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THE SPRINGER GROUP OF THE SOUTHEASTERN ANADARKO BASIN IN OKLAHOMA

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CHAPTER I

INTRODUCTION

Location

The area investigated in this research (figure 1) includes all or parts of Caddo, McClain, Garvin, Stephens, Comanche, Jefferson, Murray, and Carter Counties in south central Oklahoma, and comprises 2,204 square miles.

Problem and Procedure

The primary objective of this investigation was to formulate a regional interpretation of the geology of the Springer Group and to depict more clearly the relationships of the various petroliferous sandstones within the group. Tentative correlation of the Springer outcrops with subsurface units of the area and correlation of the locally named subsurface Springer sandstones of the Anadarko basin with those of the Ardmore basin are included.

To solve these problems, Springer outcrops were mapped on the Caddo and South Woodford anticlines northwest of Ardmore. Through use

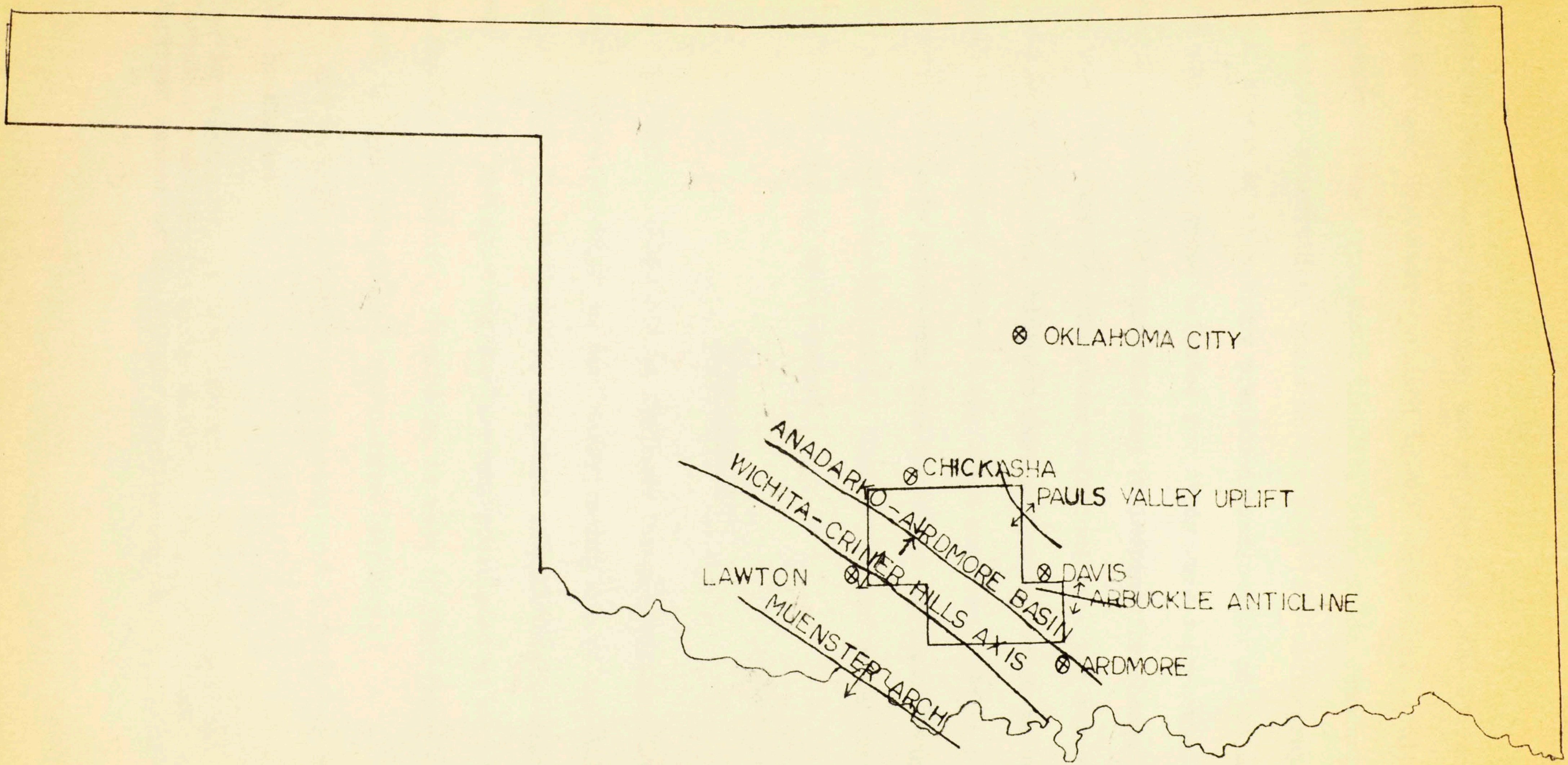

FIGURE 1

MAP SHOWING LOCATION OF AREA UNDER STUDY AND MAJOR STRUCTURES of electric logs, well cuttings, and sample logs, the characteristics of the Springer Group were studied in the subsurface. Additional information was obtained from scout tickets, corporation commission logs, and publications on individual pools in the area (see bibliography). The regional aspect of this study precluded examination of the many wells in the area, hence those selected for study were representative wells generally outlining the oil pools and reflecting the changing nature of the strata. To show the subsurface relationships, two structural contour maps and seven apparent thickness maps were constructed as well as a geologic map and three electric log cross sections. Wells plotted on the plates are those which have penetrated the Springer Group or demonstrate a known relationship to it. Larger circled wells are those in which logs or samples were studied.

Stratigraphy

For years, rocks of the Springer Group (Tomlinson 1959) have been assigned alternately to the Pennsylvanian and to the Mississippian Systems. Currently the group is regarded as essentially transitional between the two systems with the boundary postulated at or near the top of the Goddard Formation. No attempt is made in this paper to locate precisely the Mississippian-Pennsylvanian boundary.

The Springer Group is interpreted herein following Tomlinson (1959) who stated:

> The Springer group is here defined as including both the Goddard formation and the Springeran Series. Goldston's (1922) original Springer member of the Glenn formation likewise included both.

Inclusion of the Goddard shale in the Springer group has come to be general usage not only because the Goddard was long supposed to be of Pennsylvanian age, but also because its lithologic composition is practically identical with that of the Springeran Series above--so nearly identical that there is not yet general agreement among students of subsurface data as to the position of the boundary between them in some areas.

In order to clarify the relations which exist, the writer suggests that the Springer Group of Tomlinson be divided into two formations, the Goddard and the Springer (restricted) until a suitable new formational name is found to replace the latter (Springer).

The correlation chart (figure 2) is based solely upon lithology (because of faunal scarcity). Lithologic correlations were made from well to well usually commencing with the well where a recognizable unit already was named. The Springer Formation includes three named surface units: the Rod Club, Overbrook, and Lake Ardmore sandstones. To correlate these units with their subsurface equivalents, subsurface names must be established although each subsurface unit may be generally considered as a "member" in a strict sense. Thus in the subsurface the terms Sims sand, Humphreys sand, etc., are used (figure 2).

The top of the Springer Group is considered throughout the area to be an unconformable surface, with rocks of Morrowan through Early Permian age being deposited directly upon the unconformity. The base of the Springer Group is considered conformable with the underlying Caney Shale of established Mississippian age.

All named units listed within the correlation chart are essentially sandstones with the exception of the Goddard and Caney shales.

CORRELATION CHART OF SPRINGER GROUP

PERIOD			SURFACE	SUBSURFACE		
			CADDO & S. WOODFORD ANTICLINES	SHO-VEL-TUM	CARTER-KNOX	CHITWOOD
PENNSYLVANIAN			PRIMROSE	PRIMROSE	WOODS	PRIMROSE
					HORTON	
	SPRINGER GROUP (Tomlinson 1959)	SPRINGER (Restricted)		MARKHAM		
			LAKE ARDMORE	ALDRIDGE		
			OVERBROOK	HUMPHREYS		
			ROD CLUB	SIMS		
MISSISSIPPIAN		GODDARD FORMATION		GODDARD	GODDARD	GODDARD
			Red Oak Hollow	Goodwin	Hutson	Cunningham
					Anderson	Britt
						Boatright
				CANEY	CANEY	CANEY

The Springer Group varies considerably in thickness (Plate III) but thicknesses are only apparent because data concerning the dip on many structures were not obtainable. The general trend of thickening is apparently toward a depositional axis extending from slightly west of the Carter-Knox structure, over the top of the present Arbuckle anticline, and continuing southeastward. Probably the maximum true thickness (approximately 5,000 feet) should be near the Carter-Knox structure. Minimum depositional thickness in a given area can not be determined because of uplift and truncation.

Structure

Regional

The area described herein is essentially a structural province. Its principal features are: the Anadarko-Ardmore basin, the Wichita-Criner Hills axis, the Arbuckle anticline, and the Pauls Valley-Hunton uplift.

The present Anadarko-Ardmore basin (figure 1) widens northward and becomes narrow to the south where many high angle thrust faults and anticlines developed as the basin was compressed between the Pauls Valley-Hunton uplift and the Wichita-Criner Hills axis.

During most of the time of Springer deposition, this area was devoid of faulting and folding. The area was rather stable, fluctuating slowly upward and downward near wave base. The sea occupied a narrow, northwest-southeast trending basin located between the Muenster arch to the southwest and the cratonal land mass to the northeast. Black to dark-gray, soft, non-resistant shales suggest the stagnant character of the basin throughout Goddard deposition.

The Goddard Formation contains erratic sandstones which develop locally to tens of feet in thickness. Sandstones of this type are typical of the Golden Trend and Chitwood areas, where they are termed the Boatright, Britt, and possibly the Cunningham (Plates IV and V). These sandstones suggest a steadily rising land mass to the northeast although at this time in the Sho-Vel-Tum area, shale was being deposited. This gently rising land mass to the north (Pauls Valley Uplift?) elevated the northern area to sea level sometime after the deposition of the Cunningham sand and possibly before deposition of the Sims sand.

In the Sho-Vel-Tum area deposition continued without significant interruption after the Goddard Formation was laid down. Springer deposition which followed is marked by several well developed sandstones possibly indicating pulsations to the south. Tomlinson (1959) reported four inches of limstone conglomerate in the Lake Ardmore "Formation" (on the Overbrook anticline south of the thesis area), which suggested to him that uplift in the Criner Hills began during Springeran time. Thus, possibly as early as the time of deposition of the Goodwin sand, there could have been pulsations to the south and southwest in the Wichita-Criner Hills uplift creating a source area (other than the Muenster arch) for the sands of the Springer Formation.

Local

A few of the local structures present in the thesis area will be mentioned. Faulted anticlines include: Cruce, Velma, and Carter-Knox. Sholem Alechem is an anticline. Thrust faulted fields include Eola-Robbertson. An anticline which has developed by the diapiric movement of the Springer shales is the Caddo anticline. Generally, structures are much more complex between the Arbuckle anticline and the Wichita-Criner Hills uplift. Almost all faults in the area are thrusts from the southwest and trend northwest-southeastward parallel to associated anticlines and synclines. All faulting and folding occurred after the Springer Group was deposited.

CHAPTER II

SURFACE EXPOSURES

General Discussion

The Springer Group crops out in several areas around the Arbuckle anticline. These outcrops have been known for many years, but most of the detailed maps are in the possession of oil companies. Detailed mapping of a portion of the Springer outcrops is one of the objectives of this thesis. The map (Plate I) was constructed from aerial photographs and checked in the field by numerous traverses over the outcrops.

The surface mapping involves the Caddo and South Woodford anticlines located northwest of Ardmore in portions of Tps. 2, 3, and 4 S., Rs. 1 W. and 1 and 2 E., Carter County. The area shown in Plate I comprises 39 square miles of which only the Springer Group and adjacent formations were mapped.

The principal stream in the area is Caddo Creek which flows eastward; its main tributaries are Hickory and Henryhouse Creeks which flow off the Arbuckle anticline. Much of the Springer outcrop is covered by terrace gravels and alluvium of these streams. Lake Ardmore and City Lake are located upon the Caddo anticline.

Caddo Anticline

The Caddo anticline (Plate I) is asymmetrical, bulging on the northeastern limb. The anticline trends north-northwestward changing to west-northwestward on the northern end. It is bounded on the northeast by the Glenn syncline and on the southwest by the Newport basin. Numerous faults strike essentially perpendicular to the strike of Springer sandstones. Dips of the formations on the southwestern limb range from approximately 60 degrees in the southeast to vertical at the northwestern end. On the northeastern limb the dip is vertical at the southeastern end, decreasing to approximately 35 degrees on the bulge in Secs. 23 and 25, T. 3 S., R. 1 E., and then steepening to vertical (with possible slight overturn) at the northwestern end. The anticline plunges 40 degrees southeastward and 65 degrees west-northwestward.

Stratigraphy

Goddard Formation. The Goddard Shale is the oldest formation at the surface in the area of the Caddo anticline, and apparently only a few hundred feet are exposed. Lithologically, it is a sideritic, non-calcareous, dark-grey, fissile shale.

Springer Formation (restricted). The Springer Formation (restricted) includes approximately 2,300 feet of sandstone and shale. Three persistent sandstone members, the Rod Club, Overbrook, and Lake Ardmore are present. Tomlinson and McBee (1959) raised the Lake Ardmore to formational rank and redefined it to include the upper 500 feet of the Springer.

This procedure is not followed by the writer who mapped only the Lake Ardmore Sandstone Member.

Rod Club Sandstone. The Rod Club Member was described by Tomlinson (1962) as "a hard, greenish to buff, fine-grained sandstone." It contains many shale partings and several ledges of massive quartzose sandstone that developed to 30 feet in thickness. Calamites was observed in Sec. 17, T. 4 S., R. 1 E. Numerous loose sandstone blocks are marked by oscillation ripple marks, with the crest approximately two inches above the trough and ranging in length from ten to twelve inches. The sandstone weathers to brown-grey color, and the grey, fissile shale oxidizes to tan or brown color. Numerous two inch sideritic layers (which weather to limonite) associated with secondary calcite veinlets characterize the shale. The cementing material of most of the sandstone is silica.

The Rod Club Sandstone and associated shales approximate 400 feet in thickness in portions of the outcrop, but thin notably in Secs. 15, 16, and 22, T. 3 S., R. 1 E., where only 30 feet of massive sandstone is exposed. This range in thickness is characteristic of the Rod Club in which sandstones develop erratically, yet always within the same zone. In several places the formation is covered by terrace deposits and alluvium, yet in other places it forms hogbacks with a height of 100 feet.

Overbrook Sandstone Member. The Overbrook Sandstone Member is approximately 800 feet above the Rod Club Sandstone, separated by dark-grey, fissile, noncalcareous, sideritic shale. The Overbrook Sandstone is massive, buff to white, fine-grained, frosted, quartzose, subrounded, well-indurated, noncalcareous and contains some mica flakes.

The Overbrook Sandstone is uniform over the Caddo anticline, ranging from 90 to 110 feet in thickness except in the NW corner Sec. 17, T. 3 S., R. 1 E., where it is 25 feet thick (possibly as a result of faulting). It differs from the Rod Club in being more uniform and massive. It also forms hogbacks rising 100 feet above the surface and forms most of the dam for Lake Ardmore and City Lake.

Lake Ardmore Sandstone Member. The Lake Ardmore Member (Tomlinson, 1929) is a thin, noncalcareous, well-indurated, white to buff, massive, fine- to very fine-grained, subangular to subrounded quartzose sandstone which tends to completely shale out locally. Where exposed it is 8 to 25 feet thick; its position is 400 to 500 feet above the Overbrook Sandstone. Shale separating the Lake Ardmore and Overbrook is 400 to 500 feet thick and of the same composition as that underlying the Overbrook. The Lake Ardmore becomes increasingly shaly to the northwest.

The type section of the Lake Ardmore Sandstone is on the Caddo anticline in NE 1/4 NW 1/4 SE 1/4 of Sec. 2, T. 4 S., R. 1 E. It forms hogbacks only a few feet high.

<u>Primrose Sandstone Member, Golf Course Formation</u>. The Primrose was described by Tomlinson (1929) as:

> a somewhat calcareous, indurated, semi-crystalline, thin-bedded sandstone interrupted by frequent shale partings and interbedded with shale.

This typically describes the Primrose Sandstone on the Caddo anticline where it varies in thickness from 90 to 120 feet. The base of the Primrose is generally regarded as top of the Springer, where an unconformity is postulated, although the sequence is not sufficiently exposed for exact determination. Typical Springer Shale below the Primrose Sandstone is 200 to 300 feet thick.

Terrace and Alluvium. Extensive deposits of terrace are scattered on and about the Caddo anticline. These probably were derived from streams flowing off the Arbuckle anticline during the Pleistocene Epoch. Gravels at the northern end grade into finer particles southward. The terrace slopes gently southward from the Arbuckle anticline, and together with the wide flood plains of Caddo Creek and its tributaries, masks outcrops of the Springer Group in many places.

Structure

The Caddo anticline is a typical example of diapiric flowage of shales upon compression. Wells drilled upon the crest of the anticline have penetrated 3,000 feet of Goddard Shale. Were the fold reconstructed before erosion, this would result in 8,000 to 10,000 feet of Goddard Shale on the crest. Because this thickness is much greater than in other wells in the thesis area, it may be assumed that these shales flowed up the anticline from the nearby synclines upon compression. Associated faults are relatively insignificant, displacement being but a few feet, with the exception of the postulated fault in NE 1/4 SE 1/4 of Sec. 16, T. 3 S., R. 1 E., and another in NW 1/4 of Sec. 16, and NE 1/4 of Sec. 17, T. 3 S., R. 1 E. The fault in SE 1/4 of Sec. 16 indicates lateral displacement of 800 to 1,000 feet with the west side moving northward. The fault in NW 1/4 of Sec. 16 and NE 1/4 of Sec. 17 indicates movement of 800 to 1,000 feet in the opposite direction decreasing on the eastern limb to lateral displacement of but 40 to 50 feet.

Faulting occurred probably during the Arbuckle orogeny of Late Pennsylvanian time because faulting and folding apparently continue through overlying Morrowan rocks. The compressional force apparently was greatest at the west-northwestern end of the anticline as indicated by steepening of dip and more intense faulting.

South Woodford Anticline

The South Woodford anticline is a narrow fold extending from Sec. 20, T. 3 W., R. 1 E., to Sec. 33, T. 2 S., R. 1 W. It trends southeastward to west-northwestward en echelon with the Caddo anticline. It is approximately one half mile wide at the southeastern end and in Sec. 2, T. 3 S., R. 1 W., the northeastern limb seems to recurve eastward and parallel the Arbuckle anticline whereas the southwestern limb continues around the Arbuckle Mountains.

Stratigraphy

The stratigraphy is essentially the same as that of the Caddo anticline and only the key units are discussed.

<u>Goddard Formation</u>. The Goddard Shale is expressed on the surface as a series of low, rounded, grassy knobs with lenticular sandstones at the northwestern end. There are apparently two sandstones in the Goddard Formation. The lowermost is an oil-stained, grey, fine-grained, quartzose, friable, massive sandstone approximately 25 feet thick in exposures in Secs. 33 and 34, T. 2 S., R. 1 W. About 250 feet above this sandstone is a calcareous, thin-bedded, well-indurated, very fine-grained sandstone with several shale partings. This sandstone is 20 feet thick. Both sandstones dip vertically.

<u>Rod Club Sandstone Member, Springer Formation</u>. The Rod Club Sandstone is incompletely exposed here and is much thinner (40 to 75 feet) than on the Caddo anticline. It is of the same lithology, but becomes thinner bedded and more calcareous northwestward. The dip is vertical on the southwestern limb and approximates 70 degrees on the northeastern limb.

<u>Overbrook Sandstone Member, Springer Formation</u>. The Overbrook Sandstone resembles that on the Caddo anticline, except that it is saturated with asphalt and contains numerous oil seeps along the vertical dip of the southwestern limb. These seeps have been mined and slag piles and retort foundations are yet in evidence. Thickness of the Overbrook Sandstone on the southwestern limb is 140 feet, compared to a thickness of 30 feet on the northeastern limb.

<u>Lake Ardmore Sandstone Member, Springer Formation</u>. The Lake Ardmore Member is a thin, massive sandstone on both limbs, attaining a maximum thickness of 14 feet toward the southeastern end. It shales out completely northwestward.

Post-Springeran. The Primrose Sandstone as well as Pleistocene terrace and alluvial deposits, are composed of the same lithology as on the Caddo anticline.

At the extreme northwestern end of the South Woodford anticline the Springer Group disappears beneath the Vanoss and Wichita deposits of Late Pennsylvanian and Early Permian age. These deposits are ocher-colored, fine conglomerates, grading upward into limestone pebble conglomerates and limestones.

Structure

The South Woodford anticline is essentially a nose extending southeastward from the much larger Arbuckle anticline; alignment and proximity of the two structures indicate contemporaneous folding. The South Woodford anticline apparently did not experience the diapiric movement of shales as on the Caddo anticline, although intensity of folding was probably equal or greater, as indicated by the essentially vertical dips in this area.

Only four faults actually cut the Springer Group, and these are all on the northeastern limb. The largest fault is in Secs. 1 and 2, T. 3 S., R. 1 W., and is perpendicular to the strike of the beds. This apparently resulted from eastward recurvature of this limb where it becomes the southern limb of the Arbuckle anticline. A second prominent fault, Sec. 18, T. 3 S., R. 1 E., displays more movement on its northern side as shown by drag of the Overbrook Sandstone along the fault plane. Horizontal displacement approximates 500 feet.

A large, southwest trending fault enters the NE corner Sec. 34, T. 2 S., R. 1 W. This fault probably disappears in the Goddard Shale because no faulting is observable in the Overbrook Sandstone further southward.

Summary of Surface Structures and Stratigraphy

The Caddo and South Woodford anticlines are en echelon northwest-southeast trending folds separated by a narrow, shallow syncline. The time of deformation is postulated as the time of primary folding of the Arbuckle anticline in Late Pennsylvanian. Compressional force was from the southwest, causing diapiric flowage of the Goddard shales on the Caddo anticline.

The Springer Group is composed of three sandstone units separated by shales (Springer Formation restricted) and one shale formation (figure 2). The three sandstone units are the Rod Club, Overbrook, and Lake Ardmore. They are best developed to the southeast and tend to shale out or become more calcareous to the northwest. The underlying Goddard Formation has two sandstones developed at the northwestern end of the South Woodford anticline which units may correlate with the lenticular oil productive sandstones within the Goddard Formation on the Caddo anticline.

CHAPTER III

SPRINGER GROUP IN SUBSURFACE

General Discussion

The area investigated in the subsurface comprises all or parts of McClain, Caddo, Stephens, Garvin, Jefferson, Carter, and Murray Counties of south central Oklahoma, and includes oil pools which produce from the Springer Group; Caddo, Sho-Vel-Tum, Doyle, the Golden Trend, Carter-Knox, and Chitwood. The area of Springer under study is bounded at the southwest by the Wichita-Criner Hills frontal fault zone, at the east by the Arbuckle anticline and Pauls Valley uplift, and arbitrarily at the north and south by the north line of T. 5 N., and south line of T. 3 S., respectively.

In the subsurface, the Springer Group lies conformably upon the Caney Shale of Mississippian age and is overlain unconformably by rocks of Morrowan age through rocks of the Permo-Pennsylvanian Pontotoc Group. The Springer Group can be encountered at depths varying from a few hundred feet to more than 15,000 feet. The group is typically shale with some well-developed sandstone bodies in the upper 1,500 to 2,000 feet. The Goddard Formation of Westheimer (1956) comprises the lower half of the Springer Group (figure 2), and contains a few erratic sandstones and perhaps the Goodwin (Elias 1956) and Cunningham sands.

Because this thesis research involves an extensive area and many oil pools, only the general trends of formations, major faults, and anticlines are shown (Plates II and VI). The object of the subsurface study was to attempt a correlation of terminology used in the Golden Trend-Chitwood area with that of the Carter-Knox pool, then to show the relationship of this northern area with that to the south at Sho-Vel-Tum, and finally to correlate with surface exposures on the Caddo anticline. This was attempted essentially by using well cuttings and electric logs.

The structure of the thesis area is extremely complex, consisting of numerous thrust and step faults lying essentially en echelon. Compressional force originated from the southwest. Most faults are upthrown on the southwest and downthrown on the northeast. Two periods of faulting may be recognized by contrasting alignment of the structures. Those faults, which occurred during the Wichita orogeny of Early Pennsylvanian time, are aligned essentially northwest-southeast whereas those of Arbuckle orogeny (Late Pennsylvanian) are aligned west-northwest by east-southeast. A prominent faulted anticline forms the Velma-Camp-Fox-Graham oil pools. The Springer Group is eroded completely from the crest of this structure.

The Springer Group appears to be truncated from an upthrust fault block southwest of the Sho-Vel-Tum area as seen in Plate II, and on the eastern side of the area it has been eroded from the Pauls Valley uplift and the subsurface extension of the Arbuckle anticline (Plates II and III). In the Sho-Vel-Tum area the degree of erosion is indicated by the absence of the Markham sand, except near the edges. With stratigraphic depth the sandstones are progressively higher on structure until the Sims sand covers the entire area (except for the faulted Velma-Camp-Fox-Graham anticline). The structure contour map of the Sims sand (Plate VI) will give a more exact picture of the Springer Formation before truncation.

In the northern half of the area (Plate II) the Markham, Aldridge, Humphreys, and perhaps Sims sands or their equivalents are not found, either because of nondeposition or erosion. This indicates a positive area here while Springer Formation (restricted) was being deposited in the Sho-Vel-Tum area. Thus, the Springer basin was shrinking with gentle uplift in the northern half at or near the close of Goddard deposition. Subsequent deposition of the Springer Formation (restricted) in the Sho-Vel-Tum area (followed by uplift and erosion) left the entire area positive, except perhaps a small lagoon-like region across the present Arbuckle anticline. Noting the thickness of the Springer Group and the location of positive areas it would seem possible that the depositional axis of the Springer Group remained between the Carter-Know and Sho-Vel-Tum structures throughout Springeran time, with the basin becoming more assymmetrical as the Golden Trend-Chitwood area rose. As the Golden Trend-Chitwood area became positive the Sho-Vel-Tum area (and possibly the entire basin) became a shallow shelf, with thick current-deposited sandstones being interrupted by periods of subsidence and shale deposition. The dark-grey, noncalcareous shale (resembling that of the Goddard) indicates a stagnating quiescence. Truncation of the Springer Group by later uplift precludes ascertaining the exact southwestern limits of deposition. It is almost certain that there were two sources of supply for sandstones of the Goddard Formation as shown by shaling out of the northern sandstones near the southern end of the Carter-Knox structure (Plates IV, V, and XI).

Stratigraphy

General

The Springer Group in the subsurface is composed of shales and sandstones with thicker and more sheet-like sandstones characterizing the Sho-Vel-Tum area. Stratigraphy and composition will be discussed together commencing at the base of the Springer Group.

Goddard Formation. The Goddard Formation (Westheimer 1956) is a noncalcareous dark-grey to black, fissile to earthy shale containing some erratic sandstones and an occasional zone of black calcareous shale similar to the Mississippian Caney Formation. The top of the Goddard Formation is impossible to determine lithologically in the subsurface because of its similarity to the shales of the overlying Springer. Most authors consider the base of the Goodwin sand (Jordan 1957) as the top of the Goodard, but faunal evidence presented by Elias (1956) places the Goodwin within the Goddard Formation. The Goodwin is considered herein as a part of the Goddard and the top of the Goddard is placed arbitrarily at the base of the Sims sand.

Several lenticular sandstones underlie the Goodwin horizon in subsurface on the Caddo anticline and in the Golden Trend-Chitwood area (Plate IV). The Golden Trend-Chitwood area sands are the Britt and Boatright (Wallace 1954). True thickness of the Goddard Formation ranges from 2,000 to 2,500 feet, sandstones characterize the upper 1,000 feet.

In the Sho-Vel-Tum area the Goodwin sand (Plate V) is noncalcareous, white to buff, very fine- to medium-grained, quartz sandstone with subrounded grains. Maximum thicknesses are in Tatums and Velma pools (possibly the result of steep dip). The sandstone is continuous although it has shale partings in several places. The Goodwin sand disappears northward on the subsurface extension of the Arbuckle anticline.

North of the Arbuckle anticline, a thin more lenticular sandstone sequence includes the Cunningham (Wallace 1954), Britt and Boatright sands at Chitwood, and the Hutson and Anderson sands (Pate 1953) at Carter-Knox. The Hutson is considered to be correlative with the Cunningham (Plate XI) and the Anderson with the Britt (Plate XI). Herein the terms Cunningham and Britt are deemed applicable.

The Cunningham is a noncalcareous to slightly calcareous, buff, fine-grained, quartzose sandstone ranging from zero to over 300 feet in thickness. Locally it consists of two massive sandstones separated by intervening 50 to 100 feet of shaly sandstone. Generally, more massive sandstone characterizes the top of the section; the unit becomes increasingly shaly toward the base.

The Britt sand is noncalcareous to calcareous, buff, fine-grained and quartzose ranging from zero to over 250 feet in thickness. The Britt in some wells at Carter-Knox is much thicker, but this is probably the result of steep dip (Jordan 1957). By comparing Plate IV with Plate V, the Britt is noted to be much less extensive than the Cunningham. The top of the Britt sand is approximately 350 feet below the top of the Cunningham sand.

The Boatright is the lowest sandstone found in the northern half of the area. It resembles the Britt in both composition and texture. Boatright is used here to include the Spiers sand (Wallace 1954), which in some wells is found 5 to 10 feet above the originally defined Boatright sand. The Boatright sand has approximately the same thickness as the Britt and is encountered in the same locality.

The top of the Boatright sand is approximately 350 to 450 feet below the top of the Britt sand.

Comparing the total thickness of the Goddard Formation in the Sho-Vel-Tum area with that in the Golden Trend-Chitwood area it appears that the top of the Goddard Formation lies near or above the top of the Cunningham sand. The Cunningham sand is a partial time equivalent of the Goodwin sand to the south, with Britt and Boatright sandstones having been deposited to the north before the Goodwin sand was deposited to the south. Because the Cunningham is considered to be the youngest sandstone of the Springer Group in the northern area, there must be an unconformity near its top which truncates it eastward. Then it is assumed that gentle upwarping occurred in the northern area sometime after the deposition of the Cunningham. This ostensibly could be the first movement of the Pauls Valley uplift.

Britt and Boatright sands apparently lie stratigraphically below the Goodwin and have no equivalents to the south except possibly upon the Caddo anticline. The northern area is assumed to have been a shelf or platform from Boatright through Cunningham depositional time while the Sho-Vel-Tum area became a shelf only when Goodwin sand was deposited. This would indicate a possible shift of the basinal axis northward between the zero thickness lines of the Cunningham and Goodwin sands. With the basinal axis to the south, the Cunningham, Britt, and Boatright sands must have had a northern or northeastern source (possibly the Central Kansas uplift).

Springer Formation (restricted). The Sims sand (Jordan 1957) (Plates VI and VII) is considered the basal unit of the Springer Formation (restricted) and is correlative with the outcropping Rod Club sandstone (Tomlinson and McBee 1959). The Sims is a sequence of sandstones developed within a 300 to 600 foot section. A massive sandstone characterizes the top and grades downward through shaly sandstones (with occasional massive sandstone development) until the section becomes totally shale. Shale between the Sims and Goodwin sands ranges in thickness from a few feet to 100 feet, and is assigned to the Goddard Formation. The top of the Sims is drawn at the top of the uppermost massive sandstone in a section dominantly sandstone. Sims sands are typically noncalcareous, white to buff, fine- to medium-grained, subrounded to subangular, and quartzose; locally they are stained red. They are prolific oil producers in the Sho-Vel-Tum area.

Sims sands indicate a rising shelf area with deposition fairly continuous from a source to the south or southwest. If the Sims was deposited in the northern area of study it was apparently removed by erosion. This is probably the case because the Sims sand, where present, shows no general lenticular development, as might be expected of deposition in a shrinking basin.

The Humphreys sand (Jordan 1957) (Plate VIII) is a massive unit which locally has developed into upper and lower massive sandstones separated by a 20 to 100 foot sequence of sandy shale. Locally in the Velma region, a thin limestone occurs near the top of the Humphreys. The Humphreys ranges in thickness from zero to 300 feet (greater thicknesses are found on the anticlines and are probably due to steep dips rather than actual depositional thickness).

The Humphreys sands are composed of noncalcareous to calcareous, white to buff, fine-grained, subrounded, quartzose particles with shale partings. They appear to thin by nondeposition at the northern end of the Sholem Alechem anticline. This may indicate either the time of uplift or a complete withdrawal of the sea from the Golden Trend-Chitwood area. The shale interval between the base of the Humphreys and the top of the Sims varies considerably near prominent anticlines. This may be because of the dip or flowage of the shales during folding. Perhaps the true interval may be nearer 250 feet. The Humphreys appears correlative with the outcropping Overbrook Sandstone (Tomlinson and McBee 1959) although there is insufficient well control to establish a definite correlation.

The Aldridge sand (Jordan 1957) (Plate IX) is essentially a massive sandstone with shale partings. It has the same characteristics and texture as the Humphreys. Locally the cementing material is calcareous. It ranges in thickness from zero to 300 feet. Some of the greater thicknesses are not associated with present structures, possibly indicating further withdrawal of the seas. The alignment of these thick areas is discontinuous and departs from the pattern of the underlying sandstones. The Aldridge has been removed by post-Springeran erosion from much of the Velma and Sholem Alechem structures.

The shale interval (approximately 350 feet) between the Aldridge and the underlying Humphreys and the overlying Markham is approximately the same except where there is flowage of the shales near anticlines causing the interval to thicken. The Aldridge appears to correlate with the Lake Ardmore Sandstone at the surface (Tomlinson and McBee 1959) although again there is insufficient well control for a definite correlation.

The Markham sand (Jordan 1957) (Plate X) is a massive sandstone found only in restricted areas where post-Springeran erosion did not occur. The Markham is a noncalcareous, white, fine-grained, subrounded, quartzose sand with relatively few shale partings. Its maximum thickness approaches 250 feet in the synclines between the Sholem Alechem and Tatums anticlines. Distribution of the Markham typically suggests that the area was eroded before the Morrowan seas transgressed the region. Where the Markham is not eroded, it is overlain by some 200 feet of Springer shales. The Markham is assumed to have no surface correlative.

The Woods sand (Pate 1953) (Plate X) was once considered as the uppermost Springeran in the Carter-Knox pool, but later and deeper drilling combined with diagnostic evidence indicate it to be the equivalent of the Primrose Sandstone in the Chitwood area. Herein the Woods, including its lower unit the Horton (Jordan 1957), is considered Morrowan in age. The upper Woods is a semi-calcareous to calcareous, buff, fine- to medium-grained, quartzose sandstone containing glauconite and particles of green Ordovician shale. The lower Woods (Horton) contains much glauconite, but very few particles of green shale. It has several shaly zones. The Woods thins by onlap eastward. Upon this evidence, the Springer unconformity (Plates XI and XII) is placed at the base of the lowermost Woods sand.

Oil and Gas Pools and Future Possibilities

The thesis area is essentially a structural province. Most of the oil pools are on anticlinal crests or on flanks of anticlines where erosion and subsequent deposition of impervious material created a trap which prevented further migration of hydrocarbons. Several pools in the area have produced, or will produce, 100 million barrels of oil from the Springer Group. The two largest are the Velma-Milroy-Camp pool and the Sholem Alechem pool. Other notable pools are Tatums, Wilcat Jim, Fox-Graham, Cruce, Doyle, Carter-Knox, Chitwood, and the Golden Trend.

All of the Springer sands produce oil or gas in one or more of the pools. The most productive sand is probably the Sims, with more recent discoveries making the Goodwin and its equivalents a close second. Detailed studies have been published regarding these individual pools (see bibliography).

Possibilities appear favorable for future discoveries in the Springer Group. Most of the earlier wells in the Sho-Vel-Tum area were drilled to the Sims sand and they are yet producing. As these wells are depleted, the possibility of future drilling to the Goodwin sand will likely recover more production. In the Chitwood pool, the Cunningham sand is probably the most productive, although there are local areas in which no wells have been drilled to test this horizon or to determine the presence or absence of the more lenticular Britt and Boatright sands. Where these northern sandstones are present, their greater depth results in a decrease in porosity and permeability as proved in several of the deeper "wildcat" wells. With new methods of treating these "tight" sands, much more oil or gas should be produced as economics demand. Production in the northern half of the area will probably be related essentially to stratigraphic traps possibly associated with structures because these northern sands are lenticular in nature.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The Springer Group is composed of two formation; the Goddard and the Springer (restricted). The Goddard Formation contains several erratic sandstones; the thickest being the Goodwin and its partial equivalent, the Cunningham. Underlying the Cunningham sand are the Britt and Boatright sands. The Springer (restricted) includes the Rod Club, Overbrook, and Lake Ardmore Sandstones in the outcrop and the Sims, Humphreys, Aldridge, and Markham Sands of the subsurface. The Sims sand is considered to be correlative with the Rod Club Sandstone. It is missing in the Golden Trend-Chitwood area, possibly due to erosion. The Humphreys sand is considered equivalent of the outcropping Overbrook Sandstone, it is absent in the Golden Trend-Chitwood area. The Aldridge sand is considered correlative with the outcropping Lake Ardmore Sandstone. The Markham sand has no surface equivalent,occurring only in the subsurface low areas which were protected from post-Springeran erosion. The Woods sandstone is considered equivalent to the outcropping Morrowan Primrose Sandstone. The Springer Group is unconformably overlain by rocks ranging in age from Morrowan through Early Permian; the Springer conformably overlies the Caney shale of Mississippian age.

The thesis area was a narrow trough in which a regressing sea with adjacent rising land masses played a major role in deposition of sandstone bodies. The Golden Trend-Chitwood area became positive soon after the deposition of the Goddard Formation during which time the Sho-Vel-Tum area became a shelf or platform and thus remained until close of Springeran time. The axis of the Springer basin was located near the southern end of the Carter-Knox pool extending southeastward over the present Arbuckle anticline during Goddard deposition. The entire area became a shelf during Sims deposition.

The thesis area is a complicated structural province containing folding and faulting resulting from the Wichita and Arbuckle orogenies. Most faults are upthrust from the southwest and are en echelon as are the folds. Numerous oil pools are associated with faulting, folding, and accompanying erosion and post-Springeran deposition of impervious material. The Caddo anticline is considered to be a classic example of diapiric flowage of incompetent shales.

The future of this area as an oil province is promising with deeper drilling to the Goodwin sand in the Sho-Vel-Tum area and new production techniques north of Sho-Vel-Tum making the "tighter" Springer sandstones more attractive.

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APPENDIX A

PLATE XI

Descriptions of Wells used in Cross Section Plates
North-South Cross Section A-A'

	Location	Operator	Name	Elevation	Total Depth
1.	NW NE 25-5N-7W	Mercury Drilling Company	Whitener No. 1	1171	13,763
2.	NE NW NW 9-4N-6W	Kidd Williams Drilling Company	Newton John No. 1	1219	13,086
3.	SW SW 23-4N-6W	Humphrey Oil Corporation	Carney No. 1	1257	12,189
4.	NE SW NW 8-3N-5W	T. H. McCasland	Ray Horton No. 7	1262	6,075
5.	SE NW NE 29-3N-5W	British Amer. Oil Prod. Company	Harrison No. 2	1161	15,310
6.	NW SW SW 3-2N-5W	British Amer. Oil Prod. Company	Sally Krieger No. 1	1245	17,484
7.	SE SE NW 24-2N-5W	Gulf Oil Corporation	Daisy McKinney No. 1	1180	15,808
8.	SW SW NW 3-1N-5W	The Texas Company	I. Creel No. 1	1156	11,673
9.	NW NW SE 13-1N-5W	Champlin Refining Company	Morris No. 1	1190	9,105
10.	SW NW NW 31-1N-4W	Perkins Bros. and Coop. Refg. Assoc.	Clark No. 1	1140	8,189
11.	SW SW SW 31-1N-4W	Samedan Oil Corporation	Clark No. 1-A	1113	8,500
12.	NE NE SE 2-1S-4W	Stanolind Oil and Gas Corporation	Syms No. 1	1060	6,759
13.	SW NE NW 25-1S-4W	Stanolind Oil and Gas Corporation	F. M. McCollom No. 1	987	6,058
14.	SW NW SW 1-2S-4W	The Texas Company	F. E. Reynolds No. 1	1071	8,300
15.	SW SW SW 1-2S-4W	Gulf Oil Corporation	Martin No. 1	1006	6,300
16.	SW SW SE 32-2S-3W	Stanolind Oil and Gas Corporation	P. M. Brigance No. 1	1011	8,328
17.	SE SE NW 9-3S-3W	An-Son Petroleum Corporation	Skelton No. 1	1016	9,969

PLATE XII

Descriptions of Wells used in West-East Cross Section B-B'

	Location	Operator	Name	Elevation	Total Depth
1.	NE NW 16-4N-8W	Frankfort Oil Company	Pruitt No. 1	1211	17,826
2.	NE NE 3-4N-8W	Phillips Petroleum Company	Nichlos No. 1	1212	11,100
3.	NW NE 25-5N-7W	Mercury Drilling Company et al.	Whitener No. 1	1219	13,763
4.	SW SW 28-5N-6W	Magnolia Petroleum Company	Spiers No. 1	1149	11,865
5.	SW SW NE 34-5N-6W	Magnolia Petroleum Company	Newberry No. 1	1087	12,550
6.	SE SE SW 24-5N-6W	The Texas Company	Foster No. 1	1128	12,885
7.	NE SE 32-5N-5W	Sinclair Oil and Gas Company	Riddle No. 1	1131	11,185
8.	NE SW 25-5N-5W	Phillips Petroleum Company	Sterr No. 1	1016	13,362
9.	NE NE 20-5N-4W	Herman and George Brown	Flynn No. 1	1102	12,062
10.	W 1/2 NE NE 8-5N-3W	Weimer and Fitzhugh	Kemp No. 1	1049	10,822

PLATE XIII

Descriptions of Wells used in West-East Cross Section C-C'

Location	Operator	Name	Elevation	Total Depth
1. NE NE SW 28-1S-5W	Gulf Oil Corporation	Cowan No. 1	1148	9,600
2. SE SE 26-1S-5W	Skelly Oil Company	Selby No. D-2	1265	7,606
3. NW NE SE 24-1S-5W	Skelly Oil Company	K. C. Davis No. 3	1069	7,171
4. SE SW NE 16-1S-4W	Skelly Oil Company	L. G. Williams No. 1	1024	7,158
5. SE SW NE 7-1S-3W	Kirkpatrick Oil Company	McKee No. 7	936	6,030
6. NW SW SW 11-1S-3W	Seaboard Oil Company	E. C. Lael No. 1	916	5,260
7. NE SW SW NE 8-1S-2W	H. A. Howell	Hooks No. 1	949	2,369

[redacted]