any, fossils in the wells of which rotary well cuttings were examined.

The Primrose sandstone is 200 to 250 feet thick. In the upper 50 feet, it is a clean, greenish, fine to medium grained, angular and poorly sorted sandstone. The lower part is a very fine grained, shaly, micaceous, calcareous sandstone, which is somewhat glauconitic and fossiliferous. Also, several dark bands and pieces of carbonaceous material were disseminated throughout the sandstone.

Springeran Series

In the central part of the basin, the Springeran is a series of sandstones and shales in the upper part followed by 1,400 feet of shale, which is designated as the Goddard shale. Springeran sediments are not known to be represented in Kansas, and the time during Springeran deposition in Southern Oklahoma is considered to be a time of weathering and erosion of older Paleozoics in North Central Oklahoma and Kansas. (Moore, 1949.)

The top of the Springeran is arbitrarily placed at the base of the Primrose sandstone, and the lower limit is placed at the apparently conformable contact of the Goddard (Springeran) and Caney (Mississippian) shales (see Figure 1). In wells No. 25, and 26, of cross section BC, the Springeran is 2,300 to 2,600 feet thick, although 100 to 200 feet were missing at the top. The following members are recognized in the wells located in Grady County, Oklahoma, and will be discussed briefly.

Cunningham Sandstone. The Cunningham sandstone is approximately 200 feet thick in the area of well No. 25, and is composed of three sand bodies.

The upper fifty feet of the Cunningham is a light tan, calcareous sandstone containing streaks of sideritic sand. The middle member is a tan, fine grained sandstone containing fragments of soft green shale. The lower member is similar in lithology to the middle member.

Britt Sandstone. This sandstone is separated from the overlying Cunningham sandstone by 200 to 300 feet of unnamed, black shale. The Britt is commonly 80 to 90 feet thick, tight to porous, and is fine grained, sub-angular sandstone.

Spiers Sandstone. Although it is not represented in the wells of cross section BC, it commonly lies some 100 feet below the Britt sandstone. It is rarely over 40 feet thick, and occurs as erratic lenses.

Boatwright Sandstone. This is the lowest sandstone member of the Springeran and it varies in thickness from 10 to 90 feet. In places where it is present, it is a white, medium grained, clean, sub-rounded to sub-angular sandstone.

Goddard Shale. The remaining 1,100 to 1,400 feet of the Springeran is the Goddard shale, and is not shown on the cross section. It is composed of black, fissle, soft, carbonaceous shale containing sideritic nodules, and a few thin sand lenses.

MAJOR TECTONIC FEATURES

The major tectonic features in the area under consideration are shown in Figure 2. Tectonic features in Kansas include the Hugoton Embayment, Central Kansas Uplift, Nemaha Anticline, Sedgwick Basin, and Salina Basin.

Major tectonic features in Oklahoma are the Anadarko Basin, Wichita-Amarillo Uplift, Criner Hills Uplift, Arbuckle Uplift, Hunton Arch, Ardmore Basin, and the southern extension of the Nemaha Anticline.

Central Kansas Uplift

The Central Kansas Uplift is a broad, low, eroded uplift, which trends northwest across Kansas into Nebraska. It is regarded as a post-Mississippian structural uplift in North Central Kansas, upon which rocks of Pennsylvanian (Missourian and Desmoinesian) age overlie the eroded surface of the older Paleozoic and basement rocks. The Central Kansas Uplift, formerly referred to as the Barton Arch, is considered to be an element of the southwest-northeast trending Transcontinental Arch. (King, 1951.)

Hugoton Embayment

The Hugoton or Dodge City Embayment is a large synclinal area in Southwest Kansas, which is probably only an extension of the larger Anadarko Basin of Oklahoma. Rocks of Paleozoic age dip from the west flank of the Central Kansas Uplift into the embayment area.

Sedgwick Basin

The Sedgwick Basin is a post-Mississippian structural feature west of the Nemaha Anticline and south of the Salina Basin. It has been dated as post-Mississippian in origin, inasmuch as Pennsylvanian (Cherokee) beds lie on the eroded and truncated Mississippian beds. (Huffman, 1959.)

Salina Basin

The Salina Basin occupies a position in North Central Kansas. It is bounded by the Nemaha Anticline to the east, and the Central Kansas Uplift to the west, and an unnamed arch to the south, which separates it from the Sedgwick Basin. Downfolding of the basin has been dated as post-Mississippian.

In the Salina Basin, as in the Sedgwick Basin, Middle Pennsylvanian beds overly the eroded and truncated surface of the Mississippian sediments. (Lee, 1956.)

Nemaha Anticline

The Nemaha Anticline is a buried granite ridge trending northeast-southwest through Oklahoma, Kansas, and Nebraska. Rocks of Pennsylvanian age rest unconformably on igneous basement rocks in East Central Kansas, but southward, Pennsylvanian sediments unconformably overlie rocks of Cambrian, Ordovician, Silurian, and Devonian age.

Van der Gracht (1939) regarded the ridge as an uplifted and tilted fault block in the basement, which had its downthrown scarp on the eastern side.

Jacobsen proposed two diastrophic movements which created the Nemaha Anticline: the first in post-Springeran, pre-Morrowan time, and the second in post-Atokan, pre-Desmoinesian time.

Anadarko Basin

The Anadarko Basin is a deep, asymmetrical syncline, which covers that part of Oklahoma west of the Nemaha Anticline and north of the Wichita-Amarillo Uplift. The southwest flank dips steeply into the basin, away from the Wichita-Amarillo Uplift, whereas the southwesterly dip of the nrotheast flank is more gentle.

The major diastrophic movement which formed the depositional basin of Pennsylvanian time occurred in post-Morrowan time (Wichita Orogeny) when the Wichita system was uplifted. Subsequent orogenic movements during Late Pennsylvanian and Permian time (Arbuckle Orogeny) resulted in the Anadarko Basin of today.

Arbuckle Uplift

The Arbuckle Uplift is a northwest trending system of faulted and folded mountains in South Central Oklahoma. Major tectonic activity occurred during post-Mississippian, pre-Late Virgilian time (Arbuckle Orogeny). Subsequent erosion has stripped away the sedimentary layer disclosing the underlying igneous core.

Ardmore Basin

The Ardmore Basin, which is an extension of the larger Anadarko Basin, occupies a position between the Criner Hills Uplift of the Wichita Mountain system and the Arbuckle Uplift, and is near the axis of the ancestral Wichita Geosyncline. The basin's history is one of rapid subsidence and desposition during Early Pennsylvanian time, and folding and faulting during Late Pennsylvanian time (Arbuckle Orogeny). (Van der Gracht, 1931.)

Wichita-Amarillo Uplift

This system of Paleozoic mountains also includes the Criner Hills Uplift, which will be discussed separately.

The Wichita-Amarillo Uplift is a northwest-southeast trending belt of folded and faulted mountains, which extends from the Northern Texas panhandle to South Central Oklahoma. This belt of mountains also follows the axis of the Wichita Geosyncline, which originated in Late Cambrian time.

After Lower Nornick Hills (Morrowan) time, the Wichita Geosyncline was affected by extensive deformation (Wichita Orogeny), which resulted in the uplifting and folding or the Wichita system. In Late Pennsylvanian time, another disturbance (Arbuckle Orogeny) completed the deformation of the Wichita system.

Subsequent erosion has disclosed the igneous core of the Wichita Mountains, whereas the Amarillo Mountains have been buried in their own debris.

Criner Hills Uplift

The Criner Hills Uplift is the southeast extension of the Wichita system of folded and faulted mountains. It is separated from the Arbuckle Uplift by the Ardmore Basin.

Structural deformation in Late Morrowan time (Wichita Orogeny) resulted in the folding and faulting of the pre-Pennsylvanian sediments. Subsequent deformation in Late Pennsylvanian time (Arbuckle Orogeny) produced folding of the Pennsylvanian sediments and refolding of the earlier Paleozoics. (Van der Gracht, 1931.)

Hunton Arch

The Hunton Arch is an ancient positive feature having the same general trend as the Nemaha Anticline, and occupies a position north of the Arbuckle Mountains in South Central Oklahoma.

The arch is considered to have an origin in Pre-Cambrian time, extend through and beyond the Arbuckle Uplift, and antedate the Wichita Geosyncline from which the Wichita system was uplifted. During Late Pennsylvanian time, a renewed northward movement (Arbuckle Orogeny) strongly folded and crumpled the southern end of the resistant Hunton Arch, thereby creating the Arbuckle Mountains. (Van der Gracht, 1931.)

GEOLOGIC HISTORY

Pre-Pennsylvanian Regional History

This brief pre-Pennsylvanian geologic history is intended to describe regional conditions that prevailed before the advent of orogenic movements during Pennsylvanian time, which culminated in the formation of the Anadarko Basin.

Southern and South Central Oklahoma were in an intracontinental geosynclinal trough, designated as the Wichita Basin, from Cambrian to early Pennsylvanian time. During this interval, significant orogenic activity did not occur either in the basin or on the shelf area to the north. The Wichita Basin, an extension of the Ouachita Geosyncline, probably had its foreland in Northern Oklahoma. A new borderland was formed in early Pennsylvanian time by the deformation and folding of the Wichita-Criner Hills belt of folds, which depressed the low-lying adjacent area into an asymmetrical basin known as the Anadarko Basin.

Pre-Mississippian rocks of Cambro-Ordovician, Silurian, and Devonian age attained a thickness of about 10,000 feet, which was probably deposited by widespread epeiric seas. (Van der Gracht, 1931.) During this interval, the central basin was an area of slow continual subsidence, as contrasted to the infrequent emergence of the shelf area.

Of the 10,000 feet of lower Paleozoics, the lower 5,000 to 6,000 feet is the Arbuckle limestone group, which is Upper

Cambrian and Lower Ordovician (Beekmantown) in age (see Figure 3). The Arbuckle limestone is equivalent to the Ellenberger of Texas and the "siliceous lime" of Northern Oklahoma and Southern Kansas, where it thins to 700 to 1,000 feet.

Evidence which indicates a post-Arbuckle, pre-Simpson regression of the seas in North Central Oklahoma is fairly well established. Arbuckle topography was generally peneplained across this area with the exception of a few monadnocks. Existence of the monadnocks is indicated by the thinning of the Simpson group (Lower Ordovician) over these topographic highs (Wheeler, 1947).

Rocks of the Simpson group, which are Lower Mohawkian (Chayzan) age, comprise the lower part of the Ordovician system, and conformably overlie the Arbuckle group in the basin area of South Central Oklahoma, whereas on the shelf the contact is unconformable. Accumulations of reworked Quartzose sandstones within the Simpson group are indicative of the shallow seas which prevailed on the shelf area during Simpson time. Contrasted to this, are the coarsely crystalline dolomites, green shales, and dolomitic shaly sandstones of the central basin area. Rocks of Simpson age have a maximum thickness of 2,500 feet in the basin area and thin to the north and east (Huffman, 1959.)

In ascending order, the Viola limestone of Lower Cincinnatian age and the Sylvan shale of Upper Cincinnatian age comprise the remainder of the Ordovician system. Deposition of

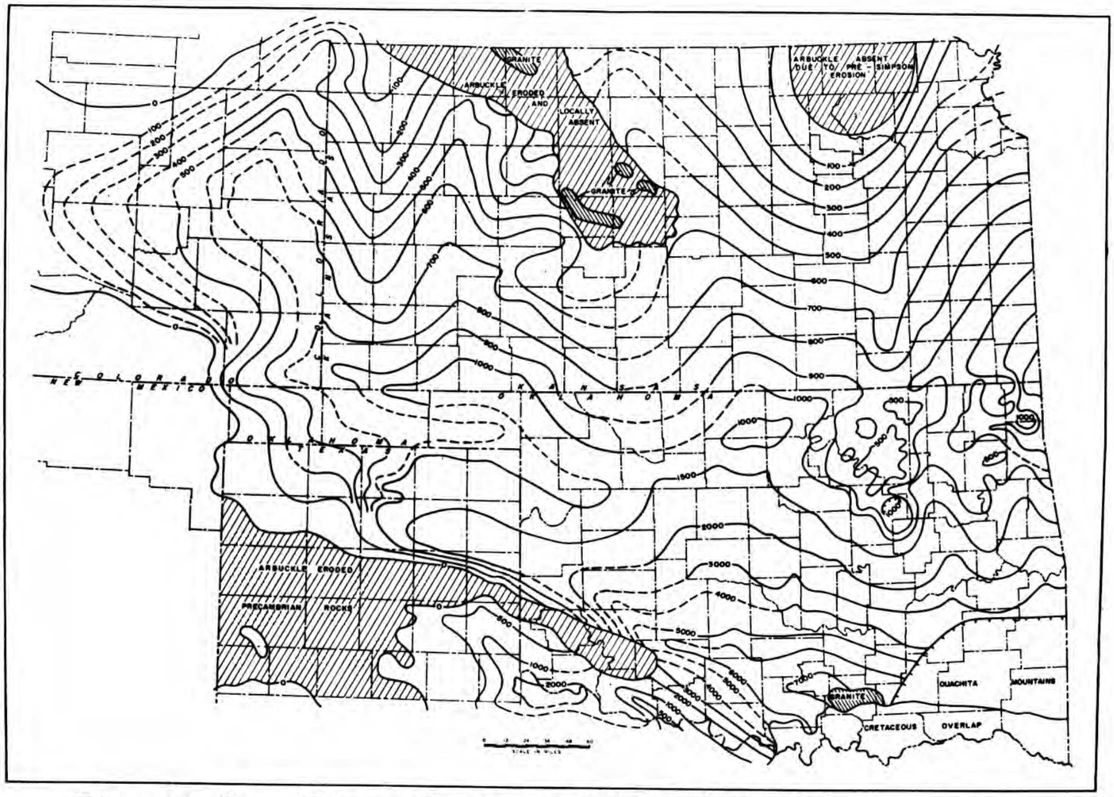

Figure 3. Isopach map of the Arbuckle group. (Adapted from Huffman, 1959.)

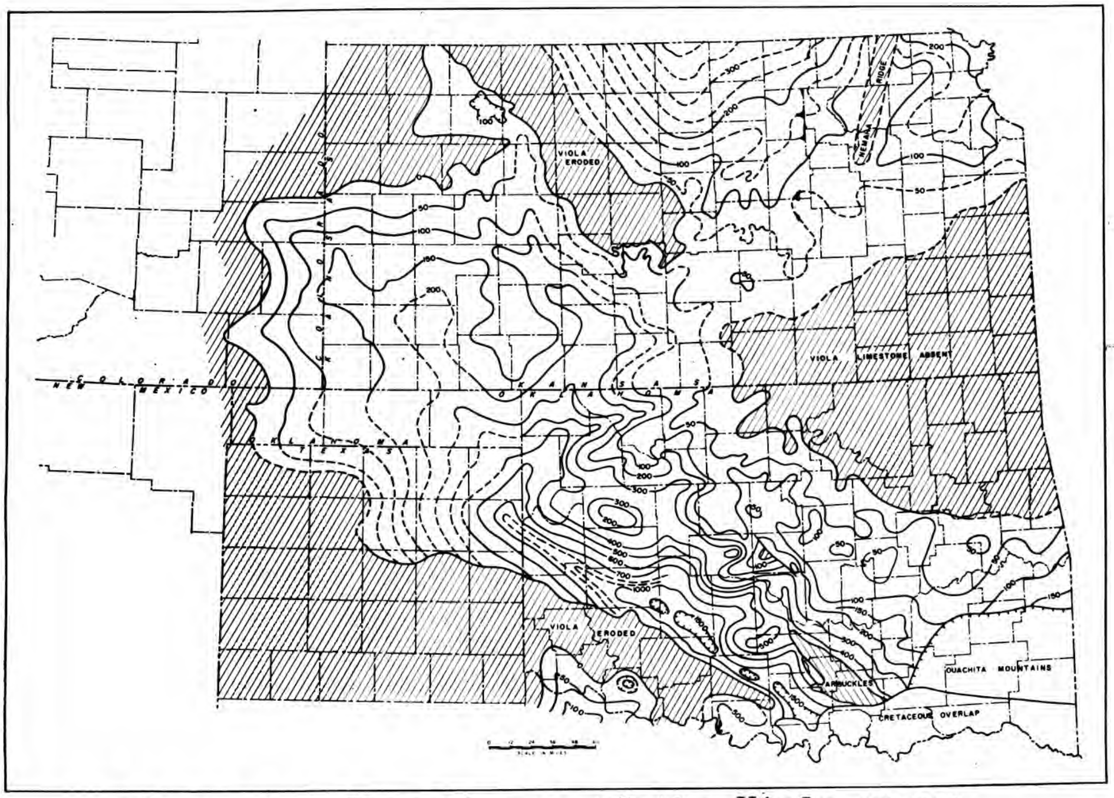

Figure 4. Isopach map of the Viola group. (Adapted from Huffman, 1959.)

the Viola limestone and Sylvan shale was continuous throughout Cincinnatian time. However, after the deposition of the Viola limestone, and epeirogenic interval began which caused the axis of the basin to migrate northward from the Wichita-Criner Hills geosyncline. (Wengerd, 1948.)

Viola rocks, which are dense, hard, fine crystalline limestones, have a maximum thickness of 1,500 feet (see Figure 4) in the central basin and thin northward. Unlike the Viola limestone, the Sylvan shale has a constant thickness of about 100 feet throughout most of the area. (Wheeler, 1947.)

Siluro-Devonian rocks of the region are represented by the Hunton limestone group, which conformably overlies the Sylvan shale, but varies in thickness owing to its stratigraphic proximity to the widespread pre-Mississippian unconformity. During the post-Devonian, pre-Mississippian time interval, the seas probably remained in the central basin area. However, in Northern Oklahoma and Southern Kansas, the Hunton limestone was stripped away by erosion after the seas had receded to the south (see Figure 5).

On the shelf, the thickness of the underlying Sylvan shale varies only over areas where the Hunton limestone is missing completely. (Wheeler, 1947.) This would suggest that any thinning of the Sylvan shale over anticlinal structures is due primarily to erosion.

Mississippian rocks are, in ascending order, the Woodford or Chattanooga shale (Kinderhookian), Sycamore or Mississippi limestone (Osagian), and the Caney shale (Meramecian and

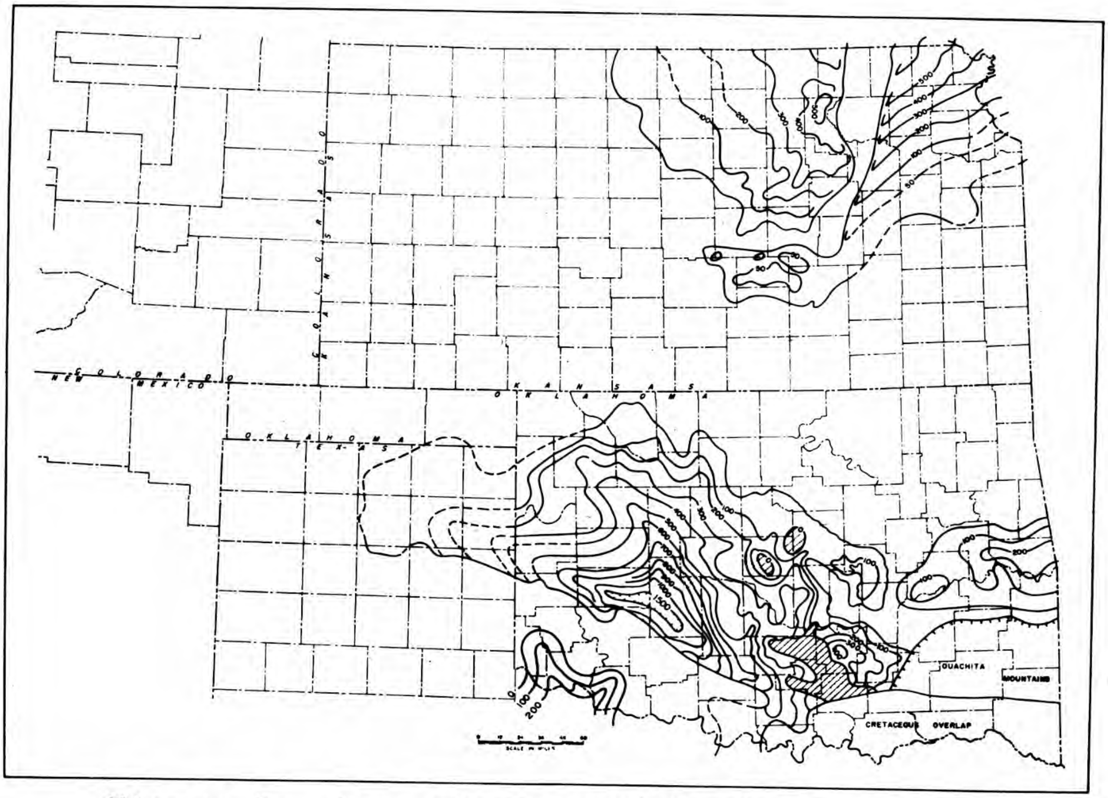

Figure 5. Isopach map of the Hunton group. (Adapted from Huffman, 1959.)

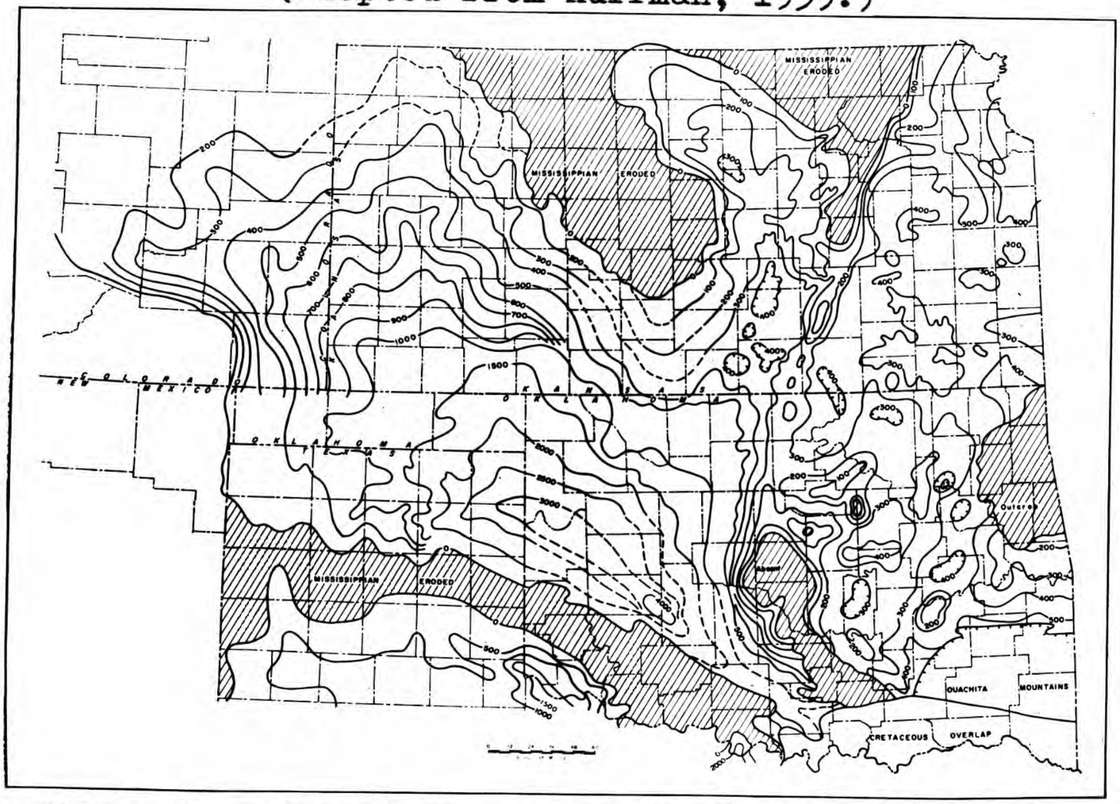

Figure 6. Isopach map of the Mississippian system. (Adapted from Huffman, 1959.)

Chesterian). These rocks are 3,500 to 4,000 feet thick in the geosynclinal area, and thin to the north and east (see Figure 6).

Following the post-Hunton period of erosion, the area was again submerged and the Woodford shale deposited unconformably on the old erosional surface. The Woodford shale indicates a time of quiet deposition of bituminous, black shales in a land locked basin (Wheeler, 1947).

Following an interval of erosion, the Mississippi or Sycamore limestone (Osagian) was deposited unconformably on top of the Woodford shale. (Lukert, 1947.) The unconformity between the Woodford shale and the Sycamore limestone has not been recognized in the few deep wells drilled within the central part of the basin. It is probable that this unconformity exists only on the shelf area and is not present in the deeper depositional areas of the basin.

On the shelf area, which includes parts of Northern Oklahoma and Southern Kansas, an interval of non-deposition and erosion occurred during all Meramecian, Chesterian, and Springeran (Lower Pennsylvanian) time. However, in the central basin, deposition was continuous through Springeran time and the Pennsylvanian-Mississippian contact in this area is conformable.

The interval of non-deposition and erosion of the north flank of the basin and shelf area has been attributed to the rise of the Nemaha Anticline, forcing the seas to withdraw to the south and west. According to Jacobsen (1949), the major diastrophic movements which affected the Nemaha Anticline consisted of two major pulsations: the first in post-Springeran, pre-Dornick Hills (Morrowan and Atokan) time, and the second in post-Dornick Hills pre-Deese (Desmoinesian) time.

Pennsylvanian Regional History

Deposition seems to have been continuous from Cambrian through Springeran time in the central basin area of South Central Oklahoma, whereas, on the shelf area of Northern Oklahoma and Kansas, a hiatus represents a time of erosion and non-deposition from Upper Mississippian to Desmoinesian time.

In the southern area, the restricted Springeran deposits rest conformably on the Caney shale, indicating that deposition continued without significant interruption from Upper Mississippian into Pennsylvanian time.

The Goddard shale of the Lower Springeran section comprises approximately 1,400 feet of black, fissile, carbonaceous shale. (See Figure 7.) This would suggest deposition in stagnant or shallow, brackish water of a lagoon or barred basin, having undisturbed sedimentation and a weak supply of sediments. The water must have been shallow, which prevented significant wave action and oceanic circulation. Abundant plant growth must have been present to supply the organic material to the sediment. Van der Gracht (1931) explained this great thickness of Caney-Goddard shale as an orogenic deposit resulting from an earlier phase of the Wichita Orogeny, which was restricted to the Ouachita system.

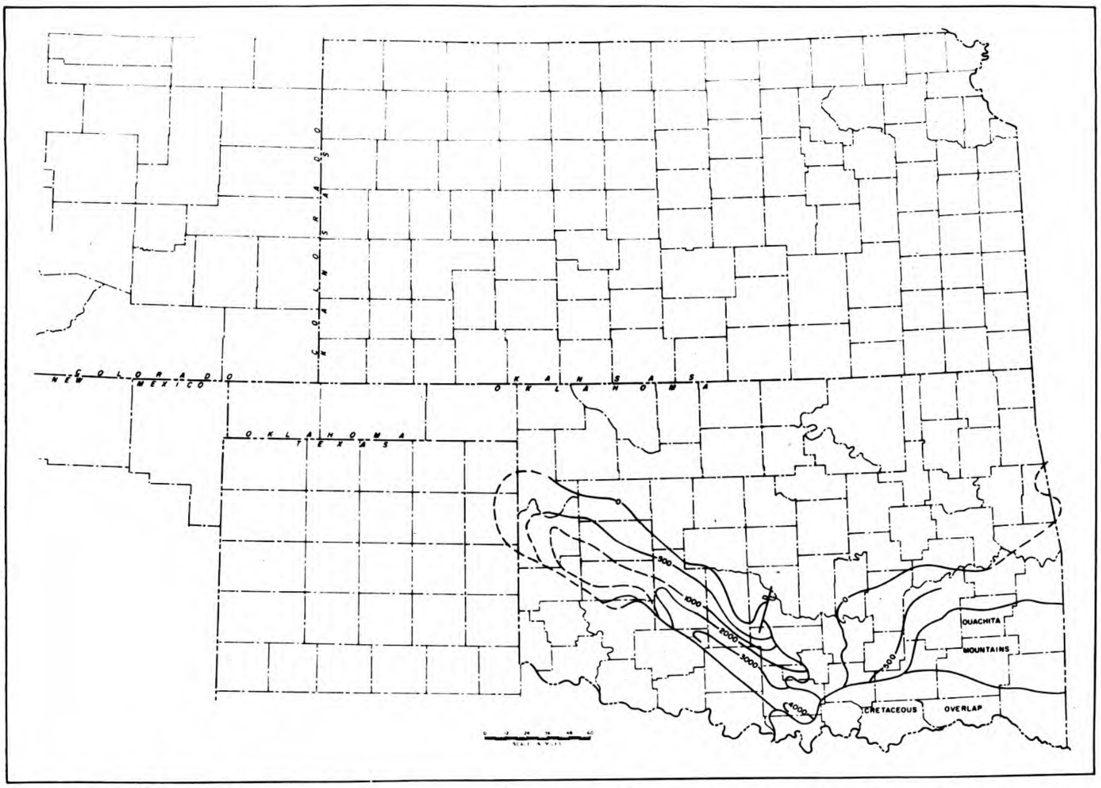

Figure 7. Isopach map of the Springer-Goddard series. (Adapted from Huffman, 1959.)

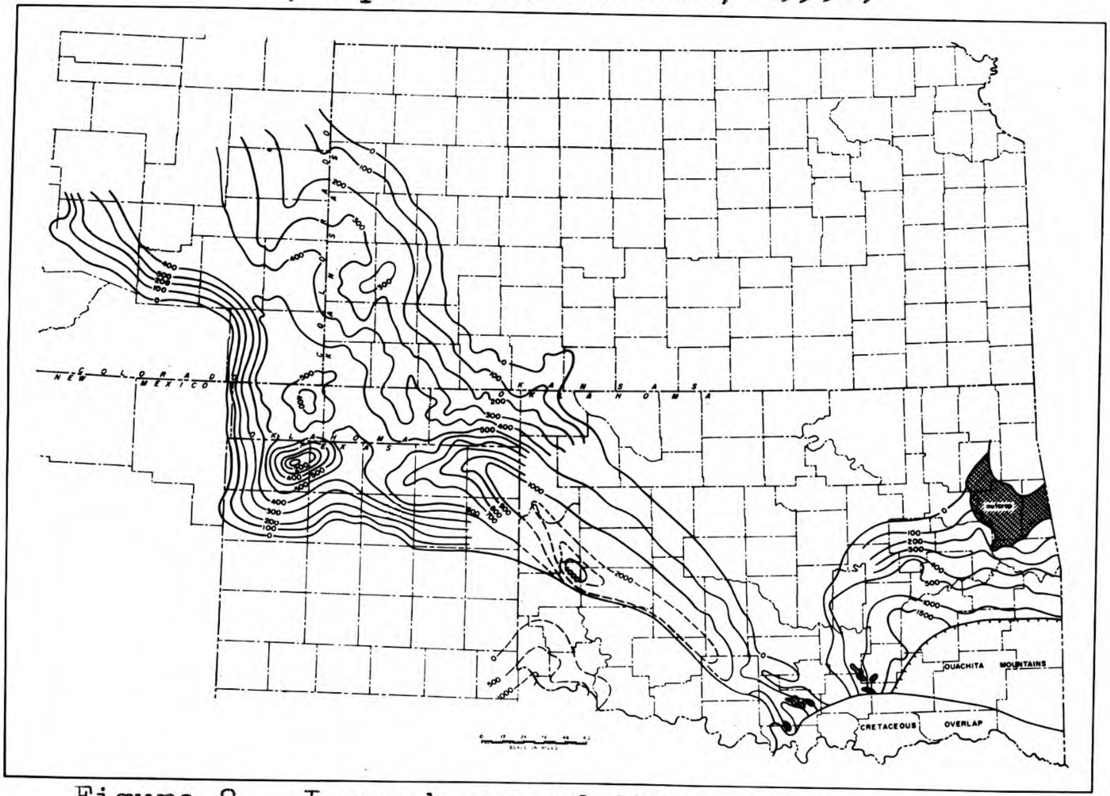

Figure 8. Isopach map of the Morrowan series. (Adapted from Huffman, 1959.)

The sandstones of the Upper Springeran section indicate possible development of a littoral zone and adjacent shallow water of a stable shelf. These sandstones, typical platform types, were probably deposited in very shallow waters, as evidenced by the plant remains and worm burrows, described by Tomlinson (1929), in the sandy shales between the sandstone. Although abundant organic material remains in the Upper Springeran, the sandstones are exceptionally clean, indicating possible reworking. The supply of debris probably did not exceed the ability of the currents to rework and redistribute the sands over a large area.

Determination of a possible source area of the Springeran sediments has created disagreement among Oklahoma's geologists. Van der Gracht (1931) postulated that the sands came from the Ouachita Mountains because of the various mineral suites present in the Springeran sandstones. He proposed the Stanley-Jackfork sequence as a possible source area in the Ouachita Mountains, but this sequence contains large quantities of garnet, whereas the Springeran sandstones contain none.

Other geologists believe that the Simpson group, if there were erosion of Simpson rocks at this time, could have supplied the sand. Wheeler (1947) does not agree with this hypothesis, however, because of the fine-grained, angular character of the Springeran sandstones in contrast to the large, rounded Simpson sand grains and the short distance of transportation.

The source area of the Springeran sediments is evidently to the southeast because the sediments thicken rapidly in that general direction. (See Figure 7.)

In the central basin area traversed by the cross sections, a disconformity between the Springeran and the overlying Lower Dornick Hills (Morrowan) group is present. This seems to indicate a local post-Springeran uplift accompanied by a minor retreat and re-advance of the sea before deposition of Lower Dornick Hills sediments (see Figure 8). In the last two wells of cross section BC, this uplift is indicated by the absence of approximately 200 feet of the Upper Springeran in the interval between the Primrose sandstone (Morrowan) and the Cunningham sandstone (Springeran). In wells west of the cross section, a complete Springeran sequence is present and the contact between Morrowan and Springeran sediments seems to be conformable.

The Primrose sandstone, originally classified as Upper Springeran by Tomlinson (1929), has been subsequently placed in the Lower Dornich Hills group by Wheeler (1947) and others, because of its different lithologic characteristics. The Primrose sandstone is shaly, fossiliferous, and highly glauconitic as compared to the clean, non-fossiliferous sandstones of the Springeran series. Glauconite forms on the stable shelf of quiescent areas having a mud bottom, in places where the rate of sedimentation is slow. (Krumbein and Sloss, 1958.) It may also form in sandy areas at a time of slow deposition. If the glauconite is authigenic, one of the above conditions probably existed. In this case, the glauconite and many complete fossil remains suggest deposition in a sandy area of a stable shelf during a time of slow deposition.

The central basin area of Central and South Oklahoma was affected by a wide-spread disturbance which terminated Morrowan time. This movement, the second and possibly the greatest phase of the Wichita Orogeny according to Van der Gracht (1931), folded the Wichita Mountains-Criner Hills chain of mountains, and initiated the Anadarko Basin. Van der Gracht (1931) proposed that faulting was the main cause of deformation in the Wichita system, although folding was an important factor toward the southeast.

Tomlinson (1929) dated this diastrophism by use of the Bostwick conglomerate of Atokan (Upper Dornick Hills) age, which unconformably overlies Viola, Simpson, and Springer-Caney formations in the Ardmore Basin. The Bostwick conglomerate is equivalent to the limestone and chert conglomerate at the base of the Upper Dornick Hills (Atokan) group in the Anadarko Basin.

During Atokan time, 600 to 1,200 feet of arkoses and "granite wash" were deposited near the Wichita Mountains. The sediments change in facies to the poorly sorted sands and dark shales of the north central basin area. Post-Morrowan, pre-Desmoinesian (Deese) erosion stripped most of the Paleozoic sediments from the Nemaha Anticline, Central Kansas Uplift, Wichita-Criner Hills Uplift, and other Late Morrowan structural features and deposited them in the surrounding lowlands. It was during this time that the Nemaha Anticline was also affected by the second phase of the Wichita Orogeny.

Following restricted Atokan deposition (see Figure 9), which originated to the southeast, the area apparently experienced the third phase of the Wichita Orogeny. Although not as wide-spread as the second phase, Van der Gracht (1931) acknowledged that "....certain movements continued after the Atokan". This, the third phase, may be represented in wells east of the cross section where the Hart (Fourth Deese) sandstone lies on top of the Goddard shale, thereby indicating orogenic movement during post-Atokan, pre-Desmoinesian time.

By the end of Atokan time, the Anadarko Basin had come into its full proportions (see Figure 9), and Wheeler (1947) believes that the Deese (Desmoinesian) sediments, which are the first to cover the entire area of the cross section, were the initial deposits of the newly formed basin. The Deese rocks do differ radically from the underlying beds, and seem to indicate different provenances.

Typically, the Deese series consists of thin limestones and arkosic sandstones separated by thicker sequences of variegated shales in Southern and South Central Oklahoma. The Deese sediments seem to be basin type sediments accompanied by differential sinking and rapid sedimentation so that the deposits were buried before they could be shifted very far from the site of initial deposition.

Determination of the source of the Deese sediments in the central basin of Central and South Central Oklahoma is a

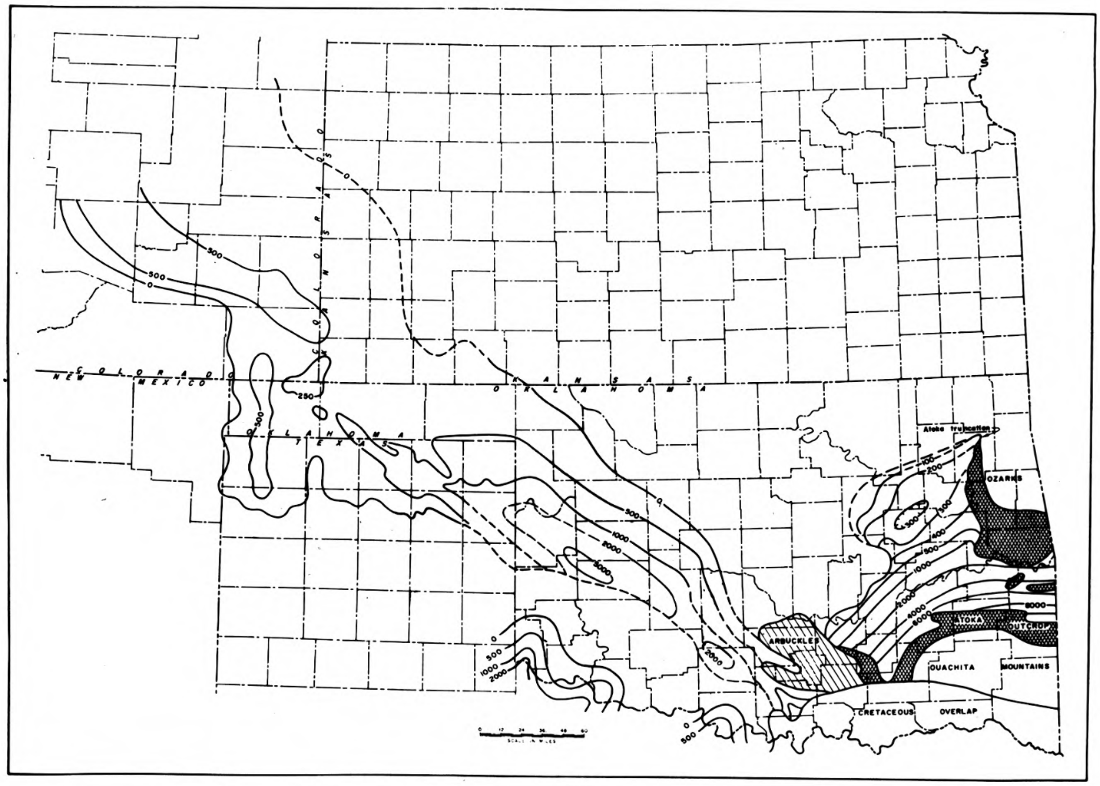

Figure 9. Isopach map of the Atokan series. (Adapted from Huffman, 1959.)

controversial problem. One source area was probably in the southeast, as suggested by Tomlinson (1929) and Dott (1941). However, the Wichita Mountains in the southwest represent another possible source area. These mountains at this time were probably just above sea level, so that only the finer material could be removed.

As the Deese sediments were traced northward to the shelf, depositional conditions changed; the thin limestones, dark shales, and bar-like sands of the Cherokee group and the overlying massive, marine limestones of the Marmaton group were deposited.

The Cherokee group, which is equivalent to the Lower Deese sediments, is indicative of the advance and retreat of shallow seas across the shelf area. This group is characterized by cyclic sedimentation of thin limestones and interbedded sandstones and shales on a stable shelf. Members of this group are missing locally by truncation and onlap over structures of pre-Desmoinesian age such as the Nemaha Anticline, which probably stood as a group of low islands in the Cherokee seas.

The lenticular bodies of rather clean sands in the Cherokee group indicate possible low bars formed in the shallow seas. Unfortunately, lateral correlation of these lensing sandstones is extremely poor over this northern shelf area so that tracing individual sand bodies is very difficult.

The biostromal nature of the limestones in the overlying Marmaton group are indicative of the quiet shallow seas which covered the area after deposition of the Cherokee group.

After Desmoinesian time, slight uplift occurred in the central basin area accompanied by the subsequent erosion of the pre-Missourian surface. Thus, the Desmoinesian sediments are separated from the overlying Missourian sediments by slight regional and pronounced local unconformity. (Wheeler, 1947.)

Orogenic movements related to this withdrawal of the Desmoinesian seas have not been carefully defined, but it is probably that any disturbance at this time was a minor pulsation of the later Arbuckle Orogeny of Virgilian.

At this time, the Missourian seas returned from a southwesterly direction spreading the sands of the Cleveland formation over a widespread area. Later deposition during Missourian time is typified by the extensive limestones which occur throughout the area. These deposits are characterized by the Checkerboard, Hogshooter, Dewey, and Avant limestones accompanied by lensing sandstone members.

The sediments were probably deposited in a shallow sea under stable shelf conditions. The oolitic character of the limestones indicate shallow water that was highly agitated. In Northern Oklahoma, rapid lateral and vertical changes in lithology of the Avant limestone indicates slight reefing conditions of sedimentation during Ochelata time.

Northward in Kansas, deposition of the Pedee, Lansing, Kansas City, and Pleasanton groups resulted in a normal marine sequence of alternating limestones and shales.

Following deposition of the Missourian sediments, the southern region of the Anadarko Basin was affected by the Arbuckle Orogeny, which has been discussed by Dott (1941) as follows:

> Late in Hoxbar time (Late Missourian-Early Virgilian), tangential forces from the southwest rejuvenated the older folds of the Wichita Mountain system, and the entire Wichita system was moved northward toward the Hunton Arch (see Figure 2), which served as a buttress. The Ardmore-Anadarko Geosyncline was greatly compressed, and the rocks folded into the Arbuckle Anticline. As the stress continued, the eastern part of the Wichita system was thrust still farther north. This intense thrusting at the eastern end resulted in minor folds developing on the major axes. Most of the folds were overturned toward the northwest. In the final stage, they broke on their overturned axis, developing into thrusts and overriding the adjacent syncline.

During and immediately following this movement, during Upper Hoxbar-Lower Pontotoc time, the resultant mountainous areas were rapidly eroded and the detrital material dumped into the adjacent lowlands. These sediments are present today as deposits of arkosic sandstone, conglomerates, and "granite wash" in the Upper Hoxbar (Virgilian) and Lower Pontotoc (Upper Virgilian-Lower Wolfcampian) groups.

These clastics of the central basin area grade laterally into the normal limestone and shale sequences of the Wabaunsee, Shawnee, and Douglas groups of Kansas and Northern Oklahoma. Thus, the inference can be made that the northern area was relatively stable during this orogeny, and that cyclic sedimentation of limestones and shales occurred in an area covered by quiet, shallow seas.

Now it can be seen, that basically, the development of the Wichita and Arbuckle Mountains, and of the Anadarko Basin, is in close accord to Week's (1952) theory of basin development. His typical basin consists of a foreland of older rocks, the basin itself, and the borderland consisting of younger rocks opposite the basin from the foreland. In his hypotheses, the original basin subsides and a sequence of sediments from the foreland is deposited. The borderland is then uplifted, depressing the trough into an asymmetrical form.

In the next cycle of deposition, the borderland will supply most of the sediments. Later, a new uplift will form a new borderland, adjacent to, and parallel to, the old one, on the inside of the basin. In this way, basins tend to become closed in a structural sense. The Anadarko Basin seems to have had a comparable origin.

CONCLUSIONS

Stratigraphic correlation of the Upper Pennsylvanian sediments on the northern shelf of the Anadarko Basin with those of the central basin can be accomplished.

For correlative purposes, the lateral tracing of the limestones and sandstones, based on variation of lithology, affords a great deal of success. However, most of the limestones present on the shelf become discontinuous or replaced by clastics as they are traced into the deeper parts of the basin.

Paleontologically, macro-fossils are abundant on the shelf and can be used extensively in correlation. However, in the central basin of South Central and Central Oklahoma, macro-fossils are scarce owing to rapid sedimentation and depositional environment. Therefore, correlation between shelf and basin units on the basis of macro-fossils is nearly impossible. A detailed study of micro-fossils within the sedimentary rocks might overcome the disadvantages of the macro-fossils, and result in more accurate correlations.

The best basis for correlation seems to be by means of the combined use of electric logs and examination of rotary well cuttings.

Economically, the organic shales of the Lower Pennsylvanian series in the basin provide sources for the origin of petroleum. In areas where the Lower Pennsylvanian sediments wedge-out against topographic or structural highs, up-dip migration and accumulation of petroleum is highly possible. The shelf of Northern Oklahoma and Southern Kansas also presents excellent possibilities for the accumulation of petroleum in the lensing sands of the Upper Pennsylvanian series.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Dr. Claude W. Shenkel, Jr., Professor of Geology, under whose guidance this investigation has been made.

Appreciation is also extended to Mr. J. J. Gladden, Gulf Oil Corporation, Oklahoma City, Oklahoma, for supplying the electric logs used in this investigation.

Thanks are also expressed to Dr. V. Brown Monnett, Head of the Geology and Geography Department, Oklahoma State University, Stillwater, Oklahoma, and to the Shawnee Sample Cut, Shawnee, Oklahoma, for their information and suggestions.

BIBLIOGRAPHY

Dott, Robert H. (1941), Regional stratigraphy of Mid-Continent: Am. Assoc. Petrol. Geol. Bull., vol. 25, pp. 1660-1680.

Huffman, George C. (1959), Pre-Desmoinesian Isopachous and Paleogeologic studies in Central Mid-Continent Region: Am. Assoc. Petrol. Geol. Bull., vol. 43, pp. 2541-2574.

Jacobsen, Lynn (1949), Structural relations on east flank of Anadarko Basin, Cleveland and Mc Clain Counties, Oklahoma: Am. Assoc. Petrol. Geol. Bull., vol. 33, pp. 695-719.

King, Phillip B. (1951), The tectonics of Middle North America: Princeton Univ. Press, pp. 1-256.

Krumbein, W. C., and Sloss, L. L. (1958), Stratigraphy and sedimentation: W. H. Freeman and Co., pp. 1-497.

Lukert, L. H. (1949), Subsurface cross section: Am. Assoc. Petrol. Geol. Bull., vol. 33, pp. 131-152.

Lee, Wallace (1956), Stratigraphy and structural development of the Salina Basin in Kansas: Kansas Geol. Survery Bull. 121, pp. 1-167.

Moore, R. C. (1949), Divisions of the Pennsylvanian system in Kansas: Kansas Geol. Survey, Bull. 83, pp. 1-197.

Moore, R. C., and others, (1951), The Kansas Rock Column: Kansas Geol. Survey, Bull. 89, pp. 1-132.

Tomlinson, C. W. (1929), Pennsylvanian system in Ardmore Basin: Oklahoma Geol. Survey Bull. 46, pp. 1-35.

Van der Gracht, W. A., J. M. van Waterschoot (1931), Permo-Carboniferous orogeny in South Central United States: Am. Assoc. Petrol. Geol. Bull., vol. 15, pp. 991-1057.

Weeks, L. G. (1952), Factors of sedimentary basin development that control oil occurrence: Am. Assoc. Petrol. Geol. Bull., vol. 36, pp. 2071-2124.

Wengerd, Sherman A. (1948), Fernvale and Trenton limestones of South Central Oklahoma: Am. Assoc. Petrol. Geol. Bull., vol. 32, pp. 2191-2231.

Wheeler, R. R. (1947), Anadarko Basin .... geology and oil possibilities: World Oil, vol. 127:

Part I, Sept. 22, 1947, pp. 38-43.
Part II, Sept. 29, 1947, pp. 33-46.
Part III, Nov., 1947, pp. 152-164.
Part IV, Jan., 1948, pp. 100-112.

APPENDIX

PENNSYLVANIAN STRATIGRAPHY OF THE NORTHERN SHELF AND EASTERN PART OF THE ANADARKO BASIN OF OKLAHOMA AND KANSAS

by

JOHN B. BUTLER

B. S., Oklahoma State University, 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

This investigation is a subsurface study of Pennsylvanian stratigraphy on the eastern flank of the Anadarko Basin of Central and South Central Oklahoma, and the northern shelf of North Central Oklahoma and South Central Kansas.

A subsurface stratigraphic cross section of Pennsylvanian sedimentary rocks was constructed that extends from Marion County, Kansas, to Grady County, Oklahoma. The cross section is nearly parallel to the west flank of the Nemaha Anticline along its southern extent. Correlations were based on electric log data and examination of rotary well samples.

The primary purpose of the investigation was to correlate the Pennsylvanian sediments of the shelf with their equivalents in the central basin. A brief discussion of the pre-Pennsylvanian geologic history was presented, and an interpretation of the Pennsylvanian geologic history, based on stratigraphic data obtained, was made.

Correlation of the Pennsylvanian limestones and shales on the shelf with the coarser clastics of the central basin was successful to a certain degree. Rapid facies changes occur as the sediments were traced into the basin. Normal marine limestones and shales grade southward into the coarse clastics, which were eroded from the surrounding highlands and deposited in a "city dump" type of sedimentation.

Isopach maps, adapted from work presented by Huffman (1959), were used to illustrate the horizontal and vertical extent of

Pennsylvanian sedimentary rocks on the shelf and in the basin. These maps also reflect the orogenic movements which affected the area during Pennsylvanian time.

The first orogenic movement, the Wichita orogeny, produced the folding and faulting of the Wichita Mountain system. The resulting highlands furnished the coarse clastics which are present in the Desmoinesian series.

In Late Pennsylvanian time, the Arbuckle orogeny rejuvenated the Wichita Mountain system and folded and faulted the Arbuckle Mountains of South Central Oklahoma. This later movement resulted in the deposition of the shales, arkosic sandstones, and conglomerates of the Missourian and Virgilian series.