ENVIRONMENT OF DEPOSITION OF THE PENNSYLVANIAN BARTLESVILLE SANDSTONE, LABETTE COUNTY, KANSAS

A Thesis

by

CHARLES TRUMAN LARS JOHNSON

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Approved as to style and content by:

(Chairman of Committee) (Member)

(Head of Department) (Member)

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ABSTRACT

Environment of Deposition of the Pennsylvanian
Bartlesville Sandstone, Labette County,
Kansas. (December 1973)
Charles Truman Lars Johnson
B.S., Texas A&M University
Directed by: Dr. Wayne Ahr

The Bartlesville Sandstone in southeastern Kansas was deposited as part of a clastic depositional system that developed on the shelf of the Pennsylvanian McAlester Basin. The reservoir sandstone of the Chetopa Field, Labette County, Kansas was deposited as a fluvial point-bar in this system.

The environmental interpretations in this thesis were made after examination of full-diameter cores from 5 wells. Grain size, composition, sedimentary structures, and morphology of the Bartlesville Sandstone all indicate a fluvial environment of deposition.

Locally, the Bartlesville has three distinct facies. (1) Point bar facies characterized by a sandstone 35 to 60 feet thick that has channel lag pebbles at its base, decreasing grain size upward, crossbeds which dip about 20 degrees at the base to

rippled laminae at the top of the sequence and a quartz composition about 50 percent of the mineral composition indicating an immature sandstone. (2) Channel-fill facies characterized by sandstones 1 to 9 feet thick interbedded with siltstones 1 to 7 feet thick, fine- to very fine-grained sandstones, some crossbedding in the sandstones which may dip up to 15 degrees. There are rippled laminae in the sandstones and siltstones, and quartz composition of 35 to 50 percent in the sandstones. (3) Cutoff-fill facies, underlying a portion of the point bar, characterized by a lower 20-foot sequence of shale-clast conglomerate and an upper interbedded sandstone and siltstone sequence 30 feet thick.

These three distinct facies, recognized in the five cored intervals, were identified in adjacent wells by means of gamma ray logs and porosity and permeability plots from core analyses. The logs and plots were variable enough to distinguish the three facies and to allow their use in establishing their lateral extent and boundaries.

The Bartlesville Sandstone isopach shows a narrow body with a maximum 6000-foot width that trends westward across the field and becomes narrower and disappears in the eastern part of the field. A paleogeographic map indicates the location of the fluvial channel that deposited the point bar. Two cross sections through the sandstone body further reveal the geometry of the point bar.

This point bar was deposited in the fluvial or fluvio-deltaic environment of the system that deposited the large Bartlesville Sandstone delta on the Oklahoma shelf as reported by Visher (1971).

ACKNOWLEDGEMENTS

I wish to express my appreciation to the members of my committee, Dr. Wayne Ahr, Dr. Robert Berg, and Dr. John Logan, for their help in the preparation of this thesis. A special thanks to Dr. Berg who suggested the thesis problem and who obtained the cores, through the generosity of Tenneco Oil Company, used in the study.

My sincere gratitude goes to Dr. Tom Tieh who was always ready to help in any way he could.

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CHAPTER I

INTRODUCTION

The interpretation of environments of deposition in ancient rocks can be useful in the field of geology. Examining sedimentary rocks and their properties, and relating them to modern environments facilitates the reconstruction of ancient depositional environments. Much can be learned about the geologic history of a region. Environmental reconstruction in the subsurface enables more precise methods of exploration for hydrocarbons. Productive locations for additional wells and new fields can be determined. Also, estimates of field size and ultimate hydrocarbon recovery can be made more accurately when the sedimentary environment and the morphology of the reservoir are known.

The purpose of this study is to determine the depositional environment of the Pennsylvanian Bartlesville Sandstone in southeastern Kansas. Subsurface data from the Chetopa Field, Labette County, Kansas, have been utilized (Figure 1). All of the wells are in a six square-mile area south of the town of Chetopa.

The format of this thesis follows that of the American Association of Petroleum Geologists Bulletin.

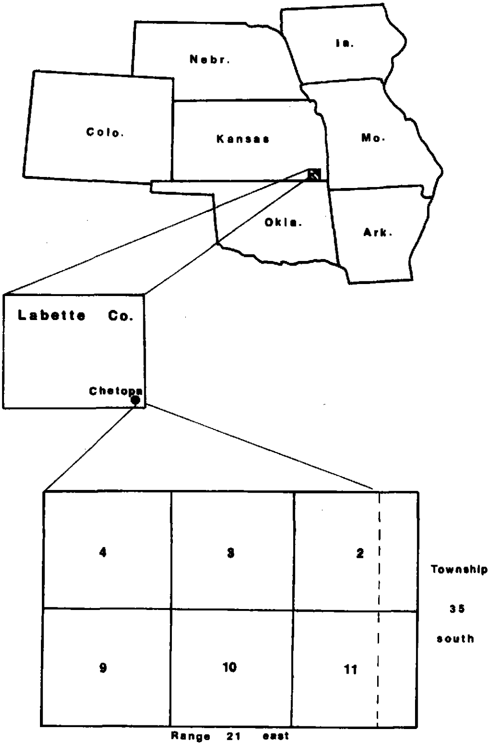


Figure 1. Location of Chetopa area.

The Bartlesville Sandstone was the reservoir rock for the now abandoned Chetopa Field and full-diameter cores, core analyses, and gamma ray logs were available for study.

Published reports on the Bartlesville Sandstone in Kansas, Missouri, and Oklahoma (Bass, 1936, Howe, 1956, Weirich, 1953; Hayes, 1963; Phares, 1969; Visher, Saitta B. and Phares, 1971) provided additional information for regional correlation.

This investigation will reveal more information on the depositional history of the Bartlesville Sandstone in southeastern Kansas. It will also complement work done on the Bartlesville depositional system in Oklahoma (Visher, Saitta B. and Phares, 1971).

CHAPTER II

GEOLOGIC SETTING

Structural History

Paleozoic structural activity in the western midcontinent involved differential subsidence and uplift and development of various basins and arches. Some of these were short-lived features relative to the entire Paleozoic Era. Basins were areas of greater subsidence than arches and received thicker deposits of sediments. In the Late Paleozoic, major basins were subdivided by minor arches (Snyder, 1968).

The Mesozoic Era was a period of structural inactivity in the western midcontinent (Snyder, 1968). The regions where Paleozoic basins and arches had formed were now stable. During the Cretaceous there was slow subsidence and a thin blanket of sediments was deposited and later uplifted (Snyder, 1968).

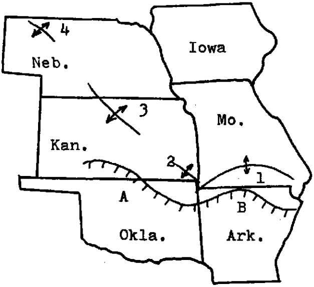
During the Cenozoic Era there was erosion and only minor uplift.

The eastern Kansas region during the early Paleozoic was flanked on the southeast by the Ozark Uplift, on the west by the Central Kansas Uplift, with the Chautauqua Arch forming a connection between the two uplifts (Figure 2). By Late Devonian time the Chautauqua Arch was no longer active. Eastern Kansas was divided by the Bourbon Arch into the Forest City and Cherokee Basins in Late Mississippian time (Jewett and Abernathy, 1945) (Figure 3). The Cherokee Basin occupied a portion of the shelf area of the larger McAlester Basin.

Sedimentation History

A transgression northward out of the McAlester Basin took place in Early Pennsylvanian time, but Morrowan deposits were restricted primarily to central Oklahoma. Extensive deposition of Atokan clastics occurred in the McAlester Basin and northeast Oklahoma shelf. Minor regressions and consequent erosion took place during the overall transgression, as indicated by unconconformities at the top of Morrowan and Atokan rocks. These periods of erosion stripped much of the Early Paleozoic rocks from the Nemaha Ridge, Central Kansas Uplift, and the Ozark Uplift (Huffman, 1959).

A Middle Pennsylvanian transgression out of the McAlester Basin reached southeastern Kansas and Desmoinsian sediments were deposited unconformably on Mississippian age rocks. The Desmoinsian deposits of the Cherokee Group are 200-350 feet thick and cyclic



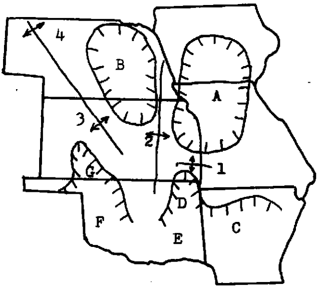
Basins

A. Ardmore
B. Arkansas

Uplifts

1. Ozark
2. Chautauqua
3. Central Kansas
4. Cambridge

Figure 2. Early Paleozoic Structural Features
(after Figure 6, Snyder, 1968)



Basins

A. Forest City
B. Salina
C. Arkansas
D. Cherokee
E. McAlester
F. Anadarko
G. Hugoton

Uplifts

1. Bourbon
2. Nemaha
3. Central Kansas
4. Cambridge

Figure 3. Middle and Late Paleozoic Structural Features (after Figure 7, Snyder, 1968).

in nature in southeastern Kansas (Moore, 1951). The seas again withdrew from the shelf creating a regional uncomformity overlain by the Missourian Series.

Late Pennsylvanian and Permian transgressions also reached the eastern Kansas area.

Stratigraphic Nomenclature

The Cherokee Group is included in the Desmoinsian Series of the standard midcontinent Pennsylvanian System. The Group is divided into two subgroups and eighteen formations (Figure 4). The cyclic or repetitive sedimentation is the basis of formational division (Searight and others, 1953). Formations include beds from the top of a coal bed to the top of the next higher coal bed.

The term Bartlesville Sandstone is an informal subsurface name for the Bluejacket Sandstone Formation of the Krebs subgroup. In this study it refers to the sandstone that lies above the Drywood Formation and below the top of the Weir-Pittsburg coal. The Seville Limestone Formation is not present in the Chetopa area.

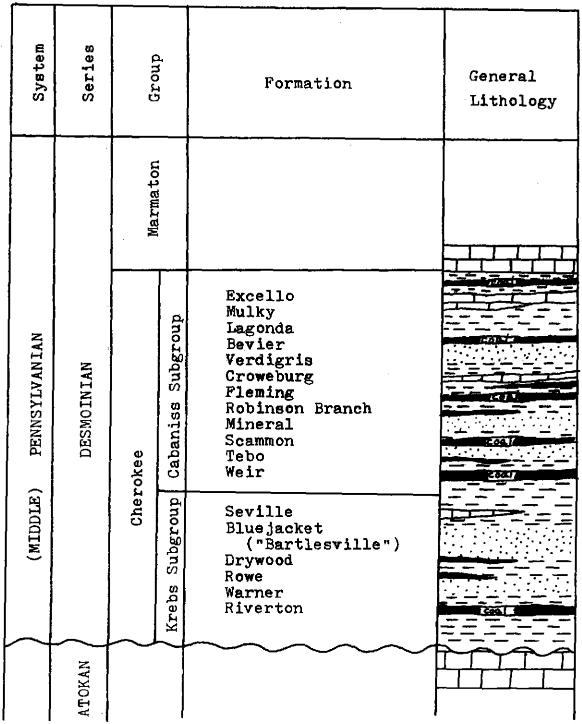


Figure 4. Stratigraphic Column (after Hayes, 1963; Searight, et al., 1953).

Previous Work

Bass (1936), utilizing subsurface information on the Bartlesville Sandstone postulates an offshore bar origin for the sandstone in east-central Kansas. He refers to them as "shoestring sands" because of the typical linear trend. He relies mostly on the strike trends and the morphological similarity to modern offshore bars to substantiate his idea.

During the Middle Pennsylvanian the transgression out of the McAlester Basin reached Kansas. The numerous cyclothems in the Middle Pennsylvanian indicate that minor regressions also occurred (Moore, 1951). The shoreline during this time has been postulated to have existed in east-central Kansas. Wierich (1953) presents paleogeographic maps which indicate shelf-type deposition in southeastern Kansas during Middle Pennsylvanian time. He also presents a generalized sandstone distribution map of the Bartlesville Sandstone in the subsurface of Kansas and Oklahoma (Figure 5).

Branson (1968) believes that the Bartlesville Sandstone consists of offshore bar and channel deposits as far south as central Oklahoma, but Visher (1968) presents evidence that the Bartlesville Sandstone of

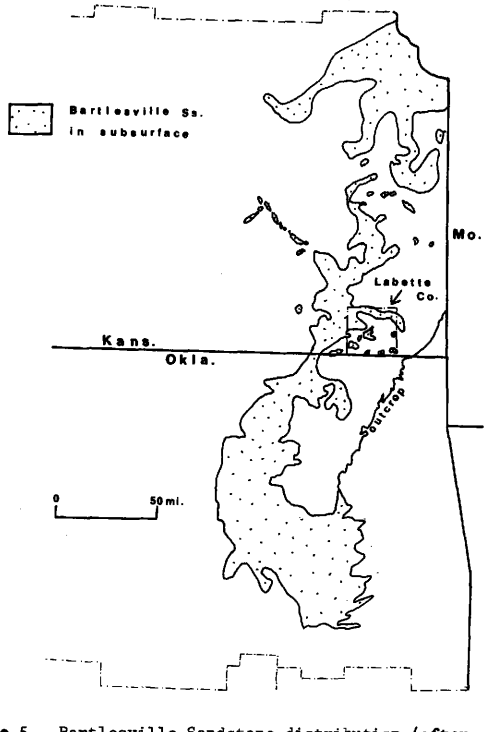


Figure 5. Bartlesville Sandstone distribution (after Weirich, 1953).

east-central and northeastern Oklahoma was deposited as part of a delta complex. He feels that the fluvial-deltaic regime extended northward into southeastern and eastern Kansas. Phares (1969) shows a major distributary channel in northeastern Oklahoma with marginal marine, bay-basin facies lateral to it. He depends primarily on well logs and has little primary data to document his ideas.

Visher and others (1971) further describe a deltaic system on the Oklahoma portion of the shelf and indicate a smaller deltaic system to the east in northeastern Oklahoma. This agrees with Phares' interpretation of northeastern Oklahoma.

If Visher's deltaic interpretation for the Bartlesville Sandstone in Oklahoma is correct, the occurrence of offshore bars 100 miles to the north and farther out of the basin is untenable. However, the offshore bar hypothesis seems equally plausible if the Middle Pennsylvanian shoreline was in central Kansas as Weirich suggests.

History of the Bartlesville Sandstone Production

The Bartlesville Sandstone has been an important producer of oil in Kansas and Oklahoma since the late

1800's. The first well drilled into what would later be called the "Bartlesville Sand" was completed in Wilson County, Kansas in 1892. Twenty-two feet of oil sand was encountered with a total depth of 832 feet (Weirich, 1968). The "shoestring" nature of the sand was recognized as oil exploration spread south from Kansas into Oklahoma. The abrupt lateral change and lenticular nature of the sandstone led initially to random exploratory drilling. In 1897, the first commercial oil well in Oklahoma was completed in the Bartlesville Sandstone (Weirich, 1968). From these beginnings the exploration for and production of "Bartlesville Oil" has continued. Today over 80 years since the first well was completed, the total oil production from the Bartlesville Sandstone is approaching 1.5 billion barrels (Weirich, 1968).

Chetopa Field History

In the Chetopa Field the Bartlesville Sandstone is found at approximately 100 feet below the surface and about 50 feet below the Weir-Pittsburg coal horizon. Heavy viscous oil is found in the Bartlesville Sandstone in southeastern Kansas and southwestern Missouri. Drilling was begun in the Chetopa area in

1964 by Tenneco Oil Company in order to develop oil production from these "tar sands" by a steam injection method. However, this project met with only minor success and the field was abandoned.

CHAPTER III

METHOD OF STUDY

For this study of the Bartlesville Sandstone, data from thirty-five wells from the Chetopa Field were studied. From these wells, full-diameter cores, core analyses, and gamma ray logs were available.

Initially, a comparison of the gamma ray logs from all thirty-five wells was made. Five wells were chosen that displayed different log characters in the Bartlesville interval. These logs indicated that three of the five wells penetrated the Bartlesville Sandstone while others were situated in the laterally equivalent Cherokee shale. The cores from the five selected wells were then slabbed and mounted on boards to facilitate study. Textures, sedimentary structures, and stratigraphic sequences were described for these intervals. These cored intervals are the principal basis for the environmental reconstruction. They were selected to show the various facies present.

Samples were taken from each of the five selected cores for petrographic study. These were selected to document the compositional and textural changes observed in the five selected intervals. Two hundred point counts for composition and fifty grain size measurements were made on each thin section.

Three maps were constructed, a local structure map, a facies map, and an isopach map. The structure map is on the top of the Bartlesville horizon and also shows the well locations. Correlation of distinctive log characters with a given rock type from the five selected wells justified the use of gamma ray logs from the other thirty wells to delineate the facies lateral extents. A sandstone isopach map further revealed the geometry of the Bartlesville Sandstone.

Plots of secondary rock properties, porosity and permeability, were made to further document grain size and compositional variation in the vertical sequences. These also aided in lateral correlation of the sandstone.

For descriptive purposes, the wells are referred to by a letter and number symbol. For example, the Tenneco Wilson No. 2 is abbreviated "TW2" in the text. A complete description and location of the wells studied is given in the core descriptions in Appendix B.

CHAPTER IV

CRITERIA FOR ENVIRONMENTAL INTERPRETATION

The most important criteria for interpretation of depositional environments are the primary rock properties: composition, texture, sedimentary structures, and morphology (Table I) (Berg, 1970). In particular the variations observed in composition, texture, and sedimentary structures in a vertical sequence are diagnostic. The nature of these properties and their variation in a vertical sequence is the result of some sedimentary process (Visher, 1965). It becomes necessary to understand the sedimentary processes that are operative in an environment. The interpretation of ancient sedimentary environments based on primary rock properties observed is then possible. Since secondary and tertiary rock properties (Table I) are dependent upon the primary rock properties, their use, when available, can be helpful in an environmental interpretation.

Composition and texture, more specifically quartz content and quartz grain size in sandstones, are significant environmental indicators (Berg, 1970). The stability and abundance of detrital quartz makes

TABLE I. Key Parameters of Sedimentary Environment Interpretation

(from Berg, personal communication)

Primary Rock Properties

1) Composition

2) Texture

3) Sedimentary Structures

4) Morphology

Secondary Rock Properties (dependent on primary properties)

1) Porosity

2) Density

3) Fluid Content

4) Permeability

Tertiary Rock Properties (dependent on primary and secondary properties)

1) Resistivity

2) Spontaneous Potential

3) Radioactivity

4) Acoustic Properties

5) Thermal Conductivity

quartz content a particularly useful indicator in most environments.

Quartz content of greater than about 75 percent is characteristic of marine bar sandstone whereas fluvial to fluvial-deltaic deposits are usually less than 60 percent quartz (Berg, 1970). Rock fragments, relatively unstable, would comprise a greater percentage of the fluvial deposits than of the marine bar sandstone (Berg, 1970).

Changes of quartz grain size in a vertical sequence reflect changes in flow regimes. Fluvial sandstones generally show an upward decrease in grain size as energy of sedimentary processes decreased up and out of a channel. On the other hand, marine bar sandstones can show either a decrease or an increase upward in quartz size depending on whether they are a transgressive or regressive deposit (Berg, 1970).

The variation of sedimentary structures in a vertical sequence also indicates change in flow regimes. Fluvial sandstone commonly show a decrease in scale of sedimentary structure upward in a vertical sequence. Coarsest sands and gravels that show large scale steeply-dipping cross laminations occupy the lower portion. These grade upward into horizontal laminations and small-scale ripple laminations at the top of the sequence. The lateral migration of the fluvial sands often produces a continuous vertical sequence of structures. Similar sequences of sedimentary structures may occur in transgressive marine bar sandstones but marine bar sandstones typically display smaller scale, lower-dipping cross laminations that grade into horizontal laminae and shale laminae at top (Berg, 1970).

Sand bodies in different environments vary in thickness, shape, and lateral extent. Hence, morphology of sandstone units and lateral facies encountered are quite important in determining depositional environments (Potter, 1967).

CHAPTER V

DESCRIPTION AND INTERPRETATION OF FACIES

Introduction

Distinct sedimentary facies can be identified on the basis of sedimentary structures, constituent grain size, and mineral composition in the cored intervals. Plots of secondary rock properties, porosity and permeability, and gamma ray logs are also useful in delineating the lateral extent of facies into adjacent wells where cores were taken but not available for study.

Figure 6 shows the local structure in the Chetopa area and the location of wells used in this study. Regional dip is toward the northwest.

Three main sedimentary facies were encountered in this study: 1) point bar facies, 2) channel fill facies, and 3) cut-off fill facies. Although each of these facies was deposited in the fluvial environment, they were formed under different flow regimes, primarily because they were subjected to different degrees of river activity.

The point bar facies was formed as a sand spit which protruded into the active river channel. In

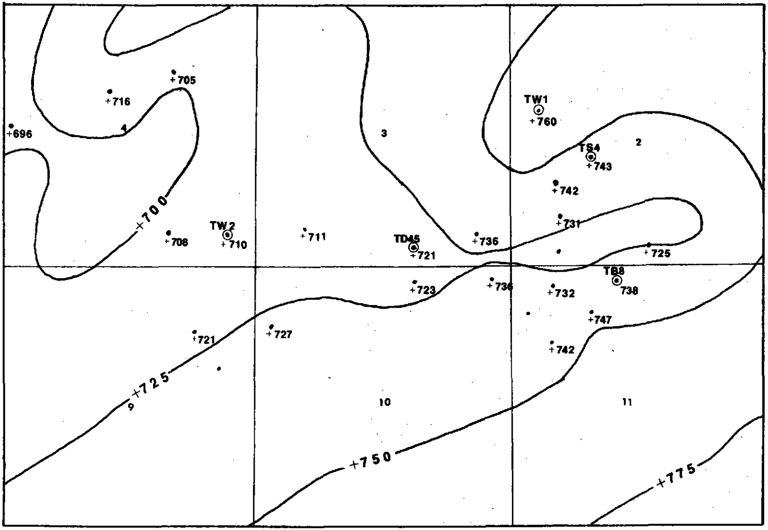


Figure 6. Local structure on top of Bartlesville Sandstone showing location of cored intervals (circled wells) and other wells (solid dots) used in this study.

deepest channel, a coarse, essentially unbedded gravel was present owing to the high flow velocity in the heart of the channel. This gravel, therefore, comprises the base of the typical point-bar sequence. In shallower water the point bar is subjected to less rigorous currents and receives finer sediments.

The channel-fill facies, in contrast to the point bar facies, was deposited as an infilling--a "plug" --in a partially or totally abandoned river channel. (Such abandonment usually takes place when meander loops are cut off during floods).

Finally, the cutoff-fill facies represents an infilled "chute" which was cut by the river during the process of bypassing a meander loop.

Point Bar Facies

Cores from three wells, TW2, TD45, and TB8, display the primary and secondary rock properties which characterize the point bar facies.

TW2 is located in the western part of the area and overlies a light gray silty shale. The sequence of sedimentary structures, from horizontal at base to large scale crossbeds dipping at 20 degrees (at subsurface depths of 130 and 108 feet) to rippled laminae at the top, is typical of a sequence deposited by the fluvial regime (Figure 7). The decrease upward in grain size (Figure 7) indicates that there was an overall decrease in flow regime upward which is typical of most fluvial deposits.

The composition of the sandstone is 50 percent quartz, 40 percent matrix, and 10 percent rock fragments and feldspar. This composition is that of an immature sandstone and is also indicative of a possible fluvial origin (Figure 7). The lowermost portion of the sandstone (subsurface depths of 155 to 167) contains a 3-foot conglomerate and a medium grained sandstone suggestive of channel-lag pebbles and coarser sandstones common in the basal portions of fluvial deposits. The gamma ray log indicates that siltstones and shales overlie the TW2 sandstone sequence.

The 60-foot sandstone sequence in TW2 displays all the characteristics of a fluvial point bar. Plots of porosity and permeability (Figure 8) show the position of the sandstone body and are useful in contrasting the point bar facies with other facies discussed later.

Rock properties of cored intervals in TD45 (Figures 9 and 10) and TB8 (Figures 11 and 12) are

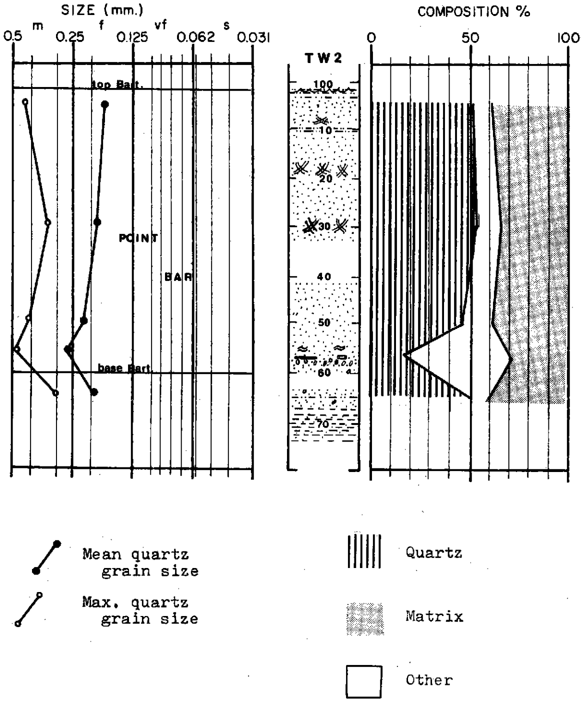


Figure 7. Grain size and composition of Bartlesville Sandstone in cored interval TW2. See Appendix A for rock type and sedimentary structure symbols.

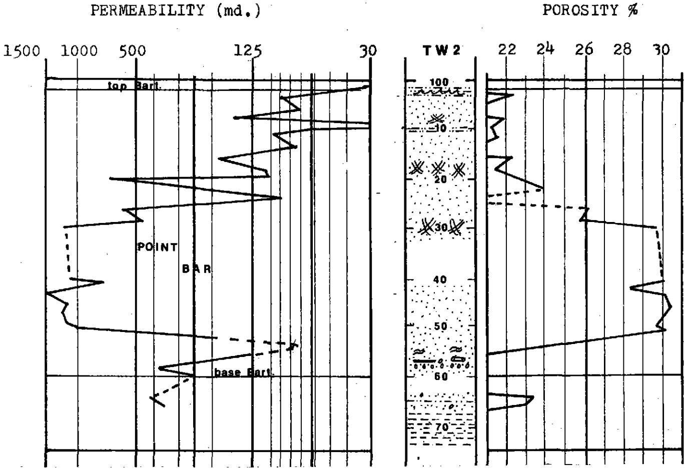


Figure 8. Permeability and porosity of Bartlesville Sandstone in cored interval TW2. See Appendix A for rock type and sedimentary structure symbols.

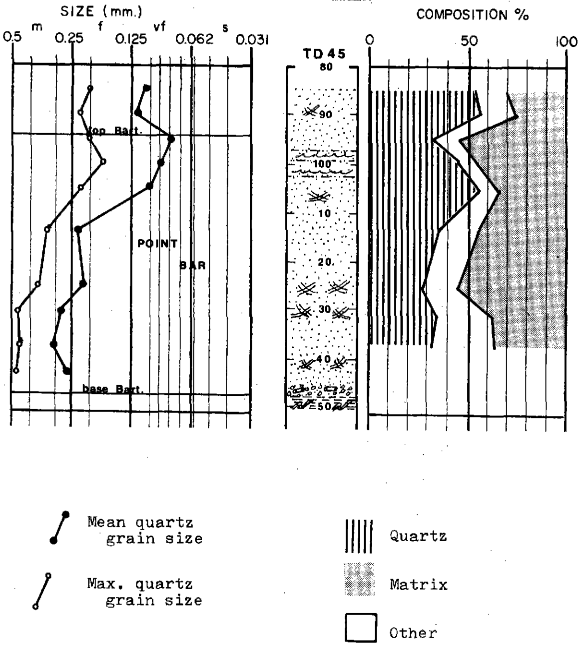


Figure 9. Grain size and composition of Bartlesville Sandstone in cored interval TD45.

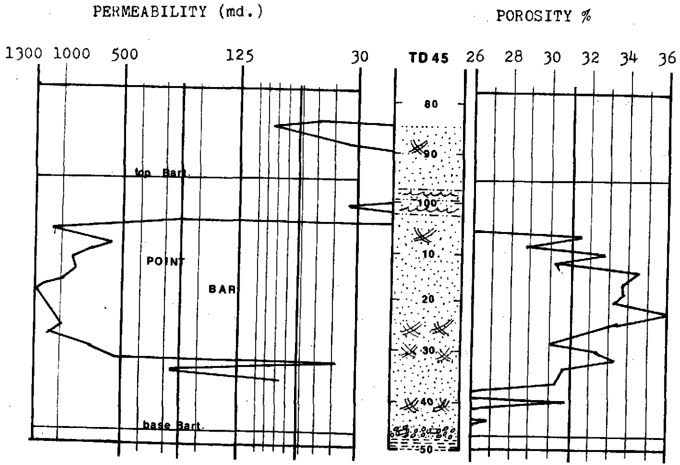


Figure 10. Permeability and porosity of Bartlesville Sandstone in cored interval TD45.

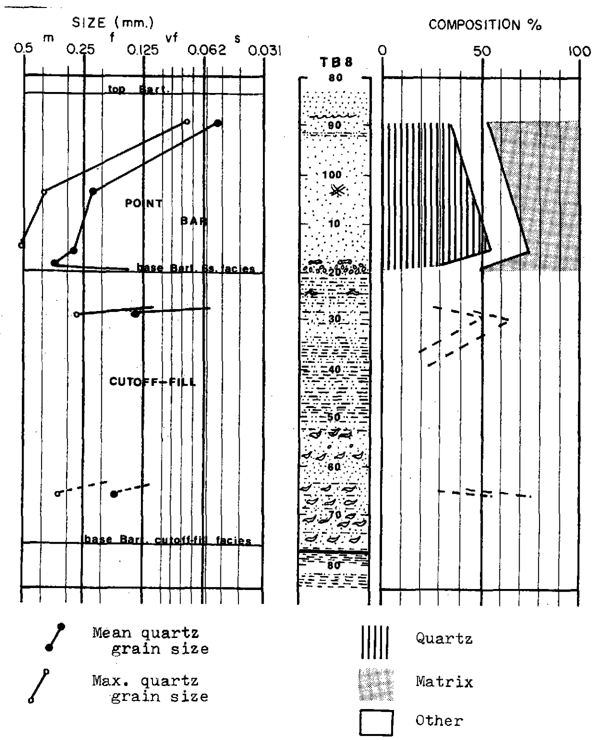


Figure 11. Grain size and composition of Bartlesville Sandstone in cored interval TB8.

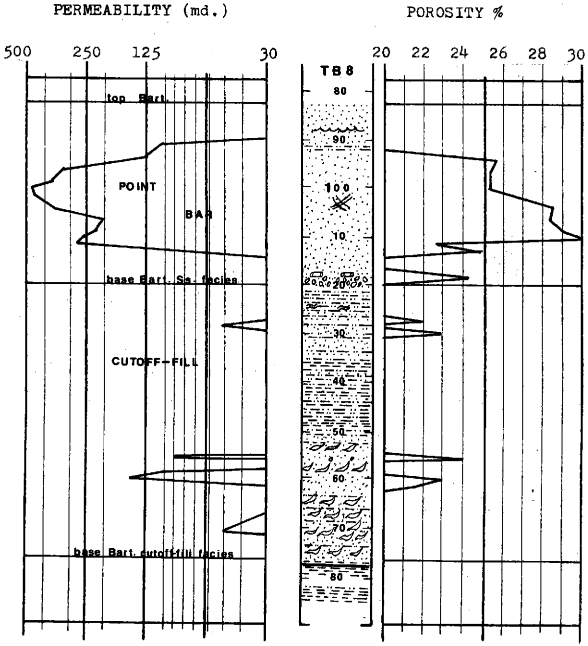


Figure 12. Permeability and porosity of Bartlesville Sandstone in cored interval TB8.

very similar to the sandstone sequence of TW2. The sandstone in TD45 and TB8 is 45 feet thick and 35 feet thick, respectively. It shows the point bar facies. Continuity of the point bar facies, in adjacent wells between these three cored intervals, was established by gamma ray logs and plots of porosity and permeability. These plots of adjacent wells showed the same overall character as the porosity and permeability of cored intervals TW2, TD45, and TB8 (Figures 8, 10, and 12 respectively).

Channel-Fill Facies

Cores from two wells, TS4 and TW1, display characteristics of the channel-fill facies, which consists of interbedded, fine-grained sandstones, siltstones, and shales. These wells are located in the eastern portion of the Chetopa area where the fluvial channel that deposited the point bar facies was located.

TS4 consists of a lower 30-foot interval of alternating dark shales and siltstones (Figure 13). The shales and siltstones contain red-brown shale laminae scattered throughout suggestive of an annual or varve type deposit. These sediments were deposited by a low flow regime.

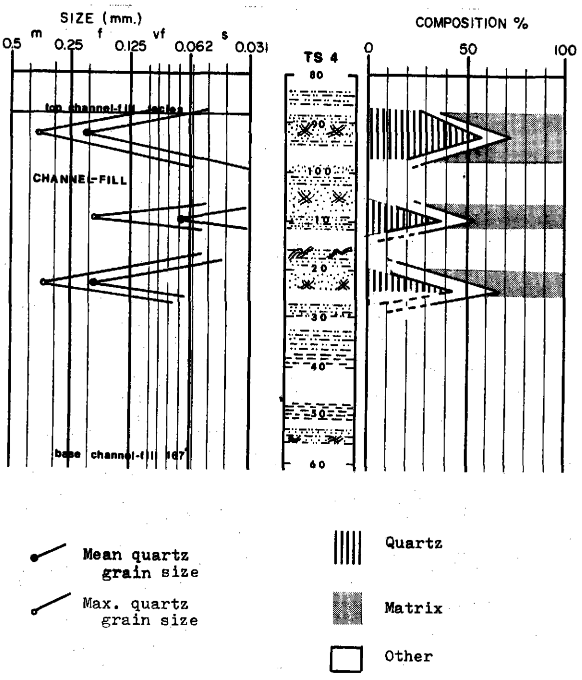


Figure 13. Grain size and composition of channel-fill facies in cored interval TS4.

Overlying this lower interval is a 48-foot sequence of alternating 1/2 to 5-foot thick sandstones and 1 to 5-foot thick siltstones (Figure 13). The sandstones are crossbedded with crossbed dips up to 15 degrees but mostly 5 to 10 degrees. The thin sandstones range from fine- to very fine-grained and grade upward into siltstones. The red-brown shale laminae are present in the siltstones as well as some very fine-grained sandstone laminae. Laminae vary from contorted to rippled in the sandstones and siltstones.

Constituent composition varies in the sandstones with samples containing from 55 to 35 percent quartz with increasing matrix content corresponding to decreasing quartz content. Little variation was found in the amount of rock fragments and feldspars (Figure 13).

Essentially all of core TS4 was deposited as fill in a fluvial channel. When the meander channel was abandoned it was partially filled with fine sediments (lower 30-foot interval). However, the alternating thin cross-bedded sandstones and thin siltstones that make up the upper 48-foot sequence indicate that minor episodes of return-to-flow through the channel took place. These episodes were not sufficient to completely rejuvenate the channel but did serve to transport sand and silt to fill it.

Figure 14 shows the variable nature of porosity and permeability in the channel-fill facies in contrast to the more continuous plots of the point bar facies.

TW1 (Figures 15 and 16) shows the channel-fill facies also. Adjacent wells, showing similar gamma ray logs and porosity and permeability plots to those of TS4 and TW1 (Figures 14 and 15), served to delineate the extent of the channel-fill facies in the Chetopa area. This facies is limited in extent and was deposited lateral to the point bar facies.

Cutoff-Fill Facies

The cutoff-fill facies is recognized in the lower 55 feet of cored interval TB8 (Figure 11, p. 29). It underlies a narrow portion of the eastern end of the point bar as interpreted from gamma ray logs of wells adjacent to TB8.

The lower 25 feet of the interval is a sandy, shale-clast conglomerate consisting of 1- to 4-inch eroded shale fragments and "normal" sand grains (Figure 11, p. 29). Most of the shale clasts are

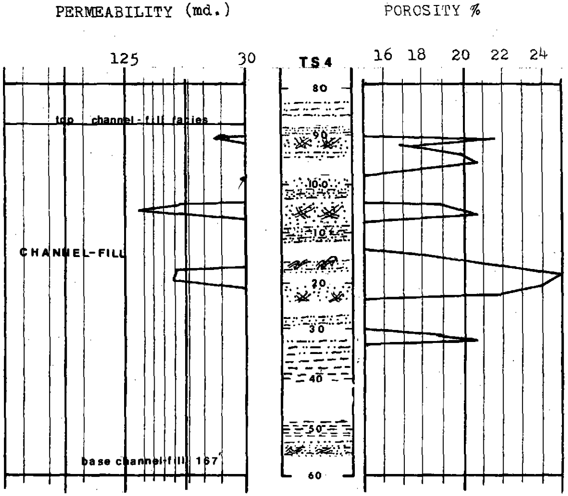


Figure 14. Permeability and porosity of channel-fill facies in cored interval TS4.

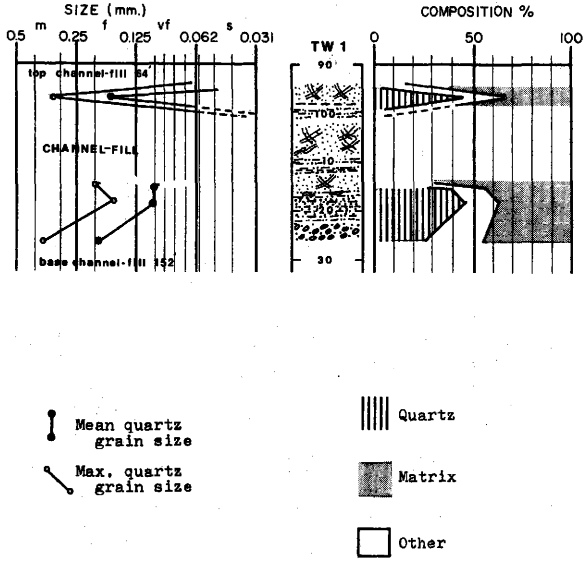


Figure 15. Grain size and composition of channel-fill facies in cored interval TW1.

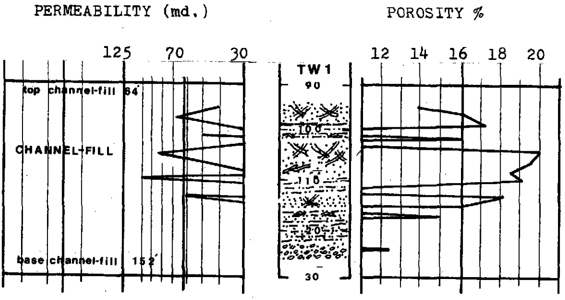


Figure 16. Permeability and porosity of channel-fill facies in cored interval TW1.

contorted and lenticular. Perhaps they were soft sediment at the time they were incorporated into the sand. Several thin siltstone beds and some siltstone laminae are present in this lower sequence.

Overlying this shale-clast conglomerate is an 18-foot siltstone with alternating sandstone and red-brown shale laminae. Rippled laminae and fine sediments that occur in this in interval, suggest that deposition took place in the lower flow regime. A 6-foot silty sandstone,and a 7-foot siltstone overlie the 18-foot unit and complete the cutoff-fill facies in TB8.

This lower 55-foot interval of TB8 probably represents an old filled cutoff. As the point bar was forming, a cutoff channel attempted to form through a low swale across the narrow end of the point bar but it failed to maintain itself. The sandy conglomerate was formed by the initial erosive action in the cutoff channel and by later deposition when flow returned to the original channel. The cutoff was eventually filled by the sands and silts deposited over the shale-clast conglomerate. These fine sediments were deposited at times of flood and flow across the top of the point bar. The point bar facies of TB8 was subsequently deposited as the meander migrated over the filled cutoff.

Morphology of the Sedimentary Body

Figure 17 is a sandstone isopach map for the Bartlesville Sandstone interval. It displays the typical curvilinear form of a fluvial point bar. This morphology may indicate that a large migrating, meandering channel, was moving laterally west to east and deposited the Bartlesville Sandstone. The three cored wells which penetrated the point bar facies (TW2, TD45, and TB8) lie within the main point bar sandstone body but the channel-fill cores (TS4 and TW1) are located adjacent to the body where the fluvial channel was located.

If the thick sandstones represent point bars an arcuate pattern for the sandstone body should be present but there is not sufficient subsurface control to contour the typical arcuate form for a point bar.

If the Bartlesville was deposited within a meander belt, then certain measurements should conform to measurements of modern rivers. From figure 18, the general form of the river channel meander can be estimated rather accurately. For this Bartlesville channel in the Chetopa area the radius of meander curvature, r, is equal to 2,000 feet and the half-length of the meander loop, L/2, is equal to 6,000

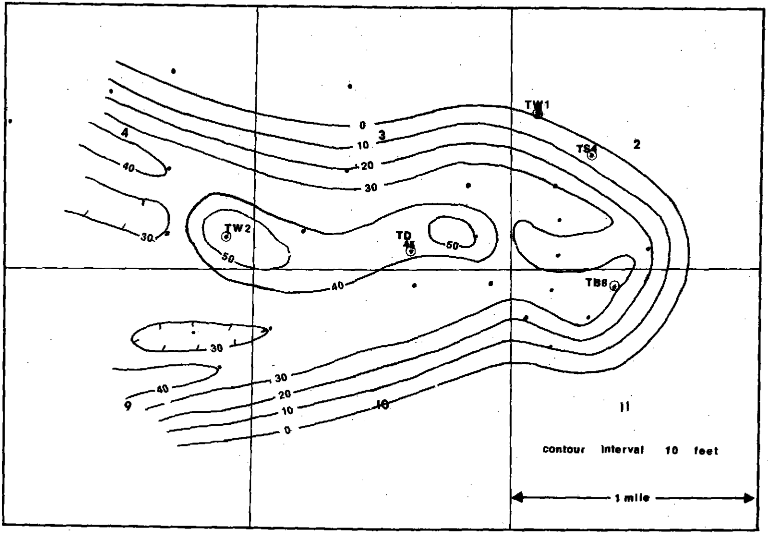


Figure 17. Bartlesville Sandstone isopach map, showing location of five cored wells used in this study (circled wells).

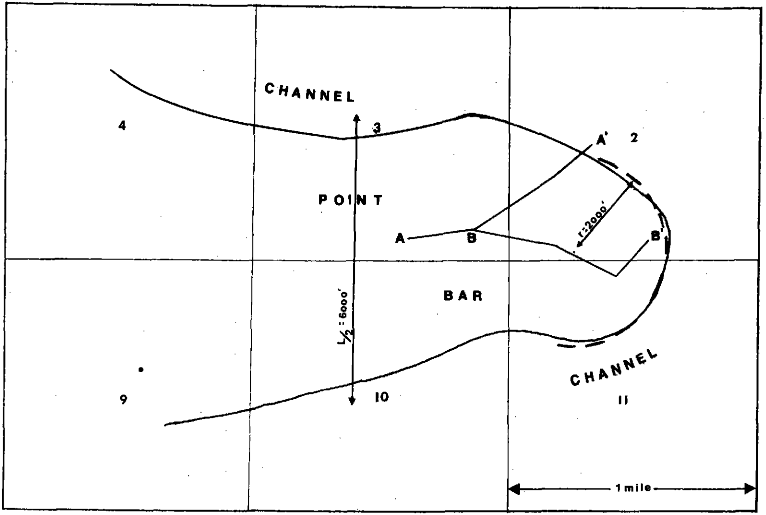


Figure 18. Paleogeographic map based on subsurface control with meander parameters: mean radius of curvature, r, and half-length of the meander, L/2, indicated.

feet for a total meander length, L, of 12,000 feet (Figure 18). It is very interesting that these measurements agree well with measurements of modern river meanders (Figure 19) made by Leopold and Wolman (1960). This is further evidence that the Bartlesville channel has a typical fluvial meander form. Based on a meander length of 12,000 feet, the Bartlesville channel was probably around 1,000 feet wide in the Chetopa area.

The relationship of this rather narrow fluvial channel-fill facies to the larger point bar sandstone facies can be seen in cross section A-A' (Figure 20) constructed by correlation of gamma ray logs. A portion of the cutoff-fill facies that underlies the eastern end of the point bar is shown in cross section B-B' (Figure 21).

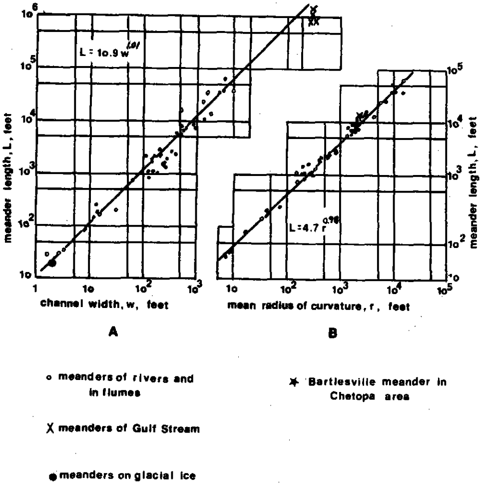


Figure 19. Channel and meander parameters for modern rivers with comparison to Bartlesville meander. After Leopold and Wolman, 1960 (Fig. 2).

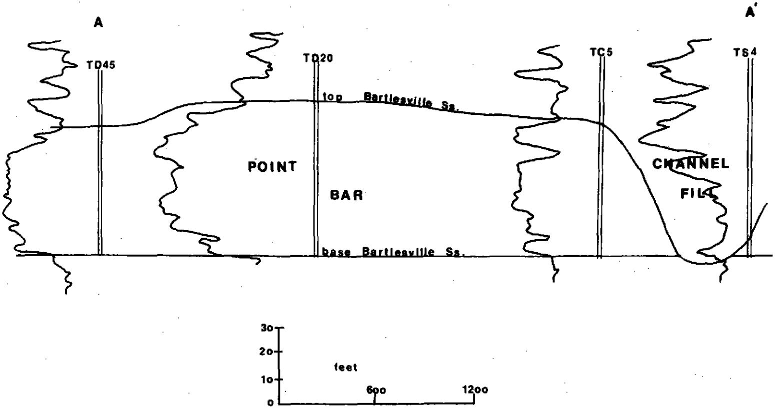


Figure 20. Interpretive cross section A-A', from gamma ray logs of indicated wells, through point bar and channel-fill facies.

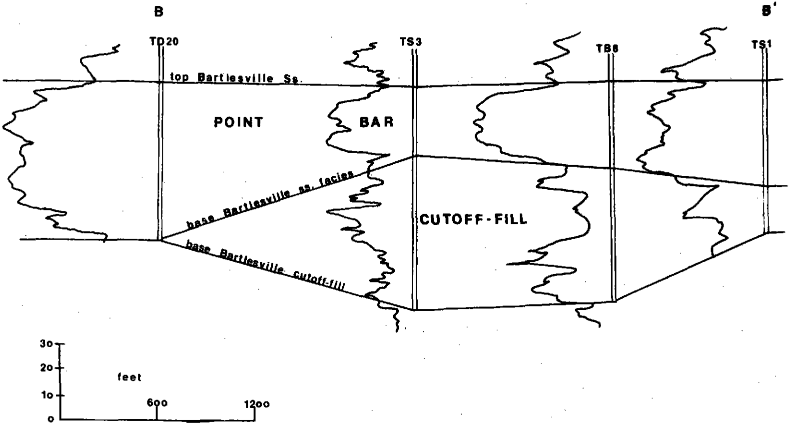


Figure 21. Interpretive cross section B-B', from gamma ray logs of indicated wells, through point bar and cutoff-fill facies.

CHAPTER VI

CONCLUSIONS

The variations in the sedimentary structures in the Bartlesville Sandstone (crossbeds at the base to rippled laminae at the top), the channel-lag pebbles at the base of the sedimentary sequence and a decrease in grain size upward, along with the moderate quartz composition of the sandstone are all common characteristics of fluvial deposits. The curvilinear, meandering morphology of the Bartlesville Sandstone also suggests a fluvial origin.

The interpretations in this study have been based mainly on primary rock properties observed in cores. Porosity and permeability, secondary rock properties, and gamma ray logs aided in correlating facies between wells in the area.

The Bartlesville Sandstone in the Chetopa area developed as a point bar of a large river located in the lower alluvial valley or upper deltaic plain on the coastal plain of the McAlester Basin. It is part of the fluvial portion of the Bartlesville depositional system that developed in Kansas and Oklahoma during Middle Pennsylvanian time. As an overall marine transgression out of the McAlester Basin took place, there was a progradation of a large delta on the northeastern Oklahoma shelf (Visher, 1971). The fluvial system associated with this delta had developed in southeastern and eastern Kansas. Probable source areas for this depositional system lay to the north in the midcontinent and possibly on the Nemaha Ridge to the west.

The marine transgression continued and shelf deposition of shales took place over the Bartlesville Sandstone. Cyclic deposits and coals indicate that periodic emergence took place in late Desmoinsian time. It was on this type of periodically emergent-submergent shelf that the Bartlesville depositional system was able to develop during the Middle Pennsylvanian marine transgression.

Further studies on depositional environments need to be done on the Bartlesville Sandstone. Some studies have indicated that early Desmoinsian sandstones in Kansas originated as offshore bars (Bass, 1936; Branson, 1968). These sandstones are also called Bartlesville but probably represent units at a different stratigraphic horizon than the sandstone in the Chetopa area. The lenticularity and discontinuity of the sandstones in the early Desmoinsian rocks of Kansas will necessitate careful stratigraphic work in conjunction with the interpretations of depositional environment. These additional investigations will reveal more about the Bartlesville depositional system as well as elucidate the paleogeography of Kansas during Middle Pennsylvanian time.

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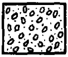
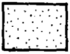
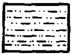
APPENDIX A

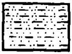
SYMBOLS FOR DESCRIBED CORES

ROCK TYPE

 conglomerate

 sandstone

 siltstone

 siltstone with sand laminae

 claystone or shale

 no core available

STRUCTURES

 cross-bedding

 ripple lamination

 convulute lamination

 wavey lamination

ACCESSORIES

 carbonaceous matter

 petrified wood fragments

 contorted shale clasts

APPENDIX B

CORE DESCRIPTIONS

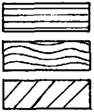
Format Used for Core Descriptions

Field
Well Name
Location
Formation Name - Age
Cored Interval (in feet)

Depth	Thickness	Description	Environment
			(Example)
Feet	Feet	Rock type, color, grain size, sorting dominant mineral, accessory minerals Primary sedimentary structures*	Upper point bar

*Sedimentary structure description:
Laminae less than 4 inches thick
Thin beds greater than 4 inches thick

Parallel Continuous

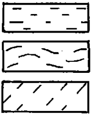


Even

Wavey

Inclined

Parallel Discontinuous

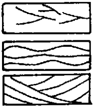


Nonparallel

Even

Wavey

Curved



Chetopa Field
TW2: Tenneco C. Wilson No. 2
Sec. 4-31S-21E Labette Co. Kansas
Bartlesville Sandstone Pennsylvanian
Core 102-175 feet

Depth	Thickness	Description	Environment
102-104	2	Sandstone, light brown to black (hydrocarbon stained), fine grained, moderately sorted, quartzose Laminae alternating sandstone and siltstone at top nonparallel, discontinuous wavey; small clay balls 1/4" or less at 103'; sandstone laminae at 104' even parallel to indistinct.	Upper point bar
104-129	25	Sandstone, black (hydrocarbon stained), fine to medium grained downward, well sorted, quartzose Sandstone laminae parallel continuous inclined 10° from 106-109'; siltstone laminae interval at 109' at least 6" thick; sandstone laminae even parallel at 110-117'; laminae inclined parallel 20° 117-120'; few clay balls 1/2" or less at 117-122'; laminae even parallel to indistinct 120-129'.	Point bar

Depth	Thickness	Description	Environment
129-155	26	Sandstone, dark brown (hydrocarbon stained), fine to medium grained downward, moderately sorted, quartzose, silty (missing cores 133-141 but good match of sand at 131 and 142) Sandstone laminae parallel inclined 15-20° at 129-130'; laminae 141-154 parallel even.	Point bar
155-158	3	Conglomerate, gray, medium grained sand, poorly sorted, quartzose, carbonaceous, with clay pebbles up to 3/4" Laminae wavey parallel with clay pebbles oriented horizontally.	Lower point bar
158-167	9	Sandstone, brown, medium grained, poorly sorted, quartzose, with few scattered pebbles Laminae indistinct, pebbles horizontally oriented, silt laminae 1 1/2" thick at 166'.	Lower point bar
168-175	7	Shale, light gray, friable, sandy Laminae even parallel discontinuous; few sandstone laminae present.	Underlying shale

Chetopa Field
TD45: Tenneco Roy Davis No. 45
Sec. 3-31S-21E Labette Co. Kansas
Bartlesville Sandstone Pennsylvanian
Core 85-150 feet

Depth	Thickness	Description	Environment
85-91	6	Sandstone, brown, very fine grained, moderately sorted, quartzose Laminae indistinct at top to nonparallel wavey to parallel inclined about 10° at base.	Upper point bar
91-106	15	Sandstone, light gray, very fine grained, moderately sorted, quartzose Alternating laminae of light gray to dark gray siltstone at top becoming sandy at base; parallel continuous even laminae at top to wavey to contorted at base.	Point bar
106-118	12	Sandstone, black (hydrocarbon stained), very fine to fine grained (downward), moderately sorted quartzose, becomes silty at base Laminae parallel continuous inclined at 10° at top to indistinct at base.	Point bar

Depth	Thickness	Description	Environment
118-137	19	Sandstone, brown to gray, fine to medium grained (downward), moderately sorted, quartzose, clay and carbonaceous stringers Laminae indistinct to parallel continuous even to parallel continuous inclined about 15° at 135'.	Point bar
137-143	6	Sandstone, light gray, medium grained, well sorted, quartzose, little carbonaceous material Laminae nonparallel even at 20°.	Lower point bar
143-146	3	Sandstone, gray, medium grained, moderately sorted, quartzose, with abundant silicified wood fragments Laminae indistinct.	Base point bar
146-150	4	Shale, gray, with brown contorted areas Laminae contorted to indistinct becoming parallel.	Shale underlying fluvial point bar

Chetopa Field
TB8: Tenneco Harry Bradley No. 8
Sec. 11-31S-21E Labette Co. Kansas
Bartlesville Sandstone Pennsylvanian
Core 83-185 feet

Depth	Thickness	Description	Environment
83-85	2	Sandstone, brown, very fine grained, well sorted, quartzose Laminae parallel continuous wavey at top to parallel discontinuous wavey with few clay balls at base.	Natural levee or over bank
85-87	2	Sandstone, gray, very fine grained, poorly sorted, quartzose, silty, becomes less silty at base Laminae parallel discontinuous even to nonparallel wavey to parallel inclined 10-15^{o} at base.	Natural levee or over bank
87-93	6	Sandstone, light gray to brown, very fine grained, well sorted, quartzose, with some silt stringers Laminae nonparallel wavey at top, alternating siltstone and sandstone laminae parallel continuous even at base.	Upper point bar

Depth	Thickness	Description	Environment
93-117	24	Sandstone, black (hydrocarbon stained), very fine to medium grained (downward), moderately sorted, quartzose, some silt Laminae indistinct to parallel continuous even to parallel continuous inclined 15° at 103' to parallel continuous even at base.	Point bar
117-120	3	Sandstone, light brown, medium grained, poorly sorted, quartzose, with clay pebbles, silicified wood fragments, and carbonaceous material Laminae parallel continuous even to parallel continuous inclined 10°.	Base point bar
120-127	7	Siltstone, brown to gray, with laminae of very fine sand Sandstone laminae parallel discontinuous even to convolute laminae at 124'; sandstone laminae becomes continuous and thicker at base.	Cutoff fill
127-133	6	Sandstone, brown, fine grained, moderately sorted, quartzose, with siltstone laminae	Cutoff fill

Depth	Thickness	Description	Environment
		Sandstone laminae non-parallel wavey; siltstone laminae 1/2"-3" thick throughout sandstone.	
133-151	18	Siltstone, dark gray, with alternating sandstone laminae and claystone laminae	Cutoff fill
		Siltstone laminae parallel continuous even; sandstone laminae non-parallel wavey from 1/16" - 1/2" thick; sandstone laminae decrease and siltstone and claystone laminae increase below 143 feet.	
151-154	3	Sandstone, gray-white, fine grained, well sorted, quartzose, with abundant siltstone and claystone clasts	Cutoff fill
		Clasts of siltstone and claystone are from 1/16" - 1 1/2" thick, lense shaped to pod shaped and contorted; laminae of claystone parallel continuous even up to 2" thick.	
154-156	2	Sandstone, brown, very fine grained, moderately sorted, quartzose, with few siltstone and claystone pebbles.	Cutoff fill

Depth	Thickness	Description	Environment
156-159	3	Sandstone, gray-white, fine grained, well sorted, quartzose, with abundant siltstone and claystone clasts Clasts of siltstone and claystone are from 1/16" - 2" thick, lense shaped to pod shaped and contorted.	Cutoff fill
159-161	2	Sandstone, brown, very fine grained, moderately sorted, quartzose, with some silt Laminae parallel discontinuous even.	Cutoff fill
161-173	12	Sandstone, gray-white, fine grained, well sorted, quartzose, with abundant siltstone and claystone clasts Clasts of siltstone and claystone are 1" - 4" thick, lense shaped to pod shaped and contorted; Siltstone laminae to thin beds at 163', 166', and 168'; laminae in some clasts contorted.	Cutoff fill
173-175.5	2.5	Siltstone, dark gray, with abundant claystone laminae, become sandy at base with silt pebbles and large siltstone clasts.	Base cutoff fill

Depth	Thickness	Description	Environment
175.5-176	.5	Coal, black Thin laminae even parallel.	
176-179	3	Sandstone, brown, very fine grained, poorly sorted, clayey and carbonaceous Laminae clayey nonparallel wavey.	
179-182	3	No sample	
182-185	3	Shale, dark gray, sandy Laminae nonparallel wavey to parallel discontinuous wavey.	

Chetopa Field
TS4: Tenneco R. Swanwick No. 4
Sec. 2-35S-21E Labette Co. Kansas
Bartlesville Sandstone Pennsylvanian
Core 82-157 feet

Depth	Thickness	Description	Environment
82-85	3	Siltstone, gray, with some sandstone laminae Laminae at top non-parallel wavey to contorted, stringers of sandstone at base.	Channel fill
85-88	3	No sample.	
88-90	2	Siltstone, gray with few sandstone laminae, claystone laminae Sandstone laminae non-parallel wavey to parallel continuous inclined 5° at base.	Channel fill
90-93	3	Sandstone, brown, fine grained, moderately sorted, quartzose, silty, few clay pebbles Laminae parallel continuous even to inclined 10° at top; laminae indistinct to parallel continuous wavey at base.	Channel fill

Depth	Thickness	Description	Environment
93-94	1	Siltstone, gray, with some very fine sandstone laminae Laminae parallel continuous even to wavey.	Channel fill
94-97	3	No sample.	
97-99	2	Sandstone, brown, fine grained, moderately sorted, quartzose, with clay laminae Laminae nonparallel wavey to parallel discontinuous inclined 10°.	Channel fill
99-104	5	Siltstone, gray, with sandstone laminae Sandstone laminae nonparallel discontinuous wavey to contorted; sandstone laminae increase downward and become thicker.	Channel fill
104-109	5	Sandstone, brown, fine grained, moderately sorted, quartzose, with two siltstone beds 6" thick with sandstone laminae Laminae parallel continuous even to inclined 15° at top to indistinct at base.	Channel fill

Depth	Thickness	Description	Environment
109-112	3	Siltstone, gray with sandstone laminae Laminae very thin parallel continuous even to nonparallel wavey.	Channel fill
112-115	3	No sample.	
115-117.5	2.5	Siltstone, gray with sandstone laminae Laminae contorted to parallel continuous even to inclined 5° to contorted at base.	Channel fill
117.5-118	.5	Sandstone, brown fine grained, poorly sorted, quartzose with clay and silt pebbles up to 1/2" in size.	Channel fill
118-121	3	No sample.	
121-124	3	Sandstone, brown, fine grained, moderately sorted, quartzose, silty Laminae indistinct to parallel continuous inclined 15°.	Channel fill
124-127	3	No sample.	

Depth	Thickness	Description	Environment
127-130	3	Siltstone, gray, with sandstone laminae Laminae nonparallel wavey to contorted at base.	Channel fill
130-133	3	No sample.	
133-137	4	Siltstone, alternating light gray, dark gray laminae Laminae nonparallel wavey becoming parallel continuous even at base.	Channel fill
137-139	2	Shale, black, with some red-brown clay laminae Laminae thin parallel continuous even.	Channel fill
139-148	9	No sample.	
148-151	3	Shale, black, silty at base Laminae parallel continuous even.	Channel fill
151-153	2	No sample.	

Depth	Thickness	Description	Environment
153-157	4	Siltstone, gray, with sandstone laminae and red-brown claystone laminae Laminae parallel continuous even with sandstone laminae discontinuous wavey.	Channel fill

Chetopa Field
TW1: Tenneco R. D. Watts A-1
Sec. 2-35S-21E Labette Co. Kansas
Bartlesville Sandstone Pennsylvanian
Core 95-126.5 feet

Depth	Thickness	Description	Environment
95-100	5	Sandstone, brown, very fine to fine grained, moderately sorted, quartzose, with few clay balls Laminae parallel continuous inclined 15° to parallel discontinuous; claystone laminae at 98' at least 2" thick.	Channel fill
100-103	3	Siltstone, gray with very fine grained sandstone laminae Laminae parallel continuous even to nonparallel wavey.	Channel fill
103-112	9	Sandstone, brown, very fine grained, moderately sorted, quartzose Laminae nonparallel wavey to parallel inclined 15° at 104-106'; laminae become contorted in middle of unit to parallel discontinuous even at base.	Channel fill

Depth	Thickness	Description	Environment
112-113	1	Siltstone, gray, with few sandstone laminae and red-brown claystone laminae at 112' Laminae parallel continuous even; sandstone laminae discontinuous.	Channel fill
113-115	2	Sandstone, brown, very fine grained, moderately sorted, quartzose, few clay pebbles Laminae parallel continuous inclined 15°.	Channel fill
115-116	1	Siltstone, gray, with sandstone laminae and red-brown claystone laminae Laminae parallel discontinuous wavey.	Channel fill
116-117	1	Sandstone, brown, very fine grained, moderately sorted, quartzose Laminae parallel continuous inclined 5° at top to indistinct at base.	Channel fill
117-124	7	Siltstone, gray, with very fine grained sandstone laminae in upper 3' of unit Laminae discontinuous to contorted.	Channel fill

Depth	Thickness	Description	Environment
124-126.5	2.5	Conglomerate, brown, poorly sorted, fine grained sand with many clay and chert pebbles from 1/4" - 1/2".	Channel fill

VITA

Name: Charles Truman Lars Johnson

Birthdate: 3 June 1948

Birthplace: Savannah, Georgia

Parents: Mr. and Mrs. Harry Folke Johnson

Education: Augustana College
Rock Island, Illinois
1966-1968

Texas A&M University
College Station, Texas
B.S., 1970, Geology

Permanent Address: 2332 Salcedo Avenue
Savannah, Georgia

The typist for this thesis was Mrs. Kathy Robinson.