

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

CENTRAL KANSAS UPLIFT - CAMBRIDGE ARCH PROVINCE  
OIL AND GAS PLAY SUMMARY

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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## TABLE OF CONTENTS

	page
Introduction _____	1
Geologic history _____	1
Source of petroleum _____	4
Exploration history _____	4
Play descriptions _____	6
Arbuckle play _____	6
Mississippian Limestone _____	9
Pennsylvanian play _____	9
Permian carbonates _____	11
Summary _____	11
Selected references _____	12
Appendix _____	14
A. Significant discoveries 1963-1983 _____	15

## FIGURES

1. Index map of the Central Kansas uplift-Cambridge arch province _____	2
2. Generalized composite stratigraphic section of rocks present in Kansas _____	3
3. Diagrammatic cross section across Central Kansas _____	5
4. Index map of Central Kansas showing Arbuckle oil and gas fields _____	8
5. Index map of Kansas showing locations of Lansing-Kansas City Group oil and gas fields _____	10

## TABLES

1. Generalized play summary, Central Kansas uplift-Cambridge arch province _____	11
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## INTRODUCTION

The Central Kansas uplift of central Kansas and the Cambridge arch area to the northwest in Kansas and Nebraska comprise American Association of Petroleum Geologists (AAPG) province #117 (fig. 1). Approximately 1.6 pct of the 37,000 mi<sup>2</sup> area of this province, 606 mi<sup>2</sup>, is federally controlled land.

Province oil and gas production is primarily from Paleozoic limestones and dolomites, with Paleozoic sandstone production. Present in this province are total estimated remaining reserves and resources of over 500 million barrels of oil (MMBO) and 245 billion cubic feet (BCF) of non-associated gas and a total production of over 2.6 BBO and 250 BCFG (compiled from Petroleum Information Corporation's (PI) Petroleum Data System (PDS) computer database, 1981). The Kansas portion of this province is one of the most heavily drilled areas of the United States.

The objective of this report is to assess the potential for developing undiscovered million-barrel equivalent oil and gas fields in petroleum plays of the Central Kansas uplift-Cambridge arch province. Million-barrel equivalent fields are defined as those containing recoverable reserves of 1 MMBO or greater or 6 BCFG or greater. Producing and potentially producing formations are grouped into plays, with the favorabilities of determining future million-barrel fields assigned to each play.

Reserve and resource favorabilities are assigned by analysis of petroleum data derived from several computer databases. These databases are the Petroleum Information Well History Control System (WHCS) drill-hole information file, the PI Petroleum Data System (PDS) field production history file, and the Nehring database, compiled by NRG Associates, which contains current and estimated ultimate production, and reserve information by field.

Contained in the WHCS database are drill hole classification codes (oil, gas, dry hole, etc.), penetrated and producing formations, and hydrocarbon show data. The PDS and Nehring databases list oil and gas field production data through 1981. This information exists for all fields in the province in the case of the PDS file and for all fields equal to or greater than one million-barrels equivalent for the Nehring file.

## GEOLOGIC HISTORY

The geologic history of Central Kansas and Nebraska is one of repeated marine transgressions and regressions. Thick marine carbonate and cyclic carbonate-clastic sequences were deposited during Paleozoic time. Shown on figure 2 is a generalized stratigraphic column of rocks present in Kansas. This column is generally applicable to producing formations present in the Nebraska part of the province as well. Cretaceous marine sandstones, limestones, and shales rest unconformably on Permian strata over most of the province. Paleozoic and Mesozoic strata exhibit gentle (1/2 degree) dips away from major structures in the province, with dips increasing near the axes of these structures.

The major tectonic features of this province are the Central Kansas uplift and the Cambridge and Chadron arches (fig. 1). General

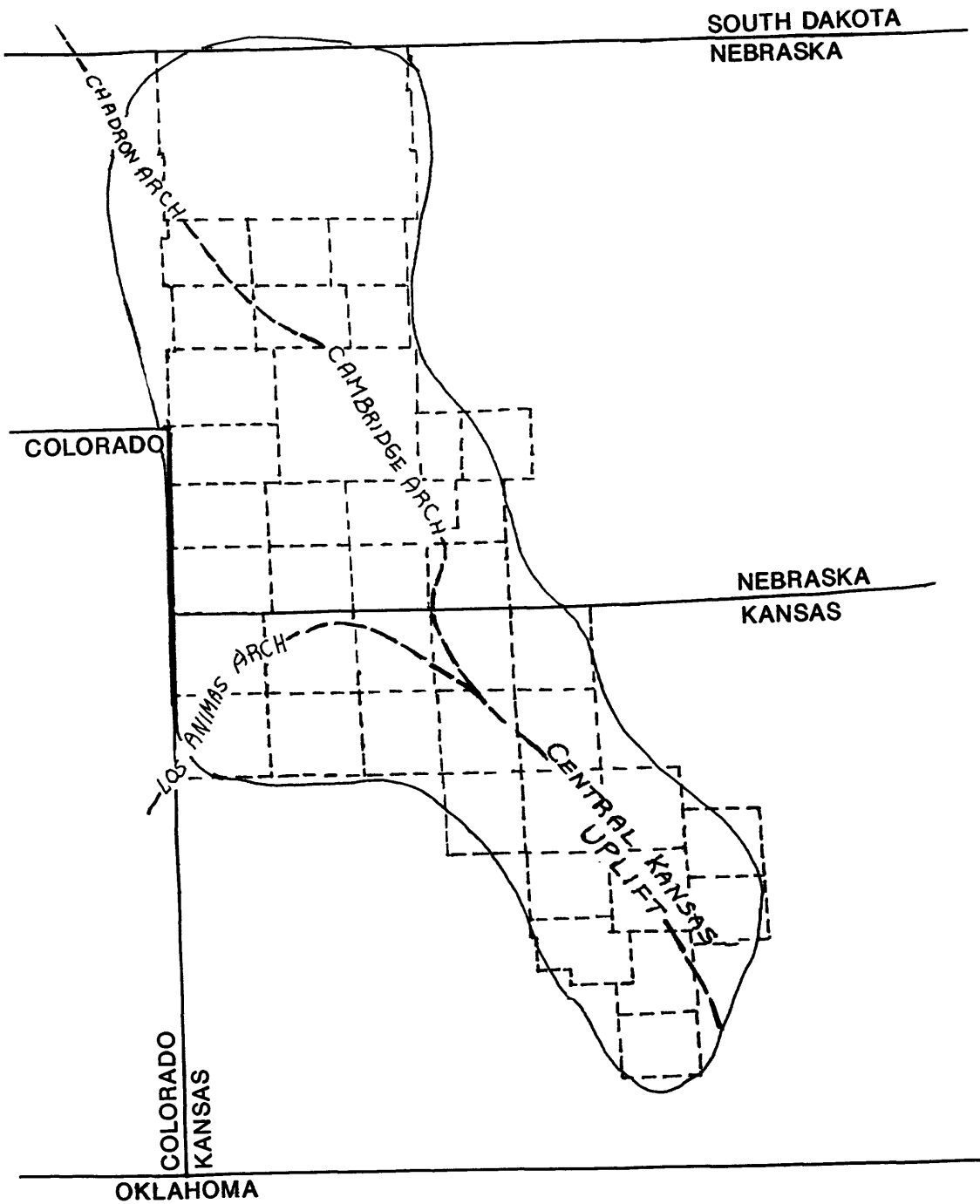


Figure 1. Index map of the Central Kansas uplift-Cambridge arch province showing tectonic uplifts in the province. The study area is shown as the solid line enclosing counties in the province.



stratigraphic and structural changes across the Central Kansas uplift are shown on figure 3. The large<sub>2</sub> northwest-trending anticlines cover an area of approximately 6,700 mi<sup>2</sup>. The Cambridge and Chadron arches are major structural features which are probably related to zones of weakness in the Precambrian basement. Repeated periods of uplift and erosion on the major structural features in the province had a profound influence on deposition and erosion during Paleozoic and Mesozoic time (Moore and Nelson, 1974). Current petroleum production for most plays is proximal and roughly parallel to these structures and associated faults and anticlines on the flanks. Prior to deposition of Pennsylvanian rocks, older beds were eroded from the Central Kansas uplift and the arches. Uplift during Atokan and Desmoinesian time resulted in onlap of the cyclic Pennsylvanian rocks. Porosity enhancement of Paleozoic strata occurred when influxes of fresher ground water entered the sediments exposed during uplift (Vinton, Moore, and Nelson, 1974). This porosity enhancement, combined with the formation of structural traps, are the primary reasons petroleum production is concentrated along the Kansas and southernmost Nebraska portions of the arch system.

#### Source of Petroleum

Walters (1958) believes that migration and emplacement of hydrocarbons into Paleozoic strata occurred during Permian time. He further states the hydrocarbons migrated from the Anadarko basin into central Kansas. Insufficient thermal maturation data was available to determine whether carbon-rich facies associated with Paleozoic plays may have generated hydrocarbons, however Paleozoic strata are generally accepted to be thermally immature (personal communication, Joseph R. Hatch, U.S.G.S., 1986).

Source beds for the Cretaceous Dakota Group were probably organic-rich Cretaceous marine shales of the Mowry, Graneros, Carlile, and Greenhorn (Clayton and Swetland, 1980). The location of the potential source rocks is the Denver basin in Colorado and possibly in the Wyoming part of the basin. Since Cretaceous rocks in the province are thermally immature, hydrocarbons would have migrated vertically and laterally from the west, or possibly from underlying Permian strata, into the sandstones and carbonates. Cretaceous rocks have very low potential for undiscovered million-barrel fields in the Central Kansas uplift-Cambridge arch province because of long migration distances and lack of effective stratigraphic trapping mechanisms. Evaluated in the Denver basin assessment are biogenic gas in the Niobrara Formation and reserves and resources for other Cretaceous formations located in Colorado, western Kansas, and southwestern Nebraska.

#### Exploration History

The Central Kansas uplift-Cambridge arch province has been explored and developed for more than 70 years. The first drill hole in the province was completed in 1915. This hole was dry but in 1919 oil was discovered, in Arbuckle Formation dolomites. Kansas is one of the most densely drilled areas in the United States (Watney and Paul, 1983), with over 87,000 drill holes in the 37,000 mi<sup>2</sup> Central Kansas uplift-Cambridge arch province alone.



Average Kansas well production is 4.25 BOPD; and 95 percent of the total oil produced from Kansas is from stripper wells. Stripper wells are defined as those that produce 10 or less barrels of oil per day. Stripper production contributed 68 percent of the 66 million barrels of oil produced in 1981, more than 45 million barrels of oil. Peak oil production occurred in 1956 with 124.5 MMBO (Watney and Paul, 1983).

The Central Kansas uplift-Cambridge arch province has produced more than 2.6 BBO and 250 BCFG (Petroleum Information's (PI) Petroleum Data System (PDS) database, 1981. Estimated total remaining reserves and resources of more than 500 MMBO and 245 BCFG are assigned to the province using computer-based reserve and resource calculations on data retrieved from the Petroleum Information Corp. PDS field database (to 12/1981).

Forty-seven percent of the original oil in place (OIP) in Kansas is from Ordovician rocks (mainly Arbuckle-Reagan with some Viola-Simpson). The Pennsylvanian play contributes 36 percent of the OIP (Lansing-Kansas City and Cherokee), with the remaining 17 percent OIP assigned to the Mississippian and the Permian (Watney and Paul, 1983). These OIP percentages are roughly applicable to the Central Kansas uplift area since most of the oil produced from these formations in Kansas is from this province.

Future exploration efforts may be concentrated on the axis and flanks of the Central Kansas uplift and the southernmost Cambridge arch. Most oil production in this province is from combination and structural traps and the arch and flanks provide the most favorable areas for trap formation and petroleum emplacement. Based on current production and discovery rates, limestones and sandstones of the Pennsylvanian cyclic sequences will probably be the primary exploration targets.

## PLAY DESCRIPTIONS

Formations are grouped into plays by similarities in trapping mechanisms, stratigraphy, or by age if the producing formation or formations have low production and potential. Two geologically-defined plays produce hydrocarbons in the Central Kansas uplift-Cambridge arch province. The Arbuckle and Pennsylvanian plays will be described briefly. Briefly described will be information on Permian and Mississippian age strata. These two groups were excluded from play analysis because of low potential for discovering million-barrel equivalent fields and low reserve and resource potential in the province. Pertinent Arbuckle and Pennsylvanian play analysis data is listed in table 1.

### The Arbuckle Play

Included in this play are Cambrian to Lower Ordovician age dolomites of the Eminence and Bonnetterre Formations of the Arbuckle Group, and the basal Reagan Sandstone unit of the Arbuckle. The Reagan Sandstone is sometimes called the Lamotte Sandstone. The Ordovician Viola Limestone and Simpson Sandstone are also included in this play, primarily because they are missing from most of the province and their low potential for discovery of million-barrel equivalent fields or further reserve and resource development does not warrant their separate analysis.



The Arbuckle Group is bounded by unconformities, with Precambrian granite at the base and middle Ordovician to Pennsylvanian age strata at the upper boundary. Where the Simpson Sandstone is present, it rests unconformably on Arbuckle dolomites.

Uplift during late Mississippian to early Pennsylvanian time resulted in erosion and enhanced porosity development for Arbuckle dolomites. The average porosity of producing dolomites is 12 pct. The time of hydrocarbon emplacement has been postulated by Walters (1958) to be Permian. He further states the source of hydrocarbons to be organic-rich rocks of the Anadarko basin.

The Arbuckle play produces mainly oil from depths of 3,200 to 4,400 feet. The Arbuckle is present over approximately 20,000 mi<sup>2</sup> in the province and is present in only the southernmost part of Nebraska. The Viola-Simpson is present only in the southern 6,500 mi<sup>2</sup> of the province.

The first Arbuckle field discovery was in 1919. Based on well classification identifier numbers, more than 97 percent of the Arbuckle play production is oil (PI's WHCS database, 1983). Over 1,400 million barrels of oil have been produced from Arbuckle dolomites and the Reagan Sandstone. The Viola-Simpson has produced over 114 million barrels of oil in western Kansas and 81.2 pct of the producing wells are designated oil wells. There is little Nebraska oil or gas production from this play. Illustrated on Figure 4 is the distribution of Arbuckle oil and gas fields in Central Kansas.

Trapping mechanisms are complex; traps are both stratigraphic and structural. As is shown on figure 4, Arbuckle fields are aligned northwest-southeast, roughly parallel to major structures. Much of the petroleum is produced from small structures proximal to the axis of the Central Kansas uplift. Porosity development within the dolomites is also an extremely important trapping mechanism, with hydrocarbon deposits occurring in updip porosity and permeability pinch-outs. Arbuckle dolomites may also produce from paleotopographic highs and from small structures isolated by discrete fault blocks, such as horsts and grabens. The Reagan Sandstone produces primarily from small structures, also proximal to the axis of the Central Kansas uplift. Trapping mechanisms for the Viola-Simpson are mainly structural with petroleum deposits occurring in anticlines and noses, however updip porosity and permeability pinchout is also an important trapping mechanism.

Future discovery of million-barrel equivalent oil and gas fields is limited in this play because of the moderate to extensive drilling density, and the low discovery rate of million-barrel fields. From 1963-1983 seven million-barrel Arbuckle and Reagan fields, with an estimated 17.4 MMBO total reserves, and one Simpson Sandstone discovery with 1.6 MMBO reserves were found (Nehring data, 1983). The Arbuckle and Reagan contained 26 pct of the fields discovered during this time period and 32 pct of the total reserves developed in the province. The Viola-Simpson contributed 3 pct of the total reserves for +1 MMBO fields during this time period (Nehring data, 1983).

Less than 2 pct of the Arbuckle play is on federally controlled land, approximately 160 mi<sup>2</sup>. For this reason the potential for discovering future million-barrel fields on federal lands is extremely limited. In addition, most of the 160 mi<sup>2</sup> of federal lands are in areas of low potential for developing significant Arbuckle play petroleum resources.

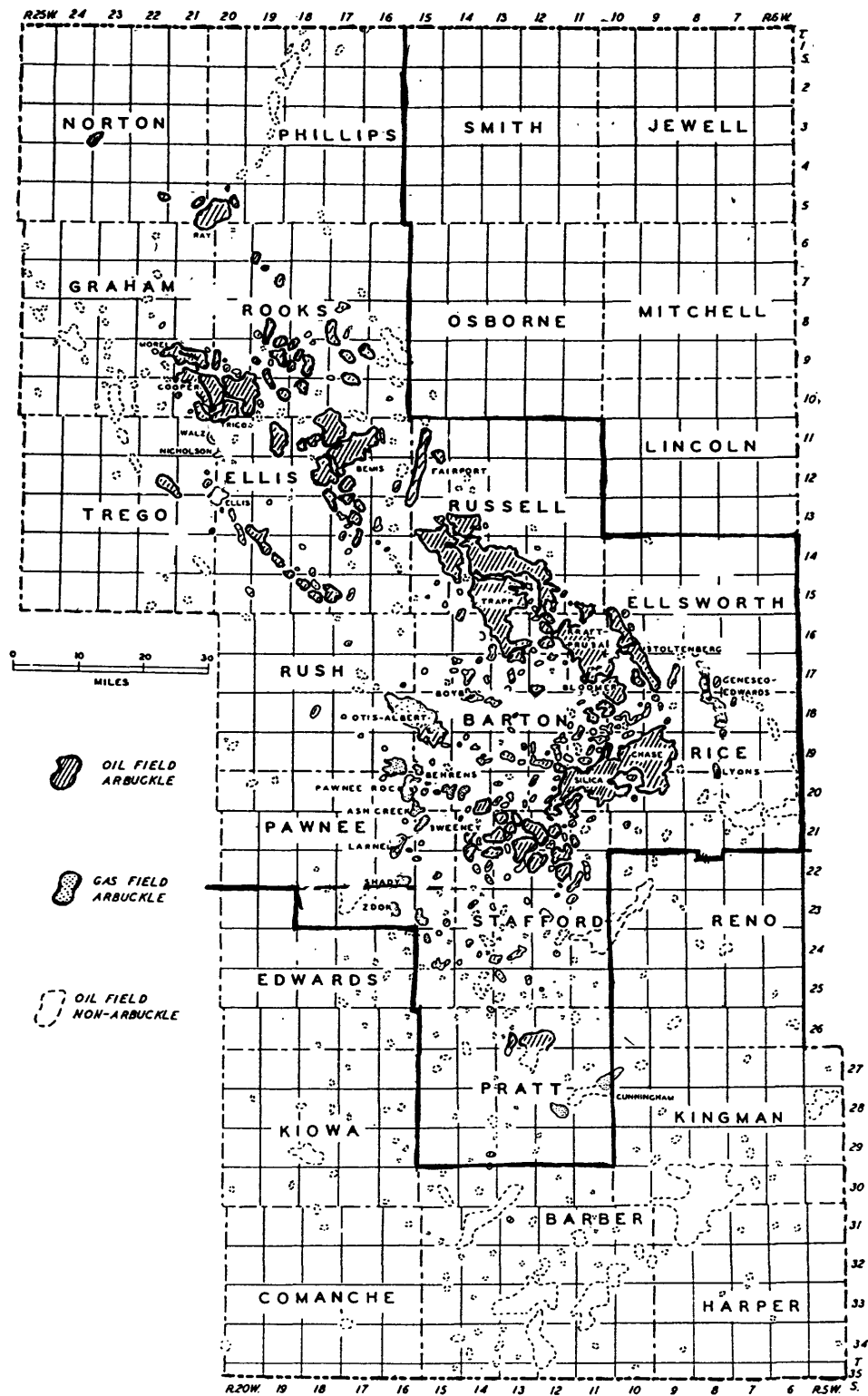


Figure 4. Index map of Central Kansas showing 1) the southeast third of the study area, 2) Arbuckle play oil and gas fields, and 3) non-Arbuckle oil and gas fields (Walters, 1958).

## Mississippian Limestone

Because to the limited areal extent of the Mississippian Limestone in this province, the Mississippian play is evaluated in the Anadarko basin assessment.

## Pennsylvanian Play

Cyclic limestone-shale-sandstone platform deposits of Pennsylvanian age comprise this play. The stratigraphic nomenclature of the Pennsylvanian System is illustrated in fig. 2. The Pennsylvanian play covers almost the entire province, missing only in Cherry County in north-central Nebraska. Included in this play are rocks of the Waubesa, Shawnee, Douglas, Lansing, Kansas City, Marmaton, and Cherokee Groups and Formations. These formations were grouped into one play because of similarities in stratigraphy and trapping mechanisms. Primary production is from multiple pay zones in limestones and dolomites. The informally named "Penn" Sandstone, Cherokee Sandstone, and "Penn" Conglomerate, all of Des Moines age, also produce petroleum.

Traps consist primarily of low relief structural noses and combinations of structure and updip porosity and permeability pinch-outs; stratigraphic trapping in bars and channel sandstones is also significant. Porosity development associated with uplift and erosion, and structures are the primary Pennsylvanian traps in this province (Watney and Paul, 1983). The Cherokee and "Penn" Sandstones and the "Penn" Conglomerate produce mainly from structural noses and anticlines.

The first Pennsylvanian discovery was in 1925 (PI's WHCS data, 1983). Most Pennsylvanian fields are located on or near the axis of the Central Kansas uplift. The Kansas field distribution is shown on figure 5 for Lansing-Kansas City Group production from the Pennsylvanian play. There is minor Pennsylvanian production in southwestern Nebraska. The Pennsylvanian play produces oil with minor gas. Oil comprises 93.2 pct of the total production with 4.4 pct gas and 2.4 pct oil and gas (PI's WHCS data, 1983).

The Pennsylvanian play area in the province covers 26,500 mi<sup>2</sup>; 6.8 pct of the play area is productive and 17.1 pct drilled with no production. Approximately 404 mi<sup>2</sup> of the play is on federal lands; this is only 1.5 pct of the play area.

From 1963-1983 18 fields were discovered with estimated total Pennsylvanian reserves of 1 million barrels or more. This constitutes 59 pct of the total reserves found in the province during this time period, or 69 pct of the new million-barrel fields discovered in the Central Kansas uplift-Cambridge arch province (Nehring data, 1983).

Future drilling for this play will be concentrated on the axis and the western flank of the Central Kansas uplift (Watney and Paul, 1983). Nebraska is marginally explored with few Pennsylvanian fields, but many of the factors responsible for porosity development in the south are not believed to have been active in the Paleozoic section of Nebraska. For this reason the Nebraska portion of the province has limited potential for discovering million-barrel equivalent fields and developing significant petroleum resources. The Pennsylvanian play in Kansas has been moderately to extensively explored and developed, especially along the arch system. The high drill density in the most favorable exploration areas will limit the number of future

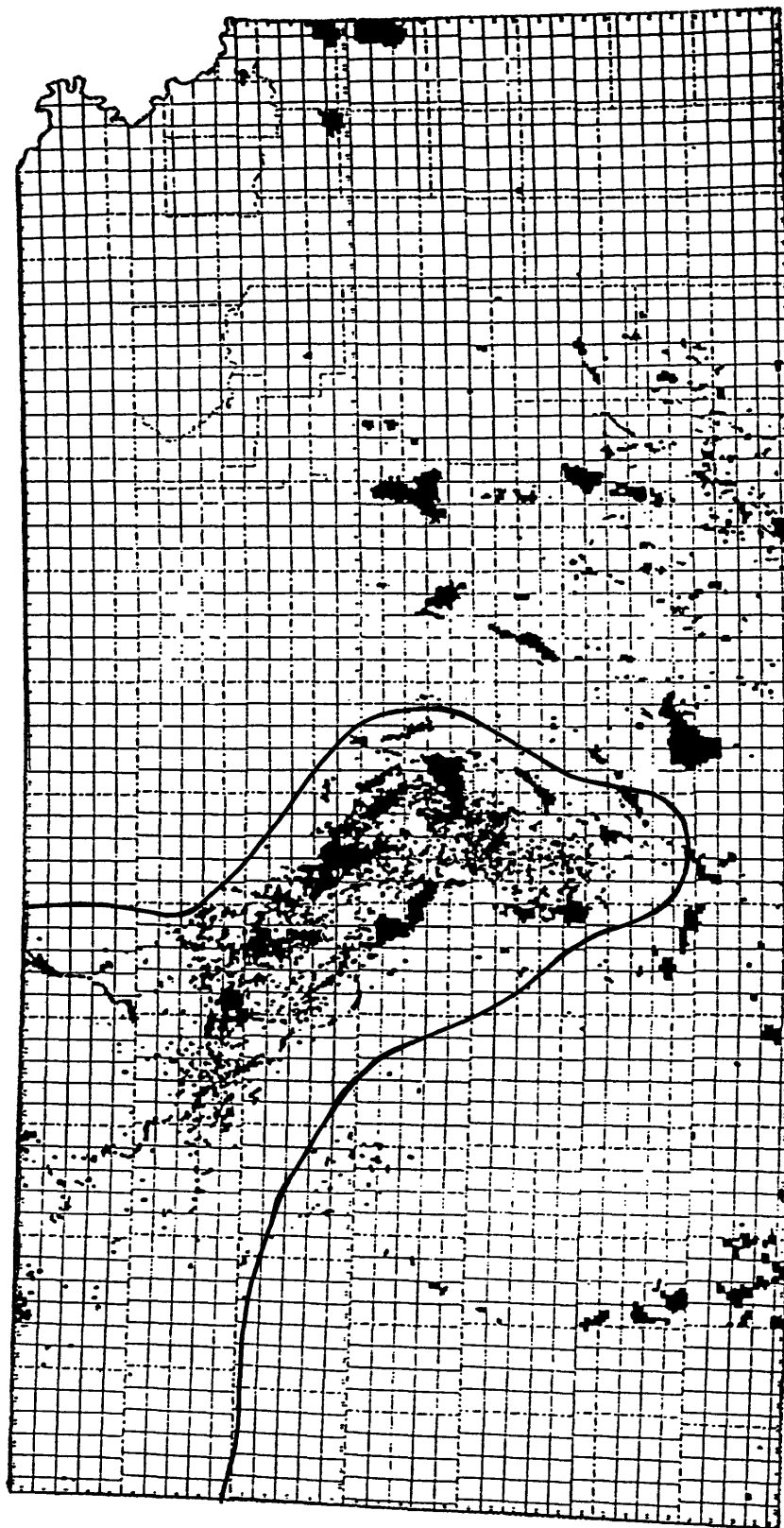


Figure 5. Kansas index map showing locations of Lansing-Kansas City Group oil and gas fields. Outlining fields from this Pennsylvanian play is the Province boundary (modified from Watney, 1980).

million-barrel fields discovered. Resource development on federal lands is limited by their small areal extent, and the lands are primarily located in areas of low potential for discovering significant petroleum resources.

### Permian

The Permian was excluded from consideration as a play because of low production and low potential for developing million-barrel equivalent fields. No million-barrel fields were discovered during the period 1963-1983 (Nehring data, 1983). Moderate to extensive drilling density in the most favorable areas also indicates limited development of future resources.

Table 1. Generalized play summary - Central Kansas uplift province

Shown is general play information, including trap type (structural (S), combination (C), stratigraphic (STRAT), and reservoir rock type (dolostone (DOL0), limestone (LST), sandstone (SS)).

PLAY NAME	AGE OF ROCK FORMATION	RESERVOIR ROCK TYPE	PRODUCING DEPTH (X100)	MAJOR HC TYPE	TRAP TYPE (S,C,STRAT)
-----					
ARBUCKLE	Cambrian to L. Ordovician	DOL0, SS,LST	32-47	oil	S, C, STRAT
PENNSYLVANIAN	Penn.	LST,SS	30-45	oil	S, C

### SUMMARY

The Kansas portion of the Central Kansas uplift-Cambridge arch province has been extensively explored and developed, especially along the arch system. The two major petroleum producing plays in the province are dolostones and sandstones of the Arbuckle play and limestones and sandstones of the Pennsylvanian play. The largest fields, including most of the million-barrel fields have already been discovered, and therefore, discovery of future million-barrel equivalent fields is limited. Although the Nebraska part of the province has scattered drilling with minor exploration, this area is less favorable for discovering million-barrel equivalent fields because of thinner rock sections, eroded sections, and poorly developed trapping mechanisms. The potential for developing significant petroleum resources on federal lands is also limited, primarily by the small areal extent of the lands and the lands' presence in areas of very low resource development potential.

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## APPENDIX A



# APPENDIX A

## SIGNIFICANT DISCOVERIES 1963-1983      CENTRAL KANSAS UPLIFT

Oil and gas new field discoveries between 1963 and 1983 with estimated ultimate recovery greater than 1 MMBO or 6 BCFG are tabulated below. Data tabulated below are determined from the Petroleum Information Petroleum Data System (PDS) database and the Nehring petroleum information database.

Field name	Disc. Year	Geologic Formation	MMBO Est.	BCFG Est.	Play Name	Trap Type
1) Bed Canyon	1966	Reagan SS.	2.65		Arbuckle	Comb.
2) Decant, W.	1965	Arbuckle Dolo	1.15		"	"
3) Hampton	1967	"	1.2		"	"
4) Hampton, NE	1967	"	2.25		"	"
5) Riffe	1978	"	8.0		"	"
6) Sleepy Hollow, NW	1968	Reagan SS.	1.70		"	"
7) Wheatland	1966	Arbuckle, L-KC	1.1		", Penn	"
8) Boevau Cyn.	1979	Lansing-KC	3.6		Penn	Strat
9) Dry Creek	1963	Lansing	2.92		"	Comb.
10) High Hill	1967	Lansing-KC	1.1		"	"
11) Kelpet	1983	Lansing	1.3		"	"
12) Knoll, N	1966	Lansing-KC	1.75		"	"
13) Meeker Canal	1976	"	2.0		"	"
14) Mellard	1963	Lansing	1.04		"	"
15) Overlook	1967	Lansing-KC	1.2		"	"
16) Reichel, E	1964	Topeka Lst	.09	8.4	"	"
17) Triangle	1983	L-KC, Douglas	1.0		"	"
18) Shaw Cr.	1969	Marmaton Lst	1.75		"	"
19) Shaw Cr., E	1980	"	1.05		"	"
20) Stoneman	1965	Lansing-KC	1.95		"	"
21) Valley View	1967	"	1.2		"	"
22) Wallace	1965	"	1.1	NGL	"	"
23) Wilson Cr.	1967	"	7.9		"	"
24) Schadel, NE	1966	Cherokee, Miss	1.6		Penn, Miss	"
25) Schadel, S	1967	Mississippian	2.25		Miss	"
26) Swisher	1976	Simpson SS.	1.6		Simpson	"
TOTAL Estimated reserves and resources			54.4	8.4		
			MMBO	BCFG		

2.09 MILLION BARRELS OF OIL ARE DISCOVERED PER YEAR, AVERAGE, FROM 1963-1983. AN AVERAGE OF ONE 1.3 MMB OIL FIELD PER YEAR WAS DISCOVERED DURING THE PERIOD 1963-1983

RESERVE BREAK-DOWN PER PLAY 1963-1983

Shown below are the estimated recoverable reserves and resources for million-barrel equivalent field discoveries for 1963-1983. The break-down by play indicates the amount of reserves and resources contributed by each play.

ARBUCKLE - 17.4 MMBO DEVELOPED, OR 32 PCT OF TOTAL RESERVES,  
26 PCT OF FIELD DISCOVERIES. VIOLA-SIMPSON - 1.6 MMBO  
DEVELOPED, 3 PCT OF TOTAL RESERVES, 4 PCT OF FIELD  
DISCOVERIES.

PENNSYLVANIAN - 32.2 MMBO DEVELOPED, OR 59 PCT OF TOTAL RESERVES,  
69 PCT OF FIELD DISCOVERIES.