THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

SUBSURFACE GEOLOGY OF RICH VALLEY AND SOUTHEAST RICH VALLEY OIL FIELDS, GRANT COUNTY, OKLAHOMA

A THESIS

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INTRODUCTION

Location

The Rich Valley area is located in the southeastern portion of Grant County in north central Oklahoma (fig. 1), and includes Townships 25 and 26 North, Ranges 4 and 5 West. This area is located ten miles southeast of Medford, Oklahoma, approximately equi-distant between the small towns of Lamount and Pond Creek. Geologically it lies on the northern shelf of the Anadarko basin, directly west of the buried Nemaha ridge.

Topography

The area lies northwest of Salt Fork tributary of the Arkansas River, and it is essentially covered with dune sand. The gently sloping hills are fairly stable, being fixed by vegetation. Elevations in the area range from 1,020

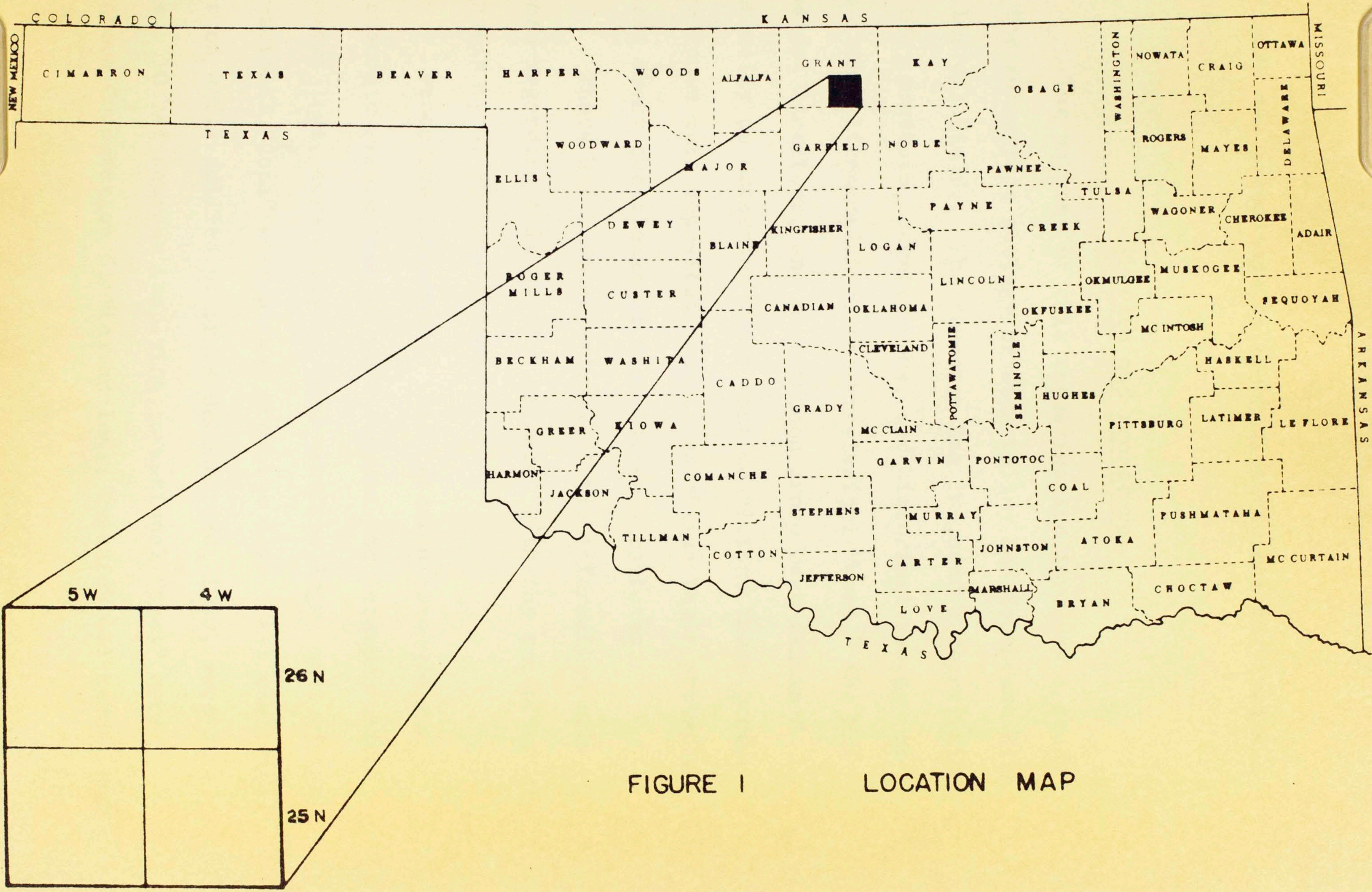


FIGURE I LOCATION MAP

to 1,040 feet; drainage is southeastward into the Arkansas River.

Problem and Procedure

The purpose of this investigation involves a study of the subsurface geology of Rich Valley and Southeast Rich Valley oil fields. The research has included a description of the structure, stratigraphy, and historical geology of the area. Lithologies of the Mississippi "chat," the Mississippi limestone, and the Simpson group were examined critically to determine under what conditions these productive zones were deposited. and to establish their probable extent about the flanks of Rich Valley structures.

There has been relatively little information published regarding this particular area, with the exception of a thesis by G. F. Dana (1954).

Procedure followed in this research involved the microscopic examination of well samples and interpretation of micro logs, core analyses, and electric logs; most of the formational "tops" were picked from the last. All electrical logs on wells drilled prior to December 20, 1960, were utilized. Other sources supplying formational "tops" were: Oklahoma Corporation Commission logs, Research oil cards, and personal communication with geologists in Oklahoma City. Locations of wells were established with the aid of oil company maps and the sources mentioned above.

Conclusions in this study were obtained through preparation of structural maps, isopachous maps, and cross sections from electric logs.

Subsurface stratigraphic correlations and names employed herein are based upon a recent article by L. H. Lukert (1949, p. 131-152).

STRATIGRAPHY

General Statement

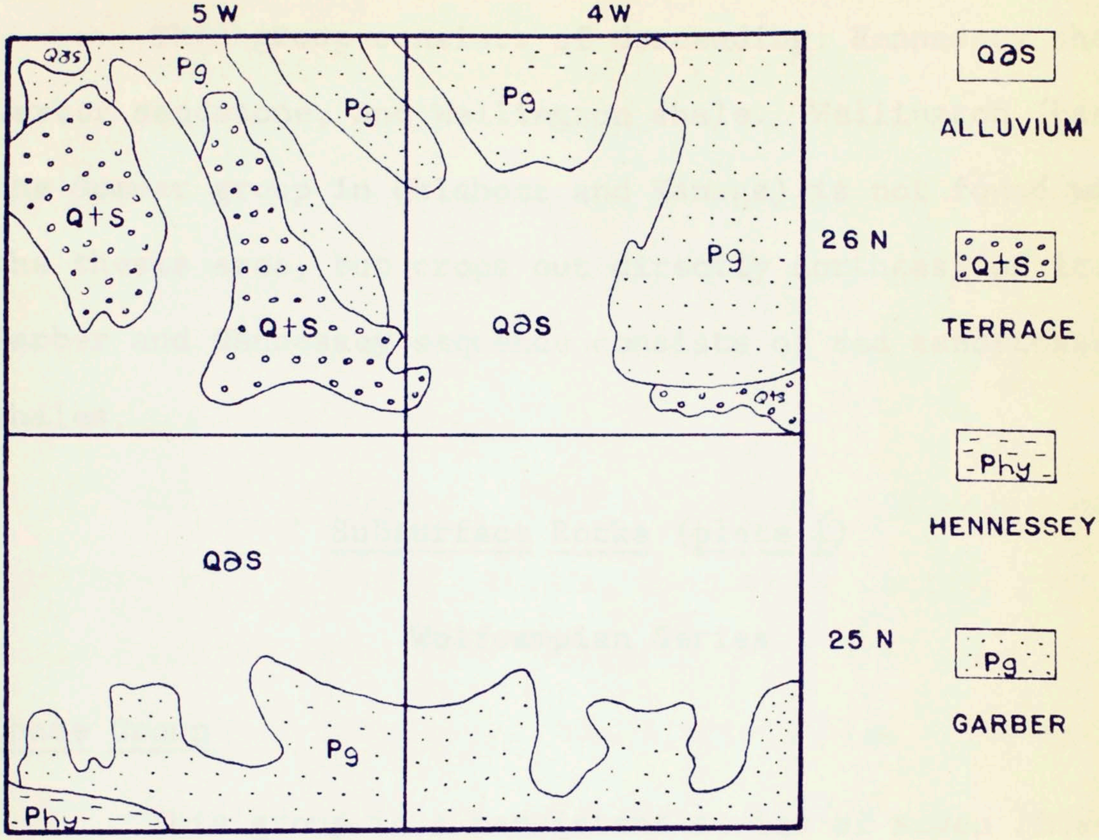
Rocks ranging in age from upper Cambrian to Quaternary were deposited in the Rich Valley area. Emphasis is placed upon rocks ranging from Permian Chase (uppermost group of Wolfcampian series) to Ordovician Arbuckle.

Surface Rocks (fig. 2)

Quaternary System

This system covers a large area of Grant County in the form of aeolian dunes originating essentially from the bed of the Arkansas River. Other deposits are flood plain deposits bordering the river channel.

Tertiary and Cretaceous sediments, which are present in the western part of Oklahoma, are absent in the Rich Valley area.



GEOLOGIC MAP OF THE RICH VALLEY AREA

GRANT COUNTY, OKLAHOMA

(AFTER OKLAHOMA STATE GEOLOGIC MAP 1954)

FIGURE 2

Permian System

Leonardian Series

Sumner Group

This group consists of descending: Hennessey shale, Garber sandstone, and Wellington shale. Wellington (base of the Sumner group in Oklahoma and Kansas) is not found within the thesis area, but crops out directly northeast of it. The Garber and Hennessey sequence consists of red sandstones and shales.

Subsurface Rocks (plate 1)

Wolfcampian Series

Chase Group

This group is a persistent series of seven limestones with interbedded shales, displaying an average total thickness of 420 feet. The Chase group includes the interval from the top of the Herington member of the Nolan limestone (Kansas) to the base of the Wreford limestone. The members of this group are descending: Herington, Krider, Winfield, Towanda, Fort Riley, Florence, and Wreford. The Herington, Winfield, Fort Riley, Wreford, and Florence limestones are readily differentiated by characteristic curves on electrical logs. The Fort Riley and Florence limestones, in particular, produce distinctive self-potential curves of practical value in correlation (Lukert, 1949).

Nolan Formation

The Nolan formation ranges in thickness from 95 to 102 feet, and includes two members: Herington and Krider.

Herington limestone. This is a buff to gray, dense, mottled limestone, exhibiting traces of dolomite. It approximates 16 feet in thickness.

Krider limestone. This is a dense, salt-and-pepper limestone with sucrosic texture, displaying coarser crystallinity near the base; it is slightly oolitic in some places.

Winfield limestone. The Winfield lies below the Krider limestone, although separated therefrom by a 40-foot sequence of gray-green, fissile shale. The Winfield is light buff to tan, coarsely crystalline, fossiliferous, and contains local chert lenses. It is 25 feet thick.

Towanda limestone. This tan to buff, medium-crystalline, somewhat mottled limestone, slightly oolitic near the base, lies 30 feet below the base of the Winfield. It is 15 feet thick.

Fort Riley limestone. A thin shale break separates the Towanda from the Fort Riley limestone, which is tan to buff, dense, fossiliferous, and contains traces of chert. This limestone averages 18 feet in thickness.

Florence limestone. This is a tan to gray-brown, dense, sucrosic limestone, displaying considerable blue-gray and gray streaked chert near the base. It is 60 feet thick.

Wreford limestone. Seventy feet below the base of the Florence lies the Wreford limestone, the intervening section being gray-green shale. The Wreford is an extremely fossiliferous bed containing blue and buff chert and pyrite zones. It ranges from soft, tan, medium-crystalline, to a semi-dense limestone.

Council Grove Group

The Council Grove group, slightly thicker than the Chase (averaging 420 feet), comprises the sequence from the base of the Wreford limestone to the base of the Foraker limestone. This group may be subdivided into: Funston, Cottonwood, Neva, Red Eagle, and Foraker, all of which are limestones separated by gray-green shales. Most of these limestones exhibit characteristic electric log curves.

Funston limestone. This relatively thin limestone lies 65 feet below the base of the Wreford limestone. It is tan to buff, medium-crystalline, and slightly mottled, displaying thickness of 19 feet.

Cottonwood limestone. This is a light gray to buff, fossiliferous, slightly mottled, shaly limestone. It is soft, slightly oolitic, and more argillaceous near the base. It ranges from 32 to 36 feet in thickness.

Neva limestone. This member, averaging 56 feet in thickness, is a gray to buff, dense, cherty limestone. Near the base it is coarser and slightly dolomitic. Abundant fusulinids characterize the member.

Red Eagle limestone. The Red Eagle lies 48 to 50 feet below the Neva, and is separated therefrom by variegated shales. The Red Eagle is a gray-pink, sucrosic, limonite-stained limestone. This unit lends itself admirably to correlation, because of its distinctive electrical characteristics.

Foraker limestone. The interval between the Foraker and the overlying Red Eagle consists of 25 to 30 feet of gray shales. The Foraker is one of the thickest Permian limestones in the thesis area, averaging 65 feet. It is light tan to dark buff, medium to finely crystalline, and contains abundant fusulinids and oolitic, gray-blue chert lenses.

Admire Group

This group includes the sequence from the base of the Foraker to the inconspicuous regional unconformity at the base of the Permian system. It is fairly persistent in thickness (100 to 110 feet), and is composed of green, gray, and variegated shales, and interbedded discontinuous tan to gray, semi-dense limestones containing mottled chert zones. A gray, medium-grained, porous sandstone lies within 10 to 20 feet of the base of this group. This basal sandy member has been termed the Indian Cave sandstone, a channel sandstone that is variable in extent (Lukert, 1949, p. 138).

No evidence was discovered to corroborate the Permo-Pennsylvanian unconformity because there is no lithologic contact between the formations above and below the contact.

Pennsylvanian System

The Pennsylvanian system consists of approximately 3,000 feet of interbedded limestones, shales, and sandstones. The system is subdivided into three series in this area: Virgilian, Missourian, and Des Moinesian. No pre-Des Moinesian Pennsylvanian formations are in Grant County.

Virgilian Series

Three groups comprise the Virgilian series (descending): Wabaunsee, Shawnee, and Douglas.

Wabaunsee Group

This group extends from the top of the Brownville limestone to the top of the Topeka limestone, and consists of shale and relatively thin, but persistent, limestones.

Brownville limestone. This unit is a light tan to brown, finely crystalline, sucrosic limestone. It averages 20 feet in thickness, and thins northward into a shaly limestone.

Greyhorse limestone. Shaly elements of this unit resemble the Brownville. This limestone is finely crystalline, mottled, slightly dolomitic, and contains local beds of chert and shale (slightly oolitic near the base). It is approximately 18 feet thick. The Greyhorse is separated from the Elmost-Reading limestone by gray-black, micaceous shale.

Elmont-Reading limestone. This limestone ranges from 20 to 22 feet in uniform thickness. It consists of thin to massive layers of tan, dense to sucrosic limestone, with white oolitic limestone near the middle. At the base of the Elmont-Reading, there is a fine-grained, gray, porous sandstone. The Stonebreaker is considered the equivalent of this limestone. The interval (essentially shale) between the Elmont-Reading and the Wakarusa-Burlingame limestone averages 50 feet.

Wakarusa-Burlingame limestone. This bed is fine- to medium-crystalline, mottled, gray, with thin shale streaks. Thirty feet of sandy shale separate this bed from the Happy Hollow limestone.

Happy Hollow limestone. Approximately 25 feet of sucrosic, porous limestone characterize this member.

Howard limestone. The top part of the Howard is a buff, coarsely crystalline, sucrosic, fossiliferous limestone; it is finely granular and softer near the base. Separating the Howard and Topeka limestones is a 12-foot, clear, medium-grained, white, porous sandstone.

Shawnee Group

All formations between the top of the Topeka limestone and the base of the Oread limestone are included in the Shawnee group. The interval includes: Topeka limestone, Pawhuska limestone, Elgin-Hoover sandstone, and Oread formation. According to Lukert (1949, p. 141), there are several

Lovell units, but for purpose of correlation, the contact of the Lovell limestone and the underlying Lovell sandstone is considered the base of the Shawnee group.

Topeka limestone. This uppermost Shawnee limestone lies 35 to 40 feet below the base of the Howard limestone, the intervening sequence being essentially interbedded thick shales and thin sandstones. The Topeka ranges in thickness from 60 feet (north) to 70 feet (south). It is a tan to brown, dense, fossiliferous limestone, with chert lenses. At the base it grades into a sandy limestone containing light gray shale lenses.

Pawhuska limestone. This bed, as the Topeka, ranges from 40 to 50 feet in thickness. It consists of white to mottled, semi-dense to sucrosic, cherty, fusulinid limestone. Resting 30 feet below the top is a zone of soft, salt-and-pepper, fossiliferous limestone. The interval from this fossiliferous limestone to the base is a finely crystalline, dolomitic limestone. R. C. Moore (1939, p. 68) considered the Deer Creek and Pawhuska limestones equivalent in age.

Elgin-Hoover sandstone. This zone consists of a comparatively thick section of thin-bedded sandstones and interbedded variegated shales and thin limestones. The zone from the top of the Hoover to the top of the Oread formation is approximately 250 feet thick. The sandstones are principally fine-grained, gray, micaceous, and calcareous. The thin limestones are sucrosic and sandy, with local chert and medium-crystalline dolomite lenses.

Oread Formation

This formation includes: Oread limestone, Endicott sandstone, and Lovell limestone. The most readily recognizable member of this formation is the Oread limestone, which is predominantly a porous to semi-dense, dark tan, mottled limestone with traces of chert; pyritic zones are common in the member.

Endicott sandstone. This unit consists of a series of shales and dirty-white, fine- to medium-grained sandstones.

Lovell limestone. The Lovell marks the base of the Shawnee group, and is considered the equivalent of the Toronto limestone of Kansas (Moore, 1951, p. 55). It is a tan to gray, finely crystalline, porous limestone with dolomitic streaks, and contains silicified fusulinids. It averages 15 feet in thickness.

Douglas Group

The lowermost group of the Virgilian series in the thesis area is the Douglas group, comprising the sequence between the base of the Oread formation and the base of the Tonkawa sandstone. The group includes: Lovell sandstone ("Lower Lovell"), Haskell limestone, and Tonkawa sandstone.

Lovell sandstone. The Lovell is off-white to gray, subangular, medium-grained, and calcareous.

Haskell limestone. This is an erratic argillaceous limestone, normally lying near the top of the Tonkawa zone.

Tonkawa sandstone. This unit averages 130 feet in thickness throughout the thesis area. It is an off-white to tan, medium- to coarse-grained, porous, micaceous sandstone containing local shale lenses. Near the base, it becomes finer, tighter, and exceedingly dolomitic. The Tonkawa is stratigraphically the youngest oil producing zone in Grant County, but it is non-productive in Rich Valley fields.

Missourian Series

In Oklahoma the Missourian series may be subdivided into the Ochelata and Skiatook groups, equivalents of the Kansas City-Lansing group of southern Kansas (Lukert, 1949, p. 146).

Ochelata Group

The shale sequence (with few sandstones) between the base of the Tonkawa sandstone and the base of the Cottage

Grove sandstone is included in this group.

Perry gas sandstone. The Perry sandstone is separated from the overlying Tonkawa by a thick shale interval. It is a tan to white, fine- to medium-grained, porous sandstone, irregular in thickness and changing facies laterally into shale. Approximately 190 feet of shale separates the Perry gas sandstone from the underlying Cottage Grove.

Cottage Grove sandstone. The Cottage Grove has long been known as the Layton sandstone in central Oklahoma. It is readily recognizable in electric logs from wells of northern Oklahoma and southern Kansas, because it displays characteristic curves. The unit is light gray to tan, medium-grained, and porous; near the middle it is micaceous; the base is slightly glauconitic.

Skiatook Group

This group includes in ascending order the Dewey limestone, Hogshooter and Checkerboard limestones, and Cleveland sandstone at the base. All the units display distinctive curves on electric logs. The Cleveland in Grant County is a shaly sandstone.

Dewey limestone. The Dewey consists of a series of thin, gray, finely-crystalline limestones in two mottled layers (sandy at top). The bed averages 80 feet in thickness.

Hogshooter limestone. This bed underlies the Dewey. It is brown to tan, finely crystalline, sucrosic, and slightly dolomitic; it may be mottled and fossiliferous.

Checkerboard limestone. Separated from the Hogshooter by 70 feet of shale, the Checkerboard is a tan, coarsely crystalline, sucrosic, cherty limestone. It averages 25 feet in thickness. Because of its distinctive lithology and electric log characteristics, the Checkerboard is a reliable datum.

Cleveland sandstone. This unit is gray, medium-grained, and micaceous; it is exceedingly lenticular in the thesis area.

Des Moinesian Series

This series includes the sequence from the base of the Missourian series to the unconformity at the base of the Pennsylvanian system. It is subdivided into two groups: Marmaton, and underlying Cherokee.

Marmaton Group

The Marmaton consists of a group of alternating limestones and shaly limestone. The principal limestones of the group are separated by shale beds. Two of the most conspicuous Pennsylvanian limestones in the area ("Big Lime" and Oswego) are assigned to this group. The "Big Lime" is correlated with the Oologah limestone, and the Oswego is correlated with the Fort Scott limestone of the Kansas section. This limestone interval is considered reliable for subsurface correlation, often being mapped as "Big Lime"-Oswego.

"Big Lime" limestone. This is a buff to gray, medium-crystalline, semi-dense to dense limestone that appears mottled near the base.

Oswego limestone. Thirty feet of gray-black shale separates the Oswego from the "Big Lime." The Oswego is a uniform 130-foot sequence of three limestone beds separated by black shales and thinner limestone layers. The two upper limestones are lighter tan to brown and medium crystalline. Near the base the Oswego is somewhat dolomitic, fossiliferous, more mottled, and darker. The lowermost of these three limestone layers marks the base of the Marmaton group.

Cherokee Group

The sequence from the base of the Marmaton group to the base of the Pennsylvanian system is included in this group. The Cherokee normally contains the following members:

Prue sandstone, Verdigris limestone, Skinner sandstone, Pink limestone, Red Fork sandstone, Inola limestone, and Bartlesville sandstone. However, in the literature concerning Grant County, the Cherokee group has never been subdivided into formations. Correlations of the Cherokee group displayed in the cross sections (plates VIII and IX) are based in part on Lukert (1949), Allen (1953), and Steele (1960).

Cherokee sediments in the thesis area consist predominantly of shale, interbedded with limestone and thin sandstones. The shale is gray to black, carbonaceous, and locally pyritic.

Limestones in the Cherokee group are brown to gray, fine- to medium-crystalline, with local shale streaks. Several of the limestones are persistent throughout the area, and display distinctive electric log characteristics.

Cherokee sandstones are off-white to buff, micaceous, fine- to medium-grained, and exhibit little porosity. In sections 6 and 7, T. 25 N., R. 4 W., a sandstone is found near the base of the Cherokee group. This sandstone has been termed "Red Fork" (Steele, 1960, oral communication), and attains an average thickness of 42 feet in the area.

The Cherokee lies at the base of the Pennsylvanian system, where there is a pronounced regional unconformity separating it from the Mississippian system. This unconformity at the base of the Pennsylvanian is indicated by the local absence of Atokan, Morrowan, and Springerian formations because of erosion prior to the onlap of Pennsylvanian seas, and by the absence of Upper Mississippian beds of Chester and Meramecian ages.

Mississippian System

This system is separated by an unconformity from the overlying Pennsylvanian system and underlying Paleozoic strata. The Mississippian system includes four series: Chesterian, Meramecian, Osagean, and Kinderhookian.

In north central Oklahoma, a conspicuous white chert of variable thickness marks the top of the Mississippian system. Rocks of this system include the Mississippi limestone and Woodford shale. The Misener sandstone, normally lying at the base of the Woodford shale, is absent in this area.

Chesterian and Meramecian series are absent in Grant County.

Osagean Series

The Mississippi limestone and other cherty limestones constitute the Osagean series. The weathered, reworked white chert discovered at the top of the Mississippi limestone is commonly termed the Mississippi "chat." It is fairly loose, soft, porous, and tripolitic. The "chat" varies in thickness throughout the thesis area. The Mississippi limestone proper is light gray to dark brown, hard, dense, siliceous, and cherty. Mottling and variation in grain size locally is observed. Near the base the limestone becomes darker, dolomitic, and glauconitic; pyrite is also present. The chert in the limestone is normally tan to pale yellow. The thickness of the Osagean ranges from 531 feet in section 36, T. 26 N., R. 5 W. to approximately 582 feet in section 16, T. 25 N., R. 4 W. The Mississippi limestone subcrop is correlated largely with the Boone chert of northeastern Oklahoma.

Kinderhookian Series

The Kinderhookian series is represented by the Woodford shale, which has been correlated with the Chattanooga shale of the Mississippi valley. Normally the Misener sandstone lies at the base of the Woodford, but it is absent in the thesis area. The Misener is definitely identifiable in only a few localities in southwestern Grant County (Dana, 1954, p. 29). The Woodford is a hard, cherty, brown to black, pyritic shale that ranges in thickness from 60 to 80 feet. It exhibits distinctive electric log curves.

Silurian and Devonian Systems

No Siluro-Devonian rocks are present in the thesis area, although there is a thin subsurface section of Siluro-Devonian (Hunton) rocks in the southwestern corner of Grant County.

Ordovician System

In northern Oklahoma, the Ordovician system is subdivided into: Sylvan shale, Viola limestone, Simpson group, and Arbuckle group, the last probably being Cambro-Ordovician in age.

Sylvan shale. This shale is absent in the area because of post-Devonian-pre-Mississippian truncation.

Viola limestone. This limestone is absent throughout the area, either because it was not deposited, or because it was subsequently removed by erosion after deposition.

Simpson Group

In descending order, the subdivisions of the Simpson are: Simpson "Dense" limestone, Simpson Dolomite, "First Wilcox" sand, "Marshall Zone," "Second Wilcox" sand, and Simpson green shale. The Simpson "Dense" limestone is absent throughout the thesis area because of post-Devonian-pre-Mississippian truncation.

Simpson Dolomite. This dolomite is fine- to medium-crystalline, light to dark brown, and sucrosic. It grades into a sandy dolomite to dolomitic sandstone near the base. The Simpson dolomite is the most readily recognizable unit of the upper Simpson, exhibiting sufficient porosity to display a characteristic electric log pattern.

"First Wilcox" sandstone. This unit lies beneath the dolomite, and is a clear, medium- to coarse-grained, subrounded, exceedingly porous sandstone, which normally displays oil staining. Large "golf ball" sand grains are more abundant in the "First Wilcox" than in any other part of the Simpson group (Dietrich, 1953, p. 10).

"Marshall Zone." This name was applied locally to the sequence separating the "First" and "Second Wilcox" sandstones, and it is principally sandstone containing shale breaks. The sandstone is tan, fine, subangular; the shale is green to dark green.

"Second Wilcox" sandstone. This sandstone is snowy-white to clear, fine- to medium-grained, angular, and normally has some calcareous cement. It is slightly tighter than the "First Wilcox," and contains a few large, rounded, frosted sand grains in the lower portion. In the basal Wilcox of the area, there are green waxy shale layers.

From the "Second Wilcox" sand to the top of the Arbuckle dolomite, there is a section of limestones and shales. This lower Simpson sequence has not been differentiated, essentially because of variation in thickness and uniformity of lithology.

Cambro-Ordovician System

Arbuckle Group

The Arbuckle limestone, oldest rock encountered in this area, is of unknown thickness. It is tan, medium- to finely crystalline, and dolomitic, and contains clear calcite crystals. It is sandy at the top, but it becomes dolomitic with depth. Pyrite and thin shale streaks are scattered throughout the limestone.

STRUCTURE

Regional Structure

The thesis area is located on the northern shelf area of the Anadarko basin, more specifically termed the northern basin platform. The hinge line of this platform has been located south of Grant County in Canadian County (Kimberlin, 1953). In western Kay County (near Grant County boundary) is the buried Nemaha ridge, which trends north-northeastward through Kay County.

The regional dip of outcrops is westward to south-westward, at less than one degree, with a regional strike slightly north of west.

This stabilized northern shelf area was gently folded and tilted while being uplifted. Unlike the Anadarko basin proper, the shelf area apparently has been subjected to a minimum of diastrophic activity because it displays very little faulting. Three regional features which probably affected the sedimentation and tectonics of the area are: ancestral Anadarko basin, Anadarko basin proper, and Nemaha ridge.

Local Structure

The Rich Valley area is located upon a structural nose trending northwestward through central Grant County.

Drilling has defined two prominent anticlines, upon which are found Rich Valley and Southeast Rich Valley oil fields. A shallow saddle separating the two fields is not too low structurally to prevent anticlinal accumulation of oil in Mississippian zones.

The northwestward strike of the Rich Valley anticlinal trend is a possible result of interaction of downwarping of the Anadarko basin (with northwestward strike) and the rising Nemaha ridge.

There is no evidence of faulting in the thesis area, and none has been reported by geological and geophysical departments of oil companies operating in this area (Steele, 1960, oral communication).

Subsurface Structural Map on Top Oread Limestone (Plate II)

The strike of beds exhibited on this Oread map is northwestward, being essentially the same trend as that of

Rich Valley oil fields. This map displays an anticlinal ridge with two separate areas of closure. The Rich Valley field has 20 feet of closure, compared with approximately 30 feet on the Southeast Rich Valley field.

The highest point of the map (-2073 feet) is on the Southeast Rich Valley anticline; the point is in SE¼ NW¼ NE¼ section 7, T. 25 N., R. 4 W. The apex of the structure here is irregular, displaying three individual "highs," with nominal closure.

The crest of the Rich Valley field is more uniform, as shown by the fact that three wells in section 36, T. 26 N., R. 5 W. display an elevation of -2083 feet.

The dip is 30 to 40 feet per mile on the west flank of the anticlinal ridge, and flattens to 26 feet per mile to the southwest. Troughs are located on both flanks, the eastern trough being more pronounced.

A small anticline is located in section 34, T. 26 N., R. 5 W. According to seismograph maps, this anticline appears smaller and not as clearly defined as Rich Valley structures. This smaller structure, in fact, displays no closure on the Oread limestone, but increasing amounts of closure are displayed on successively deeper strata. As a general rule, anticlines in the Rich Valley area exhibit increasing closure with increasing depth.

Subsurface Structural Map on Top Checkerboard Limestone (Plate III)

The Checkerboard map displays a structural pattern similar to that of the Oread (plate II). However, this Checkerboard map reveals more structural features in the thesis area, and also more closure on both Rich Valley and Southeast Rich Valley oil fields. Closure on the Rich Valley field increases from 20 feet on the Oread map to approximately 30 feet on this map, while the Southeast Rich Valley field has approximately 30 feet of closure on the Oread, compared with 50 feet on the Checkerboard. The Checkerboard is the uppermost datum displaying closure on the anticline west of Rich Valley field. Two small anticlines are mapped in the northern part of the thesis area along the trend of the Rich Valley ridge; both exhibit nominal closure.

There is slight increase in dip along the flanks of the Southeast Rich Valley field, but elsewhere the dip is essentially uniform.

Subsurface Structural Map on Top
Mississippian
(Plate IV)

In most of the thesis area, the Mississippian is marked at the top by the Mississippi "chat," but in the northwestern part of the area, a limestone bed marks the top.

This map clearly defines the subsurface structures of the area, and anticlines and troughs are more pronounced than on maps involving younger horizons. In the northwestern part of the map, the structures appear striking toward the northwest.

Closures on Rich Valley and Southeast Rich Valley fields are approximately the same as reflected by the Checkerboard (plate III). The shallow saddle separating the two fields is clearly expressed on this map, being sufficiently high, however, to permit continuous Mississippian production across the interval between the two fields. This continuous production in the saddle is permitted because the saddle is no lower structurally than -4165 feet; the lowest producing Mississippi well (Earlsboro Oil and Gas Company, No. 1 Joel Kirby, NW¼ NE¼ NW¼ section 18, T. 25 N., R. 4 W.) displays elevation on the Mississippi "chat" of -4180 feet. This well then is definitely lower structurally than the saddle. Further proof involves the fact that there are several wells in section 36, T. 26 N., R. 5 W. of the Rich Valley field which are producing from the Mississippi "chat." Thus, Mississippian production exists in both fields.

Subsurface Structural Map on Top Simpson Group (Plate V)

The Simpson map reveals structural patterns similar to those involving the three younger horizons. Accordingly, the persistent structural pattern from top Oread limestone downward indicates that the structures of Rich Valley fields were formed essentially in late Pennsylvanian or early Permian time. The structural relief of the Oread formation indicates at least a post-Oread uplift.

The trough in the eastern part of the area is most pronounced on the Simpson map; very steep dip may be observed on the eastern flank of the Southeast Rich Valley field. The western flank of the structure also displays general increase in dip (80 feet per mile) to the southwest.

The small structural anomaly in section 34, T. 26 N., R. 5 W. is also reflected with closure on this map.

The Rich Valley structure displays a maximum elevation of approximately -4720 feet, compared with -4730 feet in the Southeast Rich Valley field.

No structural anomalies were noticeable on this map that were not present on maps involving younger datum beds. In order to discover small structural anomalies one must have ample subsurface control, and use small contour intervals.

Isopachous Maps of the Effective Producing Zones Mississippian

General Statement

Data for these maps were obtained from micro logs and core analyses. Only wells were used in which either a micro log or core analysis was available. Figure 3 displays logs of Mississippian producing zones: Mississippi "chat," Mississippi limestone, and Second "chat." The Mississippi "chat" refers to the porous chert zone at the top of the Mississippian. The Mississippi limestone and the Second "chat" respectively are below the Mississippi "chat." The younger two zones generally are productive in the field areas. The Second "chat," fairly permeable and variable in thickness, is present throughout the thesis area, but it is productive only in the well in SE¼ SE¼ NW¼ section 7, T. 25 N., R. 4 W.

Figure 3 also reveals that effective thicknesses of producing zones are based on the amount of permeability within the zones. On plates VI and VII, the number above the

TYPE PRODUCTIVE ZONES OF THE MISSISSIPPIAN

TRIGG
NO. I NORMAN
SE-NE-SW
7-25N-4W

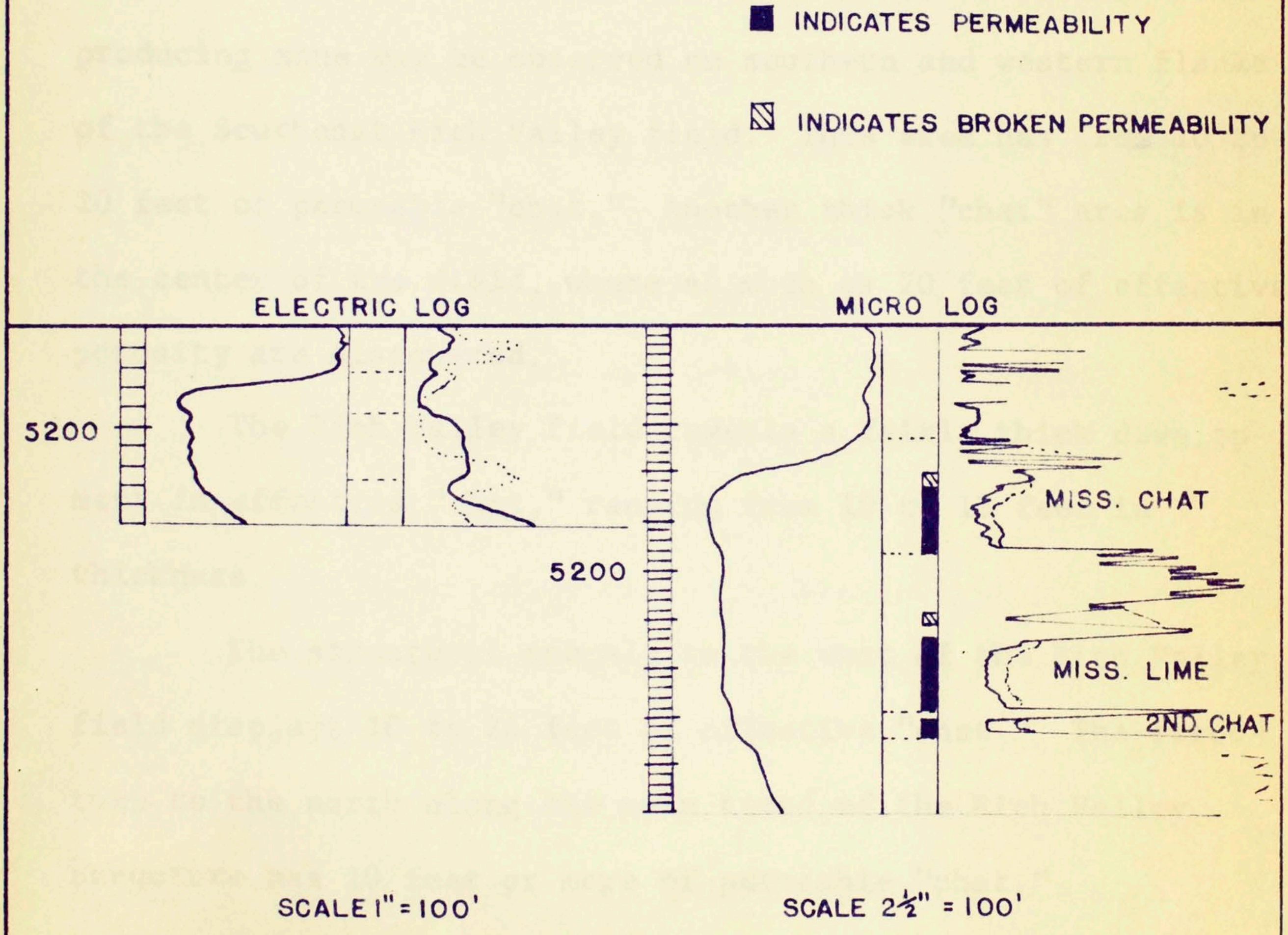


FIGURE 3

well indicates the thickness of the effective producing zone, whereas the number below the well indicates the total thickness of the zone. The maps are contoured on the thickness of the effective producing zones.

Isopach Map of Effective Producing Zone of Mississippi Chat (Plate VI)

This map reveals the irregular nature of the Mississippian throughout the area. Maximum thickness of effective producing zone may be observed on southern and western flanks of the Southeast Rich Valley field. This area has from 10 to 20 feet of permeable "chat." Another thick "chat" area is in the center of the field, where as much as 20 feet of effective porosity are discovered.

The Rich Valley field reveals a fairly thick development in effective "chat," ranging from 10 to 19 feet in thickness.

The structural anomaly to the west of the Rich Valley field displays 10 to 26 feet of effective "chat." The structure to the north along the main trend of the Rich Valley structure has 10 feet or more of permeable "chat."

The eastern flank of the structure displays little or no permeable "chat." The zero contour corresponds to the approximate location of the eastern trough. There is insufficient subsurface control to establish the zero limit of the western flank of the structure, but it probably corresponds closely to the position of the western trough.

A minor increase in the thickness of the permeable "chat" may be observed in section 16, T. 25 N., R. 4 W.

Isopach Map of Effective Producing Zone of Mississippi Limestone (Plate VII)

This map reveals essentially a thickness pattern similar to that of the Mississippi "chat" (Plate VI). The zero contour is again along the eastern flank of the structure. Also, the thickest zones of porous limestone are located on the western flank and center of the Southeast Rich Valley field, both areas exhibiting 20 to 30 feet of effectively porous limestone.

In the Rich Valley field the Mississippi limestone is not as thick, with the exception of a well in section 1, T. 25 N., R. 5 W., which has approximately 23 feet of permeable limestone. Examination of electric log characteristics of wells with micro logs and interpolating the data against well logs without micro logs permits the conclusion that the limestone is essentially impermeable in the Rich

Valley field, and the effective thickness is probably less than 10 feet throughout the area.

The structure west of the Rich Valley structure also exhibits a thickening of effective limestone (ranging from 10 to 30 feet). To the north along the trend of the structure, the small "highs" have ten or more feet of permeable limestone.

The saddle between the two fields has less than 10 feet of permeable limestone, as in the Rich Valley field.

Cross Section A-A'
(Plate VIII)

This east-west cross section extends from section 34, T. 26 N., R. 5 W., through the southern portion of the Rich Valley field, to section 31, T. 26 N., R. 4 W. Cross section A-A' reveals the structure, stratigraphic position, thickness, and electrical characteristics of all formations from the Fort Riley limestone to total depth in the Simpson group. Noteworthy characteristics of this cross section follow.

This profile subparallels the western dip of the subsurface formations, and displays the remarkable continuity of major and minor units of Upper Pennsylvanian (Shawnee) through Wolfcampian. A gentle westward dip is noted also throughout this sequence.

Perhaps the most irregular, fluctuating zone lending itself to ready identification on the electric log is the Tonkawa sandstone separating Lovell and Perry gas sandstones. This unit thins from 150 feet in well No. 1 to 100 feet in well No. 2; it thickens to 150 feet in well No. 3, and thins to 100 feet in well No. 4.

The cross section illustrates thickening of the Cherokee group in well No. 4 on the east flank of the structure, where the beds are thickest.

Post-Mississippian-pre-Pennsylvanian truncation resulted in essentially decreasing interval eastward. Maximum elevation of a Mississippian unit is in well No. 1 on the structure west of the Rich Valley field.

Truncation of the Simpson group closely resembles that on the Mississippian, with the Simpson group attaining maximum elevation in well No. 1.

Cross Section B-B'
(Plate IX)

This cross section was constructed across the crest of the Southeast Rich Valley field at right angles to the strike, from section 7, T. 25 N., R. 4 W., to section 6, T. 25 N., R. 4 W. The highest point on the crest of the

Southeast Rich Valley field is in Sinclair No. 2 Mulkey, SE¼ NW¼ NE¼ section 7, T. 25 N., R. 4 W. as shown on the cross section. Other noteworthy features of this cross section are enumerated below.

All producing zones of this area are well illustrated in Sinclair No. 2 Mulkey (Plate IX).

The same remarkable continuity of beds is noticeable in units of Upper Pennsylvanian through Wolfcampian.

The thickening of the Tonkawa sandstone is noticeable in well No. 3. This thickening is apparently a local sand lens.

The slight variation in thickness of the Cherokee sequence may be attributed to the possibility that the Cherokee was deposited upon an underlying Mississippian floor that had been differentially eroded and, accordingly, was not level in all places of deposition.

There is a marked decrease in the thickness of the Mississippian sequence in well No. 3 on the crest of the structure.

Post-Simpson-pre-Mississippian truncation is illustrated as an essentially level, but undulating, surface. The Simpson group also attains its maximum elevation in well No. 3.

GEOLOGIC HISTORY

General Statement

Northern Oklahoma has, for the most part, remained in approximately the same tectonic environment throughout the entire Paleozoic era. Nor has this area ever been covered by seas as extensive, for example, as those of the southern part of the state. The thickest units of uniform lithology involve Pennsylvanian sediments; these sediments thicken southward and thin northward as they approach the higher structural features of Kansas.

Mississippian and pre-Mississippian rocks in this region consist of large accumulations of limestone. Little is known regarding rocks of pre-Cambrian or early Cambrian ages.

Cambrian and Early Ordovician Periods

In Upper Cambrian time, the sea probably extended over all of northwestern Oklahoma, and deposited a thick section of limestone. This sea was probably an element of the earlier marine waters, which deposited a basal sandstone termed Reagan in Oklahoma, and Lamotte in Kansas. In early Ordovician time, there was a regression of the sea, and some of the Arbuckle was removed by erosion (Dietrich, 1955, p. 18). Evidence for this deduction is the apparent onlap of the overlying Ordovician sediments upon the eroded surface of the Arbuckle.

Ordovician Period

The lower Simpson group was probably deposited by a shallow, oscillating sea, which is indicated by the alternating shales and limestones in the lower part of this group. The variety of sediments comprising the group reflects fairly unstable depositional conditions.

Deposition appears to have been more or less continuous during late Ordovician (upper Simpson) time. Lithology of these units is constant over the entire area; so uniform sedimentary conditions are indicated.

Other units of Ordovician age are not present in the area.

Silurian-Devonian Periods

No Hunton limestone is present in the Rich Valley area, although the distribution of the Hunton in Oklahoma and Kansas suggests that the Hunton probably was deposited over the entire area. Post-Devonian uplift centering about the Chautauqua Arch resulted in unconformities upon the northern shelf. Erosion resulting from this uplift removed sediments from the top of the Hunton to the top of the Simpson group, and exposed over the shelf area a broad band of Simpson beneath Mississippian rocks. This uplift also tilted pre-Mississippian rocks southwestward.

Mississippian Period

In earliest Mississippian time the Misener sandstone was deposited in channels and other depositional troughs (Allen, 1953, p. 66; Caylor, 1957, p. 62). It is believed that the Misener was derived from the erosion of the Simpson sands exposed during the post-Devonian-pre-Mississippian uplift (White, 1928).

The early Mississippian Woodford shale and the Mississippi limestone are the two remaining pre-Pennsylvanian formations.

The early Mississippian (Kinderhookian) sea advanced from the south, depositing the Woodford shale. This Woodford was deposited unconformably upon the tilted, gently warped, and truncated older formations of the Simpson group.

In Osagean time, the thick-bedded, massive Mississippi limestone was deposited. The top of this massive formation is marked by a distinct concentration of nodular and angular fragments of chert, the result of weathering of the top of the formation. The surface of this limestone is fairly uneven, causing variable thickness of the overlying sequence.

The Upper Mississippian groups, Chesterian and Meramecian, were probably not deposited over the area, or if so, they were subsequently removed by erosion.

Pennsylvanian Period

No rocks of Springeran, Morrowan, and Atokan ages are encountered in Grant County. Pennsylvanian strata are chiefly basinal farther south, and probably did not extend over Grant County. Hence, the northern shelf has remained essentially a positive area or stable platform from Mississippian until the present time.

In Des Moinesian time the sea became more extensive, spreading across the northern shelf and depositing less clastics toward the north. There is a loss of section northeastward by onlap, of the base of the Cherokee group at a rate of 7 feet per mile (Dana, 1954, p. 49). In upper Des

Moinesian, or Marmaton time, a persistent series of carbonate rocks was deposited throughout the thesis area.

Structures of north central Oklahoma owe their origin, in part, to the uplift of the Nemaha granite ridge, which probably began in early Pennsylvanian time and continued throughout the late Paleozoic. The oil fields of north central Oklahoma roughly parallel this structure and form structural trends only a few miles apart. These trends persist as far as central Oklahoma, where the granite ridge apparently ended.

Anticlines of the Rich Valley fields were formed essentially in late Pennsylvanian or early Permian time. The structural relief of the Oread formation indicates at least a post-Oread uplift.

Clastic sedimentation was dominant in the Missourian epoch, shale being the principal deposit; the Cottage Grove, in fact, is the only thick sandstone of the series.

Permian and Later Periods

In the Wolfcampian series (Lukert, 1949), there is a striking continuity of thin limestones. Wolfcampian sediments display very little lithologic variation from the underlying Virgilian rocks.

After the Wolfcampian epoch, the sea was restricted and with restriction came evaporation and subsequent deposition of anhydrite beds. These sediments are considered to be Leonardian in age (Lukert, 1949).

After the Leonardian epoch, the area was slightly uplifted and eroded. This erosion removed Upper Permian and younger beds, so that rocks younger than Leonardian do not crop out in Grant County. The westward dip of Permian and Pennsylvanian strata in the area is probably due to post-Leonardian uplift (Caylor, 1957, p. 67).

No formations considered to be either Triassic or Jurassic are found in Grant County.

Quaternary surficial sediments are represented by stream alluvium and eolian deposits.

DEVELOPMENT OF RICH VALLEY OIL FIELDS

History of Development

The first well drilled in the Rich Valley area was the Bw-Vi-Bar, No. 1 Hurst, in center SW¼ section 25, T. 26 N., R. 5 W. It was completed as a dry hole in 1930.

The discovery well for the Rich Valley field was the Viersen-Cochran, No. 1 Vollmer, NE¼ NE¼ NE¼ section 1, T. 25 N., R. 5 W. It was completed in early January, 1948, as a flowing oil well from the "Second Wilcox" sand, and produced 940 barrels of oil per day.

In the Southeast Rich Valley field, the discovery well was the Sinclair Oil and Gas Company, No. 1 Hyder Mulkey, NW¼ NW¼ NE¼ section 7, T. 25 N., R. 4 W. It was completed early in June, 1951, flowing 412 barrels of oil and 536,000 cubic feet of gas per day from the "Second Wilcox" sand.

In these fields (and adjacent area), 100 wells have been drilled, of which 76 were oil wells, one was a gas well, and 23 were dry holes. The latest producing well was drilled in September, 1960, being completed in the Mississippi "chat"--this is the Earlsboro Oil and Gas Company, Inc., No. 1-B Moore, 150 feet east of SW¼ SE¼ SE¼ section 36, T. 26 N., R. 5 W. There was a drilling operation in progress in the Southeast Rich Valley field on December 15, 1960.

There have been 39 wells drilled to date in the Rich Valley area. Thirty-one of these were drilled to the "Second Wilcox" sand; of these 18 were completed as oil wells. Recently, five of these 18 were plugged back and completed in the Mississippian (Table 1) and one of the original dry holes was recompleted in the Mississippian as a producing oil well. The remaining 8 wells were drilled to the Mississippian, and 4 were completed as oil wells. Of the original 23 oil wells, 15 have been abandoned.

Sixty-one wells have been drilled to date in the Southeast Rich Valley area. Twenty-five of these were drilled into the Simpson series, and 35 were drilled into the "chat" and limestone series of Upper Mississippian.

Fifteen producing "Second Wilcox" sand wells were completed in this field; and 4 have been plugged back and completed in the Mississippian as producing wells. Six original dry holes in the Simpson were recompleted in the Mississippian, with 5 of these being producers, and one being non-commercial.

Of the 35 wells drilled to the Mississippian, 32 have been completed as producing wells, two were completed as dry holes, and one was temporarily abandoned as a dry hole.

As of November 1, 1960, there are 60 oil wells and a gas well producing from the following reservoirs: Mississippian, 48; "Second Wilcox" sand, 12; and dual production from Mississippian and "Second Wilcox" sand, 1.

Production

Production in the Rich Valley fields is closely related to structure. Productive limits of the Rich Valley field and the eastern flank of the Southeast Rich Valley field are readily apparent in the line of unprofitable wells or salt water producers about the structures.

Both flowing wells and those which require initial pumping are common in the Rich Valley area. In general, the Simpson wells flowed upon initial completion, whereas many of the Mississippian wells required pumping.

The moving energy in both Mississippian reservoirs is gas in solution; while in the Simpson, it is water drive. The "Second Wilcox" is the discovery zone of the fields, and it was the major oil producing horizon during the early development of the area. The Mississippian is now the main producing formation.

The upper oil-bearing Mississippian section averages 48 feet in thickness, with an average net effective pay section of 31 feet. Production is obtained from both the "chat" and limestone and normally both are treated with water and acid to increase the well-bore permeability. It is estimated that there is approximately 200 to 270 barrels of recoverable oil per acre-foot of net effective pay for the Mississippian section (Steele, 1960, oral communication).

In the Rich Valley fields, water in great amounts is produced with the oil, ranging from 30 percent to 40 percent. There appears to be no relationship between structure and the amount of water produced. Some of the lower structural wells produce less water than the ones along the crest of the anticline.

As of November 1, 1960, the Rich Valley fields were producing pipe line "runs" of 636 barrels of oil per day, and their total cumulative production was approximately 3,016,702 barrels of crude oil of approximately 41° gravity API.

Drilling and Completion Methods

The wells in the Rich Valley area were drilled with rotary tools, using a 20-acre spacing pattern. Electrical logs were obtained from all wells, and micro-logs obtained from most of the recent wells. Generally, drill stem tests were made only in wells drilled to the Simpson. Drill stem testing in the Mississippian is not particularly successful, because of low porosity and permeability prior to treatment.

Eighteen to 21 days were required to drill a well to 5,200 feet to the Mississippian; and 25 to 30 days, to 5,800 feet to the Simpson. Costs of drilling and completing wells ranged from $55,000 to $60,000 for the Mississippian, to $60,000 to $70,000 for the Simpson.

General practice involved setting 100 to 165 feet of 10 3/4-inch surface casing, and cementing it with 100 to 115 sacks of cement. Generally, the size of the oil string is 6 5/8 to 7 inches for the Simpson wells, and it is set atop or 1 to 2 feet within the "Second Wilcox" sand. In the Mississippian well, the oil string is 4½ to 5½ inches, and it is set through the "chat," and approximately 1 foot within the limestone. Treatment of the pay zone was required in most wells. Normally, the procedure for Mississippian wells was to set a packer between the "chat" and limestone, and to water-frac the "chat," and acidize the limestone. "Second Wilcox" wells locally required acidization.

Coring routine included use of diamond bits; normally all coring footage was recovered. Coring programs were practically confined to the productive portion of the Mississippian.

Transportation of Rich Valley oil and gas is accomplished by a pipeline gathering system. The two operators of the pipelines are Mid-Continent Oil and Gas Company and Tulsa Crude Oil Company.

TABLE 1

DRILLING AND COMPLETION STATISTICS, RICH VALLEY OIL FIELDS

Year	Wells Drilled	Simpson Pay Zone	Mississippian Pay Zone	Dry Holes	Mississippian Recompletions	Mississippian Plug Backs	Abandoned	Total Producing Wells
1949	9	6	0	3	0	0	0	6
1950	0	0	0	0	0	0	0	6
1951	11	11	0	0	0	0	1	16
1952	22	12	2	8	0	0	0	30
1953	4	1	1	2	0	0	2	30
1954	1	1	0	0	0	0	3	28
1955	3	1	2	0	0	1	0	31
1956	13	0	8	5	4	4	0	43
1957	13	0	11	2	0	1	1	53
1958	8	0	6	2	0	1	1	58
1959	9	0	6	3	0	1	0	64
1960	4	0	3	1	0	2	5	62

TABLE 2

PRODUCTION AND DRILLING STATISTICS, RICH VALLEY OIL FIELDS

(Production in Barrels)

Year	Wells Drilled	Wells Producing	Wells Abandoned	Daily Average Production	Cumulative Production
1952	22	30	0	1,115	1,041,224
1953	4	30	2	630	1,386,217
1954	1	28	3	366	1,579,403
1955	3	31	0	571	1,776,111
1956	13	43	0	622	1,965,468
1957	13	53	1	761	2,229,316
1958	8	58	1	903	2,507,951
1959	9	64	0	813	2,797,314
1960	4	62	5	636	3,016,712*

*As of November 1, 1960.

FUTURE POSSIBILITIES

General Statement

Because of the proximity of the Nemaha uplift to the Rich Valley area, there are probably more small structural anomalies in this area than have been discovered to date. Seismograph surveys have indicated the possibility of a structural anomaly subparalleling the Rich Valley fields to the west. Indications of structural movement date from the Devonian period, and recurring uplifts that occurred during Pennsylvanian and Permian periods provided a long period of geologic time in which structural anomalies might have formed.

Permian

Permian beds in the Rich Valley area are at or very near the surface, and afford few possible traps. Although the Wellington anhydrite has been productive to the west, this zone offers very little possibility for petroleum accumulation in this area. The established structures of Rich Valley fields are but slightly reflected in Permian strata;

the only possible productive zones would be of Wolfcampian age.

Pennsylvanian

To date there has been no production from Pennsylvanian strata in the Rich Valley area. However, oil stains have been noticed in this sequence.

The remarkably uniform character of the Pennsylvanian beds, as illustrated on the cross sections (plates VIII and IX) in this area suggests that any petroleum traps that may be discovered herein will be stratigraphic in nature. Possibilities for stratigraphic traps in the Rich Valley area would involve lateral gradation of a porous, permeable bed into a permeability barrier, such as shale or tight limestone.

Mississippian

The Mississippian system now includes two leading producers of oil in the Rich Valley area: Mississippi "chat," and Mississippi limestone, the "chat" being the main producing zone. Sufficient micro-logs and core analyses have been obtained from wells in both Rich Valley fields to conclude that many porous and permeable zones occur in the "chat" and limestone (plates VI and VII).

Because of lesser permeability of the "chat" and limestone in the Rich Valley field, it is not as promising a reservoir rock here, as it is in the Southeast Rich Valley field. There is no other reason, however, why additional substantial oil reserves cannot be established in the Southeast Rich Valley field from both the Mississippi "chat" and limestone. Several locations may prove productive from these horizons on acreage along southern and western flanks of the Southeast Rich Valley field. Additional locations could possibly prove productive west of the Rich Valley field, provided the acreage is upon anticlinal structure.

Ordovician

The Simpson group was originally the leading producer in the area, and it was the objective of all early drilling. The "Second Wilcox" sand is the leading producer in the Simpson group, with a minor amount of oil obtained from the Simpson Dolomite. The "Second Wilcox" sand has been replaced as the most prolific oil-bearing formation by Mississippian zones. Most of the wells that were completed in the Simpson as early as 1952 have been either abandoned or plugged back to Mississippian zones (Table 1). Limited closure on all maps indicates that the anticlines themselves are not of sufficient magnitude to trap large quantities of oil.

The Simpson group has been relatively untested during recent drilling activity, especially in southern and western portions of the Southeast Rich Valley field. Although the outlook for future Simpson production is not encouraging, the southwestern part of the Southeast Rich Valley field offers the best possibilities for expansion of Simpson production, because it has not been tested.

The Arbuckle limestone has not been sufficiently explored to determine its potential as a future producing horizon, because only one well in the Rich Valley area has penetrated the top of the Arbuckle. The top of the Arbuckle produces commercially in southern Kansas and in Woods County, Oklahoma. There is a possibility that it may be investigated more commonly in the future, because of the recent discovery in Woods County.

CONCLUSIONS

The following results are presented from this detailed subsurface study of Rich Valley oil fields in Grant County, Oklahoma:

1. Rich Valley oil fields lie upon the eastern edge of the northern shelf of the Anadarko basin.

2. Surface formations from Quaternary to late Enid (Leonardian) are exposed in the area.

3. The strike of the beds is northwestward with dip of one degree or less southwestward.

4. The surface expression of the Southeast Rich Valley oil field has apparently influenced the course of the Salt Fork of the Arkansas River.

5. The Herington limestone is the youngest bed correlated in the subsurface. Permian sediments as old as early Leonardian are predominantly of continental origin, while pre-Leonardian strata are essentially marine.

6. The Pennsylvanian-Permian contact is questionably unconformable. Evidence of an unconformity separating

Pennsylvanian and Permian sediments in the Rich Valley area is inconclusive.

7. Anticlinal structures of the Rich Valley oil fields were formed essentially in late Pennsylvanian or early Permian time.

8. The Virgilian series (Upper Pennsylvanian) are principally limestones and shales with several sandstones.

9. Missourian and Des Moinesian series (Middle and Lower Pennsylvanian, respectively) consist of shales, sandstones, and limestones.

10. Base of the Pennsylvanian system is at the base of the Cherokee group; and the system was deposited upon an irregular, eroded Mississippian surface.

11. There is no production from Permian and Pennsylvanian strata in the Rich Valley area.

12. Pre-Pennsylvanian production involves the Mississippi "chat," Mississippi limestone, and Simpson sandstone and dolomite.

13. The Mississippi "chat" is fairly thick over the area, and contains porous zones favorable for accumulation of oil.

14. The Mississippi "chat" and limestone thicken and become more permeable on the western flank of the Southeast

Rich Valley oil field.

15. The upper productive Mississippian section averages 48 feet in thickness throughout the area, with an average net effective pay section of 31 feet.

16. Most favorable possibilities for future production in the Rich Valley fields are in the Mississippi "chat," Mississippi limestone, and Simpson zones about the western flanks of the structure.

17. A profound regional unconformity marks the base of the Woodford. The Woodford shale rests upon Simpson strata, thus indicating a post-Devonian-pre-Mississippian erosional hiatus.

18. Silurian and Devonian sediments are not present in the thesis area.

19. The local structural anomaly in section 34, T. 26 N., R. 5 W. has possibilities for production from Mississippian and/or Simpson zones.

20. The Arbuckle limestone (Ordovician) is the oldest rock encountered in the area.

21. Porous elements of the Arbuckle limestone may produce oil in the future.

BIBLIOGRAPHY

Allen, A. E., 1954, The subsurface geology of Woods and Alfalfa Counties, northwestern Oklahoma: Shale Shaker, Oklahoma City Geol. Soc., vol. 4, no. 8.

Bryan, R. C., 1950, The subsurface geology of the Deer Creek, Webb, and North Webb oil pools, Grant and Kay Counties, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.

Cary, L. W., 1955, The subsurface geology of the Garber area, Garfield County, Oklahoma: Shale Shaker, Oklahoma City Geol. Soc., vol. 5, no. 6.

Caylor, J. W., 1957, The subsurface geology of Western Garfield County, Oklahoma: Shale Shaker, Oklahoma City Geol. Soc., vol. 7, no. 4.

Clark, G. C., and Cooper, C. L., 1927, Kay, Grant, Garfield, and Noble Counties, Oklahoma: Oklahoma Geol. Survey, Bull., vol. 2, no. 40.

Dana, G. F., 1954, The subsurface geology of Grant County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.

Dietrich, R. F., Jr., 1955, The Simpson group along the northern flank of the Anadarko basin: Shale Shaker, Oklahoma City Geol. Soc., vol. 5, no. 5.

Gould, C. N., 1925, Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35.

Green, D. A., 1936, Permian and Pennsylvanian sediments in central and west central Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 20, no. 11, p. 1454-1475.

Ingalls, P., 1953, Oil on the Anadarko shelf jumps west: Oil and Gas Jour., vol. 52, no. 18.

Kimberlin, P., Jr., 1954, The subsurface geology of Canadian County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.

Lukert, L. H., 1949, Subsurface cross-sections from Marion County, Kansas, to Osage County, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 33, no. 2, p. 131-152.

Moore, C. A., 1952, Stratigraphic trap possibilities in the Anadarko basin: The Petroleum Engineer, vol. 24, no. 12, p. B7-B16.

Moore, R. C., 1939, Guide Book, Eleventh Annual Field Conference: Kansas Geol. Society.

________ et al., 1951, The Kansas rock column: Kansas State Geol. Survey, Bull. 89.

Stanbro, G. E., 1960, A subsurface study of the "Cherokee" group of Grant County, and a portion of Alfalfa County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.

Vance Rowe Production Reports, 1952-1960, Northwestern Oklahoma, Tulsa, Oklahoma: Petroleum Statistical Guide, Inc.

Wheeler, R. R., 1952, Anadarko basin geology and oil possibilities: World Oil, vol. 127, no. 4.

White, L., 1928, Correlation of the Wilcox sandstone series, Oil and Gas in Oklahoma: Oklahoma Geol. Survey, Bull. 40.

Personal Communications:

Steele, G. M. Jr. (oral communication), 1960.