THE SUBSURFACE STRUCTURE AND STRATIGRAPHY RELATED TO PETROLEUM ACCUMULATION IN RICE COUNTY, KANSAS

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A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1954

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INTRODUCTION

Purpose of Investigation

The purpose of this report is to analyze the geologic history, subsurface structure and stratigraphy of Rice County, Kansas and to determine the relationship of these geological factors to the accumulation of petroleum.

Area Covered by the Report

Rice County is in central Kansas (Fig. 1,appendix). It is bordered on the west by Barton and Stafford Counties, on the north by Ellsworth County, on the south by Reno County and on the east by McPherson County. Rice County is enclosed by Townships 18, 19, 20 and 21S., and by Ranges 6, 7, 8, 9 and 10W. It contains about 20 townships and has an area of about 721 square miles. The area lies in the Plains Border section of the Great Plains province and comprises dissected uplands and filled valleys that present low topographic relief. The Arkansas River and its tributaries drain the area.

Procedure

The Arbuckle dolomite of Ordovician Age and the Mississippi "Chat" of Mississippian Age appear to be the most significant horizons to reveal structure and stratigraphy. The Arbuckle is the largest producer and portrays the most structure while the Mississippi "Chat" shows interesting stratigraphy, although it does not produce over as large an area as the Lansing-Kansas City formations of Pennsylvanian age. Next, all elevations available were used to construct structural contour maps of these two formations. These points were obtained from Herndon Maps and from the Geological Survey of Kansas.

GEOLOGY OF THE AREA

Geologic History

Paleozoic Era. Records of deep drilling in Rice County show that a thick section of Paleozoic rocks exists above the pre-Cambrian surface. The pre-Cambrian surface is found at depths ranging from 3,240 to 4,100 feet. Marine Cambrian and Ordovician rocks were deposited over this igneous and metamorphic floor. Silurian and Devonian rocks are absent over most of the county. They either were not deposited over much of the area or were removed by erosion following the pre-Mississippian uplift of the Ellis arch (Fent, 1950). According to some geologists the Central Kansas uplift was not formed until Mississippian times and the pre-Cambrian surface of pre-Mississippian time is called the Ellis arch. The southeastern tip of the Ellis arch extends into Rice County and pre-Mississippian rocks in part of northwestern Rice County were removed by erosion, leaving the Ordovician surface exposed. Cambrian and Ordovician rocks in the southeastern part of the county on the flanks of the uplift were tilted and beveled by erosion. Mississippian rocks form an angular unconformity with the underlying rocks.

The Mississippian rocks were later tilted and uplifted by the crustal movements that formed the central Kansas uplift which extends into Rice County from the north-northwest (Fent, 1950). Mississippian rocks were removed by erosion over most of the county (Fig. 4, 5, and 6, appendix). Tilted Mississippian rocks occur in the southeastern and eastern part of the county on the flanks of the uplift. The area was again submerged and more than 3,500 feet of Pennsylvanian and Permain beds were deposited on the beveled erosional surface of the earlier rocks. Lower Pennsylvanian beds are in contact with Ordovician rocks in parts of Northwestern Rice County.

Another major period of emergence and erosion followed the deposition of the Permian. Thick red shales, salt, gypsum and anhydrite occur in the upper part of the Permian. A major unconformity at the contact of the Permian with the overlying Cretaceous rocks indicates a long period of erosion.

Mesozoic Era. The area was probably land during Triassic and Jurassic time. In early Cretaceous time, fine grained sandstones and siltstones of the Cheyenne sandstone were deposited on the eroded surface of the Permian.

The dark marine shales of the Kiowa were deposited above the Cheyenne. Evidence of a minor erosional interval exists between the Cheyenne and Kiowa rocks.

As the comparatively shallow seas receded, the area was covered by near-shore marine sandstone and beach deposits. Alternating marine and continental deposits near the close of Early

Cretaceous time indicate near-shore conditions and an oscillating shore line. These conditions of depositions of the sandstones and clays of the Dakota, which immediately overlies the Kiowa, have been compared to conditions of deposition of sedimentation existing in the lower Mississippi delta (Plummer and Romary, 1942). In such an environment, shifting stream channels deposited sand, silt, and clay over a wide area slightly above sea level. Deposition barely balanced submergence of the land mass. Such conditions of sedimentation can be postulated for most of the Dakota formation.

Marine Cretaceous beds were deposited over the Dakota formation in the county. This is indicated by the presence of Graneros and Greenhorn beds a short distance to the north and west. It is estimated that at least 900 feet of Cretaceous beds (Fent, 1950) were removed by erosion following the uplift at the close of the Cretaceous.

Cenozoic Era. Rice County probably was subjected to erosion during most of the Tertiary Period and by late Tertiary it was an area of low relief. Remnants of late Tertiary sediments are found in the western, northwestern, and central parts of the county.

Renewed erosion in early Pleistocene deeply dissected this surface. Deep valleys were carved into Cretaceous and underlying Permian beds. At least four major changes in the relative effectiveness of the forces of erosion and deposition during the Pleistocene (Fent, 1950) are recorded in the thick unconsolidated deposits mantling the rugged early Pleistocene topography.

Stratigraphy

Surface to Pennsylvanian. This section is covered as one unit because there are no important oil horizons within this section in Rice County. It also lies above the section covered in Fig. 4, which is the part of the stratigraphic section that is stressed.

The outcropping rocks of Rice County include Quaternary, Cretaceous and Permian. Pleistocene and Recent deposits outcrop throughout the county with the Dakota formation and the Kiowa shale formation of Cretaceous age outcropping in the northeastern and eastern part. The Harper sandstone member and the Ninnescah shale member of Permian age outcrop in a small area in the extreme east-central part of the county.

The average thickness of the section from the surface to the top of the Pennsylvanian ranges from 2,500 feet in the southeast to 2,800 feet in the northwest. The Quaternary and Tertiary rocks range in thickness from 0 to 100 feet and are composed of dune sands, medium to fine gravel, and sand composed mostly of fragments of Cretaceous "ironstone, sandstone, and limestone." The rocks of Cretaceous age belong to the Colorado group which is represented by the Cheyenne sandstone, the Kiowa shale, and the Dakota formation. Their thickness ranges from 400 to 700 feet.

The Permian rocks in the Rice County area may be divided in an upper Red-bed section, the Cimarron series and a lower, less red, more calcareous section, the Big Blue series. The approximate thickness of the Permian rocks is about 2,200 feet.

Pennsylvanian. The top of the Pennsylvanian System is picked at the unconformity at the base of the Indian Cave sandstone of Permian Age. Pennsylvanian beds on the crest of the Central Kansas uplift are about 1,000 feet thick, but on the flanks are considerably thicker. A regional thinning of Pennsylvanian beds occur toward the west and northwest.

The Central Kansas uplift was not covered by Pennsylvanian sediments until Kansas City time in Rice County (Fig. 4). The differential character of the structural movement in this region is revealed by gradual thinning of all Pennsylvanian groups above the Desmoinesian over the crest of the uplift and other minor anticlines.

Wabaunsee Group. The Wabaunsee group includes the youngest rocks of Pennsylvanian age. In Rice County the Wabaunsee group is commonly a series of micaceous sandy shale, relatively thin limestone beds, and important red shale zones.

Shawnee Group. The Shawnee group in Rice County consists of limestone, shale and sandstone. The group is divided into four thick limestone formations which includes shale members. They alternate with thick shale formations, some of which include thin limestone beds. The Shawnee Group is present across all of Rice County. Shawnee beds thicken toward the Salina Basin. The average thickness is 325 feet (Moore, et al., 1951).

Douglas Group. The Douglas Group underlies the Shawnee group conformably, chiefly composed of clastic rocks, shale, and sandstone. Limestone, coal, and conglomerates are quantitatively of minor importance. In Rice County, the thickness is approximately 200 feet.

Pedee Group. The only representative of the Pedee Group in Rice County is the Iatan limestone. Drillers and Geologists log this as the "Brown Lime". It is a light bluish-gray to nearly white limestone. The texture is very fine and dense, but there are numerous thin, irregular plates of clear calcite. The average thickness is 15 feet.

Lansing-Kansas City Groups. The combined thickness of the Lansing-Kansas City groups ranges from 350 to 450 feet in Rice County. The variations in the thickness are due, in part, to the unconformity at the top of the Lansing but are mainly due to the result of differential structural movements. The Lansing-Kansas City sequence consists of cyclic deposits of limestone and shale, the latter being minor in total amount and occuring in thin breaks in the sequence. The most characteristic feature of the Lansing-Kansas City, and one which may be used to distinguish it from other parts of the Pennsylvanian surface section, is the oolitic nature of many of its members.

Nearly all of the oil production from the Lansing-Kansas City has been found in these oolitic zones. One well in a pool may miss an oolitic zone, and likewise miss production, although its offset is a profitable producer from the same depth. Certain more or less cherty zones may also be identified. The producing zones in the Lansing-Kansas City are generally named from the distance they occur from the top of the lime. Post Lansing-Kansas City erosion has removed more of the Lansing-Kansas City beds in some areas than in others.

The Lansing-Kansas City top is generally the first top logged by geologists in Rice County when sitting on a well.

Pleasanton Group. The Pleasanton Group is all but absent in Rice County so therefore it is not logged on Fig. 4. It ranges from a featheredge on the outer flank of the Central Kansas uplift to about 35 feet thick in the center of the Salina Basin in Northern McPherson County.

Marmaton Group. The Marmaton group consists of the rest of the Pennsylvanian rocks in Rice County with the exception of the Pennsylvanian Basal Conglomerate. It extends from the base of the Kansas City to the conglomerate, if the conglomerate is present, or to the unconformity separating the Pennsylvanian from the Mississippian, if the conglomerate is missing.

The Marmaton group is composed of alternating thin shales and thin and massive limestones, with some sandstone present. The Marmaton group is not sub-divided on the Isometric Panel Diagram (Fig. 4, appendix) but is known to contain the Oolagah and Fort Scott limestones. In the subsurface these limestones are referred to as the "Big lime" and the Oswego limestones. Together they form an excellent zone for correlation.

The Marmaton group ranges in thickness from a featheredge in the Northwest of the County to more than 250 feet in the Southeastern part, which is in the Salina basin.

The Cherokee formation is included with the Marmaton in the Isometric Panel diagram (Fig. 4). It is present only in the Southeastern part of the county and reaches a thickness of approximately 50 feet. The Cherokee deposits consist of various kinds of shale, beds of sandstone, and infrequent thin beds of limestones and coal.

Pennsylvanian Basal Conglomerate. The conglomerate underlies rocks from Lansing-Kansas City to Marmaton in age. The conglomerate is a transgressive deposit, overlying rocks from Ordovician to Mississippian in age. In its most common development it is a coarse cherty, partly sandy conglomerate, commonly cemented with red shale. In Eastern Rice County, the red shale composes most of the material. The chert is commonly white, yellow, red, brown, gray, or black, partly oolitic dolocastic, rarely sandy, but everywhere weathered and reworked. Dolomite, green shale, gray shale, and other types of pre-Pennsylvanian and Pennsylvanian material are intermixed.

The conglomerate is clearly derived from what ever type of sediments were at hand for reworking and redepositing as the first Pennsylvanian sea advanced upon the uplift. It represents the first deposit of a transgressive sea.

The conglomerate is missing in Northeastern Rice County, where in this part of the Salina basin the sediments were not reworked. The conglomerate ranges from a featheredge to more than 50 feet in the Wherry Pool area.

The producing zone in the Wherry Pool, located in south-central, southeast Rice County (Fig. 2, appendix), is in this Conglomerate. It is called the "Sooy" conglomerate in the Wherry Pool.

Mississippian. The Mississippian limestones were deposited on the nearly flat surface of the Chattanooga shale. After the Mississippian rocks were deposited, they were folded and elevated, by renewed activity of the Central Kansas uplift. Erosion of the uplifted area removed the whole sequence of Mississippian rocks and some additional older rocks from its crest before the beginning of Pennsylvanian deposition (Fig. 4). The erosion reduced the surface in pre-Pennsylvanian time to a flat, horizontal peneplane. Figure 6, a structural contour map of the erosion surface of the Mississippian, shows the pre-Pennsylvanian surface. It shows a homoclinal dip to the east off of the Central Kansas uplift.

The erosion following the upheavel completely removed the Chesteran series and most of the Meramecian in Rice County.

The Mississippian thickness ranges from a featheredge in the Northeast and South-central to over 450 feet in the Southeast.

The thickness of the Mississippian limestone in Rice County bears a close relation to the geologic structural features of the County, and thus to the occurrence of the oil and gas deposits.

Production in Mississippian rocks is dependent on the porosity of the limestone. The base leveling of the folded rocks brought the various formations of the Mississippian to the surface at different places and subjected them to weathering and leaching. In some places where the ground-water had been lowered by erosion, porous zones (Lee, 1939) are present to a depth of over 100 feet below the surface of the Mississippian.

Meramecian Series. The Meramecian rocks originally extended throughout Rice County but were eroded from most of the county before Pennsylvanian deposits were formed. The only Meramecian rocks in Rice County are in the extreme southeast. On the Isometric Panel Diagram (Fig. 4), the Meramecian limestone is listed with the Mississippi "Chat" of the Osagian Series.

The Meramecian Series of Rice County consists mainly of oolitic limestone with some interbedded dolomite. There rocks are designated as the Mississippi "Lime" by drillers and oil men.

Osagian Series. The Limestones of the Osagian series are referred to as the Mississippi "Chat" and contain some of the best oil wells in Rice County. In the southeastern part of the county the "chat" consists of dolomitic limestones interbedded with vitreous dark to almost black chert. Farther west, the dolomitic limestone changes gradually to semigranular limestones with variable amounts of semitranslucent limestone with variable amounts of semitranslucent to translucent bluish, gray, and colorless chert.

The isopach map (Fig.5) shows the thickness and distribution of the Mississippian "Chat" along with what little Mississippi "lime" is present.

The isopach map (Fig. 5) shows the section of Mississippian from the top of the Kinderhookian to the base of the Pennsylvanian basal Conglomerate. It shows the "chat" thickness to range from a featheredge in the northeast, central, and southwest to over 250 feet in the southeast.

The zero line of the Isopach map (Fig. 5) was adapted from plate 8, bulletin 74, Kansas Geological Survey, 1948, by Wallace Lee. Subsequent drilling, since this article, alters the line to the present position. The dotted line shows Mr. Lee's original line.

The Welch, Bornholt, and Smyers oil fields of southeast and eastern Rice County are more or less centered on the 100 foot isopach line. The oil from these oil fields is produced from a very tightly compact cherty zone ranging from 15 to 25 feet below the top of the "Chat". They are so compact that fracturing is needed to make these wells produce. Fracturing is done by injection of a fluid which contains sandstone in suspension. The sandstone holds the fractures open and permits the oil to flow into the well.

The Osagian Series overlies the Kinderhookian with a low angular unconformity.

Kinderhookian. The Kinderhookian is the lower most of the Mississippian rocks and has the greatest lateral extent. The Kinderhookian ranges in thickness from a featheredge in western Rice County to over 175 feet in eastern Rice County (Fig. 4).

The Kinderhookian consists of three formations; the Gilmore

City limestone, the Sedalia dolomite and the Compton limestone. The Gilmore City limestone consists of non cherty, soft chalky limestone characterized by oolites of irregular shape. The Gilmore City ranges in thickness from a featheredge to 50 feet.

Devonian? The shale sequence between the Mississippian and Devonian limestones in Kansas is divided into two formations; Boice shale above and Chattanooga shale below. They are separated by a marked disconformity with topographic relief. It is probable, although not proved (Moore, et al.,1951), that the Boice shale is of Mississippian age and the Chattanooga shale (often miscalled "Kinderhook" shale) is of Devonian age. The Boice shale is absent in Rice County.

The Chattanooga shale (Leatherock and Bass, 1936) is a widespread thin formation of remarkably uniform character. It consists of black carbonaceous fissile shale that is of uniform character throughout and is prominently jointed and weathered into thin flakes. Small nodules of pyrite are found in the shale in some localities. In Rice County the Chattanooga ranges in thickness from a featheredge on the Central Kansas uplift to approximately 50 feet in the Salina basin in the eastern part of the county (Fig. 4).

The Chattanooga shale is classified as Devonian by the United States Geological Survey, but is classified as Mississippian by most mid-continent geologists. (Leatherock and Bass, 1936) In Northern Oklahoma and Southern Kansas this is called Mississippian because the overlying Kinderhookian is a shale of

Mississippian Age and they seem to grade into each other. In Rice County, this writer prefers to call the Chattanooga a Devonian sediment because the overlying Kinderhookian is comprised of massive limestones and dolomites and there is a slight unconformity between them.

Devonian. The Devonian rocks of central Kansas consists of relative pure lithographic limestone that grade northwestward into dolomite. A cherty zone commonly occurs a few feet above the base. Basal Devonian beds, consisting of sandy dolomite or limestone, are distinguished readily from the non-sandy Silurian. An unconformity which occurs at the base of the Devonian section is one of the most important in the geologic sequence of Rice County, for it represents local pre-Devonian erosion of Silurian and older rocks hundreds of feet thick.

Misener Sandstone. The Misener sandstone is an irregular impure limy or shaly sandstone, ordinarily not more than 10 feet thick. The Misener lies beneath the Chattanooga shale. In southern Kansas this sandstone is only a few inches thick, and is considered a basal member of the Chattanooga shale. In Southern Kansas it overlies various formations some thought to be at least as old as Simpson, but in Rice County it lies on Viola, Maquoketa, and Hunton beds (Fig. 4). In places it is an oil resevoir, but no production is derived from the Misener in Rice County.

Kansas oil geologists have called this the "Misener sand" because of its stratigraphic position beneath the Chattanooga shale. Its thinness, fine-grained texture, irregular distribution, and superposition on various formations, above which is a black or gray shale, indicates a long pre-Chattanooga erosional interval during which near-by land was near base level.

Hunton Limestone. Hunton strata thin from about 400 feet in the northeastern part of the Salina basin to zero on the outer flanks of the Central Kansas uplift (Fig. 4). Most of the beds are crystalline dolomitic limestones, but near the southern and western edges of the basin there are some calcitic beds. Three somewhat similiar chert zones appear in the thickest sections. It is believed (Taylor, 1946), that as Hunton strata thinned toward the southwest the lowest cherty zone disappears because of overlap; the highest cherty band is gone, perhaps through offlap and erosion; and the middle cherty zone is the most widespread of the three. There is some evidence of a break in sedimentation above the zone (Taylor, 1946). If the Hunton in the Salina basin area is both Silurian and Devonian in age, this break may be the line between those two periods.

At least 12 miles separate Salina basin Hunton beds and a limestone section to the south of Rice County which is considered of lower Hunton age. For this reason, this writer is considering the limestone section on the south as Silurian and the dolomitic section in Rice County as Devonian in age.

Silurian. In the Silurian time, in Rice County, there was either a positive landmass with no deposition, or else the rocks have been removed by erosion.

Ordovician. The Ordovician System is represented in Rice County by the Maquoketa shale, the Viola limestone, rocks of Simpson age, and rocks of Arbuckle age.

Maquoketa Shale. The Maquoketa beds form the top most Ordovician over much of Central Kansas and approximately equivalent in age to Maquoketa beds in Iowa and to Sylvan strata in Oklahoma (Taylor, 1947). They normally consist of two members: (1) an upper dolomitic gray shale, which is siliceous and cherty in some areas, and (2) a lower soft flaky shale. These beds are the thickest in the Central part of the Salina basin.

The Maquoketa shales were deposited on the flanks of the Central Kansas uplift, which was a positive platform during early Paleozoic time, but pre-Pennsylvanian erosion removed many of these beds from the higher parts of the uplift, and left the main body of upper Ordovician shales some distance out on the flanks, and in the Salina basin to the east.

In Rice County pre-Chattanooga erosion removed much of the Maquoketa leaving it only in the eastern and southeastern part. It ranges in thickness from a featheredge in central Rice County to a maximum of 50 feet in the extreme southeast (Fig. 4). The two shale members change gradually, one to the other. They thin toward the west, become darker gray and brown, less dolomitic, and are not separable into two members.

Viola Limestone. Lying unconformably beneath the Maquoketa shale is the Middle Ordovician Viola limestones, named after the Oklahoma surface section. The Viola limestone is separable, lithologically into six member zones, three of which are cherty. Numbered downward, these zones are designated as (1) upper limestone, (2) upper cherty member, (3) middle limestone, (4) middle cherty member, (5) lower limestone, and (6) lower cherty or basal clastic member. The upper section of the Viola is dolomitic while the lower part is calcic. Most Viola production comes from zones 4 and 5.

Zone 5 is the most widespread, representing the maximum advance of Viola seas. The overlying members developed in less extensive seaways which advanced from the north. Viola beds are truncated on the flanks of the Central Kansas uplift, but formerly covered at least part of that structure. The areal extent and stratigraphic relationships of the six Viola members indicate that there was discontinuous limestone deposition in Central Kansas in Viola time.

In Rice County dirty gray, cherty, shaly, dolomitic limestones of zone 4 overlie clear, tan, crystalline, calcitic limestones of zone 5 (Fig. 4). This is all of the Viola in Rice County. The lower limestone (zone 5) is the most widespread member of the county, and extends farthest into the flanks of the high areas associated with the Central Kansas uplift. It is commonly 20 to 40 feet thick and may be more than 60 feet thick in northwestern Rice County (Fig. 4). In Rice County the strata disappear on the flanks of the Central Kansas uplift and associated high structures.

The Viola limestone is an important oil-producing formation in Kansas, with many widely separated counties deriving a share of their production from these beds, but no Viola production is found in Rice County.

Simpson Group. The Simpson group of Middle Ordovician Age underlies beds of Viola and Maquoketa and overlie beds of the Arbuckle group in Rice County (Fig. 4). The Simpson rocks in Rice County include the Platteville formation, of Middle Ordovician Age, and the St. Peter sandstone and slightly older rocks of Early Ordovician Age.

Rocks of Simpson Age were formerly present throughout eastern and central Kansas, but pre-Devonian and pre-Chattanooga erosion removed them from considerable areas on the Central Kansas uplift. A low angular unconformity separates the St. Peter and associated Simpson beds from underlying rocks. The Simpson ranges in thickness from a featheredge in Northwestern Rice County to more than 75 feet in the southeastern part.

Upper beds of the Platteville formation in Kansas consist of dolomite, limestone, sandstone, and green shale in varied succession, and at the basal part is a persistant dolomite. Only the upper part, consisting of a few feet of green shale and sandstone is present in Rice County.

The St. Peter sandstone formation is represented by white dolomitic sandstone and is underlain by a dark-green shale. A shaly zone in the middle of the sandstone is also apparent. The sandstones are glauconitic.

The oil production from the Simpson Group is derived from the St. Peter sandstone. In Oklahoma the oil geologists call this the "Wilcox" Sand. The Simpson is one of the major oil producers of the United States and is the one large pay horizon in Oklahoma. The only production from the Simpson Group in Rice County is in four gas wells in the Lyons pool (Fig. 2) in Central Rice County.

Arbuckle Group. The Arbuckle Group is Cambro-Ordovician in age in most parts of the country, but in Rice County the Arbuckle of the Cambrian and early Ordovician is missing therefore it is called Ordovician in this report. It is thought that in Central Kansas the area was a positive landmass during Cambrian and early Ordovician time. In Rice County the Arbuckle group consists of the Cotter and Jefferson City dolomites, Roubidoux formation, the Gasconade dolomite and the Van Buren formation in the southeastern part. The Arbuckle is present throughout Rice County and lies directly upon the pre-Cambrian basement Complex everywhere except in a few places where the Lamotte sandstone of Cambrian Age is present.

The Arbuckle has an average thickness in Rice County of approximately 500 feet. It is a little less over the Central Kansas uplift and a little more in the Salina Basin.

The Arbuckle forms one of the most widespread and uniform stratigraphic units in the Mid-Continent region, and is an important producer of oil and gas. It consists predominantly of dolomite and limestone with some chert, sand, and shale. The Arbuckle is the oldest stratum that produces large amounts of oil and gas, and it is most important in Central Kansas. The Ellenburger of Texas which is an excellent producer is the equivalent age of the Arbuckle in Kansas.

The Arbuckle in Rice County shows a homoclinal structure from Southeast to Northwest (Fig. 7). It portrays the eastern flank of the Central Kansas uplift very nicely. It ranges in depth from -2500 in southeastern Rice County to -1500 feet in the Northwest sector. A warping is shown by the Geneseo Anticline in central Rice County (Fig. 7), on which the Geneseo and Lyons oil and gas pools are located (Fig. 2). The elevation reaches -1500 feet along this trend also.

The Arbuckle is the major producer in all the oil fields from the Geneseo and Lyons pools west, (Fig. 2) including the Geneseo and Lyons oil pools. No oil (Bartram, et al., 1950) has been found in the Arbuckle in the Salina basin. This would seem to indicate an upward migration of the oil to the highs, leaving no production in the low areas of the Arbuckle.

Characteristics which the Arbuckle of Central Kansas has in common with Arbuckle and Ellenburger of other areas are: (1) the character of the Arbuckle-Ellenburger formation which consists pre-dominantly of limestone, dolomitic limestone, dolomite with chert and siliceous oolites, and minor amounts of sandstone and shale; (2) an abundance of formational water wherever porosity and permeability occur; (3) the direct association of commercial accumulation of oil and gas with structural features which may have been formed by folding alone, or by folding with later truncation and overlap.

Other features which differ widely in various producing areas are (1) the character of the porosity and permeability which varies from the multiple open fractures of the producing zones of the Ellenburger in the fields of the Central Basin platform to the vesicular, honey-comb, solution-type producing zones of the Arbuckle fields on the Central Kansas uplift; (2) the vertical magnitude of structural uplift and the areal extent of the oil pools which range from the major folds of the Central Basin platform and the Granite ridge with uplift measured in many hundreds, if not thousands, of feet to the low dip and broad closures of central Kansas.

Cambrian. The Cambrian System is relatively unimportant in this report and was therefore excluded from the Isometric Panel Diagram (Fig. 4). The Lamotte sandstone, which is the earliest of Cambrian deposits is logged in some places in Rice County.

The sand grains composing the Lamotte sandstone are ill sorted, rounded to angular, and coarse to fine (Moore, et al., 1951). Arkosic material occurs in the lower part adjacent to pre-Cambrian rocks. The Lamotte averages about 20 feet in thickness where it is found.

Pre-Cambrian. The basement rocks of Kansas are granite, schist, quartzites, arkose, and red clastics.

Major Structures

Central Kansas Uplift. The Central Kansas uplift occupies an area in Central Kansas (Fig. 3) and probably part of South-central Nebraska, whose present northwestward trending structure has been developed by several periods of warping and truncation, the earliest of which dates back to pre-Cambrian time (Koester, 1935). Warping on a broad scale in northwest and southeast directions, which has recurred throughout Paleozoic and Mesozoic time, has been modified by depositional thinning toward the northwest of some of the Paleozoic systems and by folding in approximately northeast and southwest directions along old existing lines of weakness. Warping has occurred chiefly in post-Algonkian (?), post-Canadian, post-Hunton, early Pennsylvanian, post-Missourian, and post-Cretaceous time (Koester, 1935). Depositional thinning in the north and west has affected mainly Cambro-Ordovician and Pennsylvanian strata (Fig. 4). Most of the northeast-southwest folding occurred in early Pennsylvanian and post-Cretaceous time.

The Central Kansas uplift is covered by Quaternary, Tertiary, Cretaceous, Permian, Pennsylvanian, Mississippian, Devonian and Ordovician. The pre-Cambrain basement rocks are granite, schist, quartzites, arkose and red clastics. The lighter granite and quartzite occupy the nucleus of the uplift, while in general the schist and thicker arkoses and red clastics have been found on the flanks or saddles of the warped area. It is consistent with these facts to consider the forerunner of the uplift as a series of more or less parallel batholiths which in pre-Cambrian time were intruded into the younger schist and quartzites. Truncation has laid bare the granite core and produced the arkose and red clastics which have accumulated in depressions, to a thickness of a few hundred feet. The number of periods of uplift and erosion in pre-Upper Cambrian time is unknown (Koester, 1935). In Eastern Rice County the Paleozoic rocks are much thicker and the Mesozoic are thin and in Western Rice County the Paleozoics are thin and the Mesozoic thick. This is caused by the Paleozoic rocks wedging out and being eroded off of the uplift while the Mesozoic sediments have been deposited over the top of the uplift with little erosion working on them.

From the southwestern portion of Rice County and extending into Ellsworth County is a relatively steep fold called the Ellsworth anticline. The Chase and Ploog pools are on this axis (Fig. 2). This is an early Pennsylvanian fold which has been formed at the front of the southwestward plunging Central Kansas uplift. Its position suggests that the uplift had acted as a buttress repelling a force from the southeast, possibly from the Ozarks (Koester, 1935).

The Geneseo uplift in North-central Rice County (Fig. 3) shows a true structural high in the Ordovician and pre-Ordovician. The effect of warping is shown by Pennsylvanian resting on a very thin section of Simpson.

The periods of warping to which the uplift was subjected varied in size and scope.

<u>Salina Basin</u>. The Salina basin is a pre-Pennsylvanian syncline bounded on the east by the Nemaha granite ridge, on

the southwest by the Central Kansas uplift, and on the south by the saddle between the Chautauqua Arch and the Central Kansas uplift (Fig. 3). The basin continues northward into Nebraska, where its exact termination is unknown.

The section encountered in the area of the Salina Basin ranges in age from Quaternary to pre-Cambrian. The sequence of pre-Pennsylvanian rocks in the Salina basin is shown in Fig. 4. This Figure also shows the range of thickness of the pre-Pennsylvanian rocks, and the characteristics by which the several formations were deposited originally throughout the area, but many of them were later removed in whole or in part from certain areas during recurrent periods of emergence and erosion. Some of the formation, however, were deposited only locally and never extended across the area. In consequence, no columnar section showing the sequence of formations is representative of the basin as a whole.

The interpretation of structural movements from thickness maps is based on the following concept; if a sequence of rocks is deposited on an originally flat surface, and if this sequence of rocks is warped and folded before the development of a younger flat horizontal surface, the variations in thickness of the rocks between the two surfaces will reveal the amount and place of the deformation (Lee, et al., 1948).

Five periods of folding are distinquished in the Salina basin. They are: (1) Upper Cambrian and Lower Ordovician dolomites lying below the St. Peter sandstone were deformed before the deposition of the St. Peter sandstone. The structural movement resulted from many minor movements that occurred at different times prior to the deposition of the St. Peter sandstone. In central Kansas, a parallel syncline is revealed by this movement.

(2) Another period of folding extended from St. Peter time to the beginning of deposition of the Mississippian limestone and may have continued through Kinderhookian time. During this period the structural deformation was a complete reversal of that preceding St. Peter time. Events that were contemporaneous with the subsidence of the North Kansas basin and the rise of the Ozarks were the development of the Chautauqua arch and the Central Kansas uplift on the South and West.

(3) A third period of folding began at least as early as the beginning of Mississippian time, culminated diminished movement through Pennsylvanian into Permian time (Lee, et al., 1948). The principal structural features developed in Kansas were the Nemaha anticline and the Central Kansas uplift. The Salina basin was a synclincal area which trended northwest and paralleled the northern flank of the Central Kansas uplift.

(4) A fourth period of deformation occurred after Permian time and before Cretaceous time. It involved the development of a broad synclinal basin in southwestern Kansas which gave the Permian and Pennsylvanian rocks of eastern Kansas a southwesterly dip.

(5) A fifth period of deformation occurred after the de-

position of the Cretaceous rocks. As a result of this deformation these rocks were tilted toward the north and northeast in western Kansas and toward the north and northwest in central Kansas and were raised 1,500 to 2,000 feet above sea level in the Salina basin.

Each change in the pattern of structural movement altered the altitude of earlier anticlines as well as earlier regional structure. Changes in the direction of dip shifted the position of the crests of low anticlines in some cases and destroyed the closure in other (Lee, et al., 1948). In consequence, the exposed crests of low anticlines in the younger rocks do not, in all cases, reveal accurately the position and configuration of those anticlines in older more steeply dipping rocks.

Minor Structures

<u>Geneseo Uplift</u>. Geologically, the Geneseo uplift is the easternmost, semi-detached lobe of the Central Kansas uplift (Fig. 3). The structure, as mapped on the Arbuckle dolomite (Fig. 7), is that of an ovoid uplift complicated by superimposed anticlinal folding. The principal period of folding (Clark, et al., 1948) was late Mississippian or early Pennsylvanian in age as evidenced by the angular unconformity between the Mississippian and Pennsylvanian sediments. The structure was further complicated by regional tilting and recurrent uplift during post-Mississippian time.

Surface and subsurface rocks include beds of Quaternary, Cretaceous, Permian, Pennsylvanian, Mississippian, Ordovician, and Cambrian age, the latter resting unconformably on the pre-Cambrian complex. The major gaps in this stratigraphic column represent, for the most part, periods of non-deposition.

Six oil fields and one gas field are associated with the Geneseo uplift.

The Geneseo and Edwards oil fields and the Lyons gas field (Fig. 2) are anticlinal accumulation located on a sharp structural ridge which extends along the west edge of the Geneseo uplift (Fig. 3). The principal producing formation is the Arbuckle dolomite, although in the Lyons field minor quantities of oil and gas are produced from the Simpson sand. The Wherry field (Fig. 2), which produces from the Pennsylvanian basal conglomerate, and the Welch, Bornholdt, and Smyers fields, which produce from the Mississippian chert, are primarily stratigraphic accumulations and are located on the south and east flanks of the uplift.

<u>Conway Syncline.</u> The lowest part of the Salina basin from a structural standpoint in Rice County lies in the southeastern part of the county (Fig. 7). This low area which is just west of the Voshell anticline (Fig. 3) in McPherson county is called the Conway syncline.

The center of the Conway syncline extends north and south through western Ottawa, Saline, and McPherson Counties and southwest across Reno County (Fig. 3). In the sector adjoining McPherson, the western flank of this syncline lies in eastern Rice County. In some places dips are modified, steepened and even reversed by local structural features. The Welch, Bornholdt, and Smyers oil fields in eastern Rice and western McPherson counties (Fig. 2) lie along the trend of one such terrace-like modification in dip. Faulting is uncommon in the area, but along a fault zone on the west side of the Voshell anticline in McPherson and Harvey counties, beds on the east are several hundred feet higher than those on the west.

The Ordovician beds remain fairly even in thickness, following the slight dip of the Syncline, while the Mississippian beds increase in thickness rapidly (Fig. 4). The Conway syncline trend is portrayed in the Arbuckle Structural Map (Fig. 7), while it is not noticeable on the Mississippian Structural Map (Fig. 6).

HISTORY OF RICE COUNTY OIL FIELDS

Production

Rice County holds the distinction of being one of the first counties in the state in which gas production was found and the second county in western Kansas in which oil was discovered.

In 1888 gas was discovered in a 1,230 foot well drilled in Lyons. This gas was piped to a hotel and nearby dwellings and used for some months before an explosion put a stop to the local gas industry for a period of over 35 years.

Rice County became an oil producer in 1924 with the discovery of the Welch pool (Fig.2) in the southeastern part of the county. This was the year following the discovery of the Fairport pool in Russell County, and for some years these two fields were the only oil fields in Western Kansas.

At the end of 1952, Rice County ranked third among counties in acreage with 51,630 acres, fourth in cumulative production, with 182,288,202 barrels, fourth in number of producing wells, with 1,588 and ranks first in estimated reserves.

Drilling and Producing Methods

With the exception of a few early cable-tool wells, drilling in Rice County has been by rotary method. Standard practice has been to protect shallow fresh-water beds by cementing a short string of surface pipe, and to drill a 7 7/8 to 9 inch diameter hole to the top of the "pay". Drilling and samples are watched closely for the top of marker beds.

After the "pay" horizon has been reached, a string of casing ranging from five to eight inches is set. The hole is usually loaded with water to reduce the fire hazard while drilling into the "pay". After what is deemed the proper penetration, the well is cleaned out, or is allowed to clean itself. A potential test is taken by physical test, or draw-down method, and the well placed on production. Some operators prefer to set pipe above the top of the "pay" zone, drill in with cable tools, and shut off any caving formation by running a perforated liner. Others prefer to drill to the total depth with rotary and then treat the wells or test with cable tools. These practices vary widely with individual operators and on individual wells.

The wells in the Arbuckle dolomite are acidized to help increase production while fracturing is used in the Mississippi "Chat". Several poorer wells have been shot with nitroglycerine in an effort to increase production, but with the exception of a few isolated wells, no increase has been obtained.

Crude and Production Problems

The crude and production problems are not great in Rice County. The Wherry pool (Fig. 2) has encountered more problems than the other pools.

Wherry pool crude has a paraffin base and is black in color. The crude contains much salt, the highest concentration being in the southeast end of the pool.

Several production problems are encountered because of the nature of the crude in this pool. Thus, in areas of excessive salt concentrations, it is necessary to remove much of the salt to make it acceptable as pipe-line oil. This is done principally by treating the oil with fresh water. Paraffin precipitation is also the cause of much trouble. Casing, tubing, and rods in the older wells are thickly coated with paraffin. After the oil reaches the surface, it is very viscous and hard to handle at low temperatures. The precipitate of paraffin catches and holds a variable amount of water which does not separate without the application of heat. Much trouble is caused by gun barrels, stock tanks, and surface lines by these deposits. These can be dissolved with paraffin solvent or by heat treatment.

Water Disposal

Disposal of the small amount of brines produced in Rice County is by evaporation and by subsurface disposal.

For subsurface disposal, deep wells are drilled at strategic locations to a depth of 175 to 200 feet below the top of the Arbuckle dolomite. Each water disposal well can handle the brine from 40 to 50 wells. In 1939, these wells produced an average of approximately six barrels of water per day per well. This has been slightly increased by 1954.

The water is carried by gravity from all leases which are connected to it, as the disposal wells are low in surface elevation. The brine is not treated, but is diluted, one part fresh water to five parts brine, before being turned into the well. The wells take all the water by gravity, have needed no clean out jobs, and have an indicated capacity much greater than the load it is expected to carry.

Evaporation is accomplished by means of surface ponds. Due to the small amount of water produced with the oil, a relatively small area of water surface is sufficient to take care of the brine. To date there has been no pollution of near-surface fresh-water beds.

Secondary Recovery Methods

Repressuring of oil-bearing rocks by injection of water, air, or gas or a combination of these agents, has become a principal method of oil production in Kansas since official sanction and status given the practice through the passage of a law in Kansas in 1935. The older fields in eastern and southeastern Kansas are using these methods to a great advantage. There is very little secondary recovery taking place in Rice County.

CONCLUSIONS

The possibilities of finding oil in Rice County are still very good, despite the fact, that drilling has been going on in the county since 1924. There has been an average of four to five new pools discovered every year for the past few years plus one or two old pools revived. At the close of 1952 there were 55 oil pools in operation and they produced 9,566,545 barrels of oil and 450,848 thousand cubic feet of gas during the year.

Only a few of the pools have been drilled to there lateral limits and there are great possibilities for expansion.

The best possible exploration lies on the Central Kansas uplift and its associated uplifts and minor anticlines. The best pay horizon would be the Arbuckle, with the Lansing-Kansas City formations next in line. On the flanks of these uplifts there are good possibilities of stratigraphic sand lenses of Misener and Simpson Age.

Another good possibility lies in the Mississippi "Chat" regions of east and southeastern Rice County. The best wells are centered along the 100 foot thickness line of the Mississippian Isopach Map (Fig. 5). There is room for expansion north and south of the established pools along this line.

Since the fracturing treatment was developed in 1950 there is a good chance to make producers out of old abandoned wells. Wells that were drilled into the Mississippi "Chat" before 1950 and abandoned because the formation was too tight could be good producers.

ACKNOWLEDGMENTS

The writer is indebted to Dr. Claude W. Shenkel Jr., Associate Professor of Geology, for his valuable information, advice and suggestions while preparing this thesis and for the criticisms and suggestions while editing the thesis. Sincere thanks are also expressed to the staff of the Department of Geology for their help and consideration. Thanks also are extended to the State Geological Survey, Lawrence, Kansas for furnishing a wealth of material.

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APPENDIX

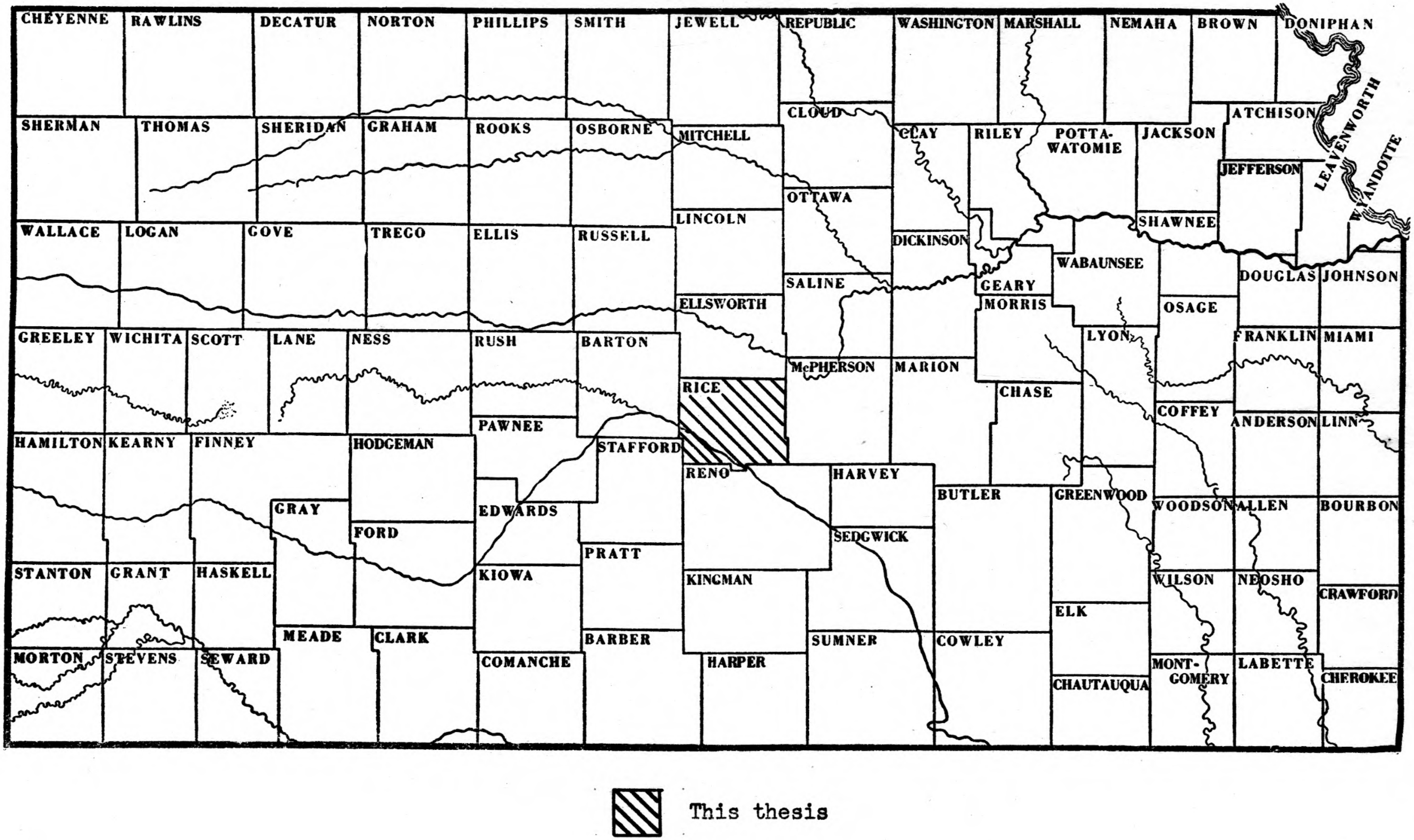


Fig. 1. Index map of Kansas showing location of Rice County.

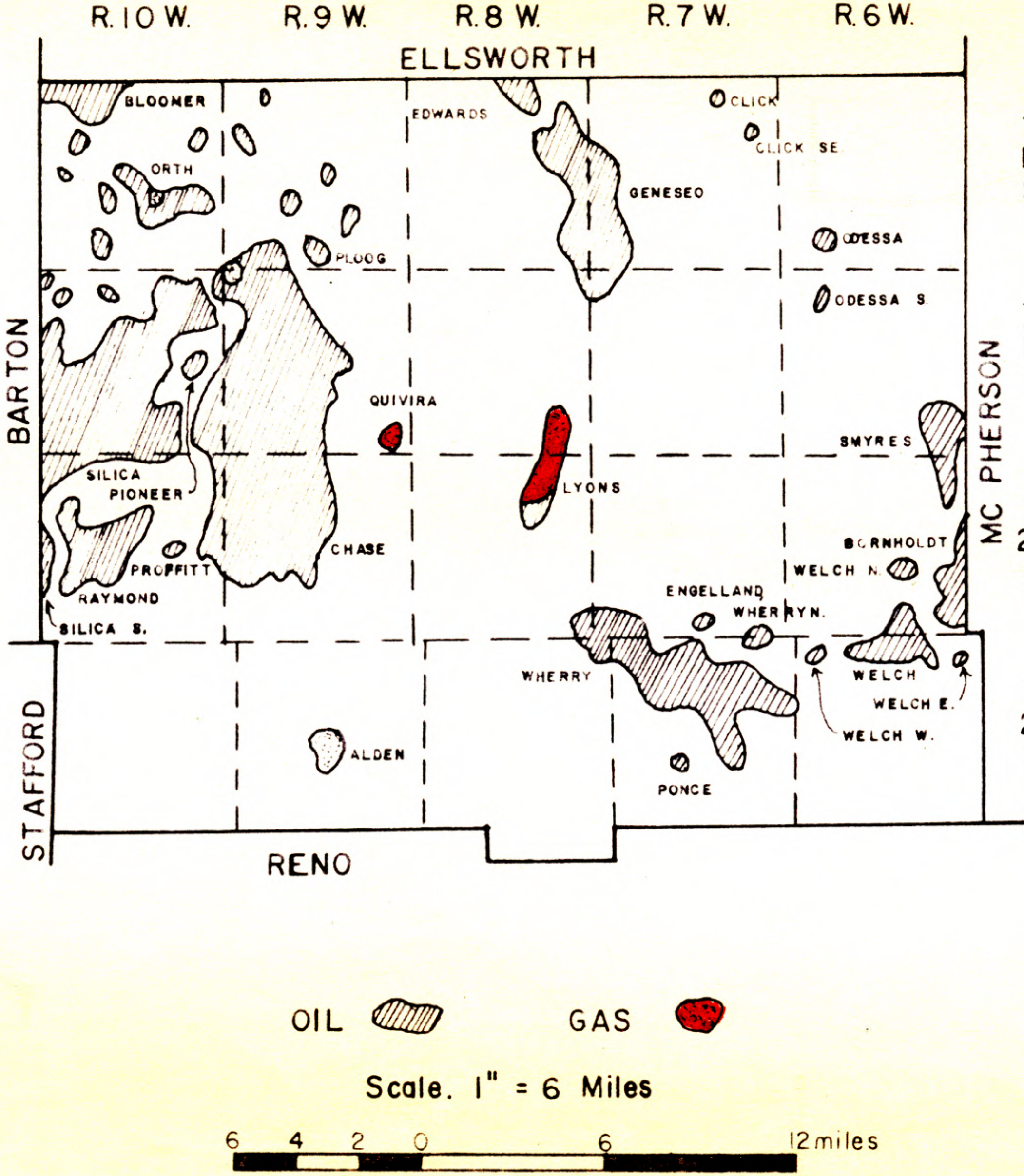
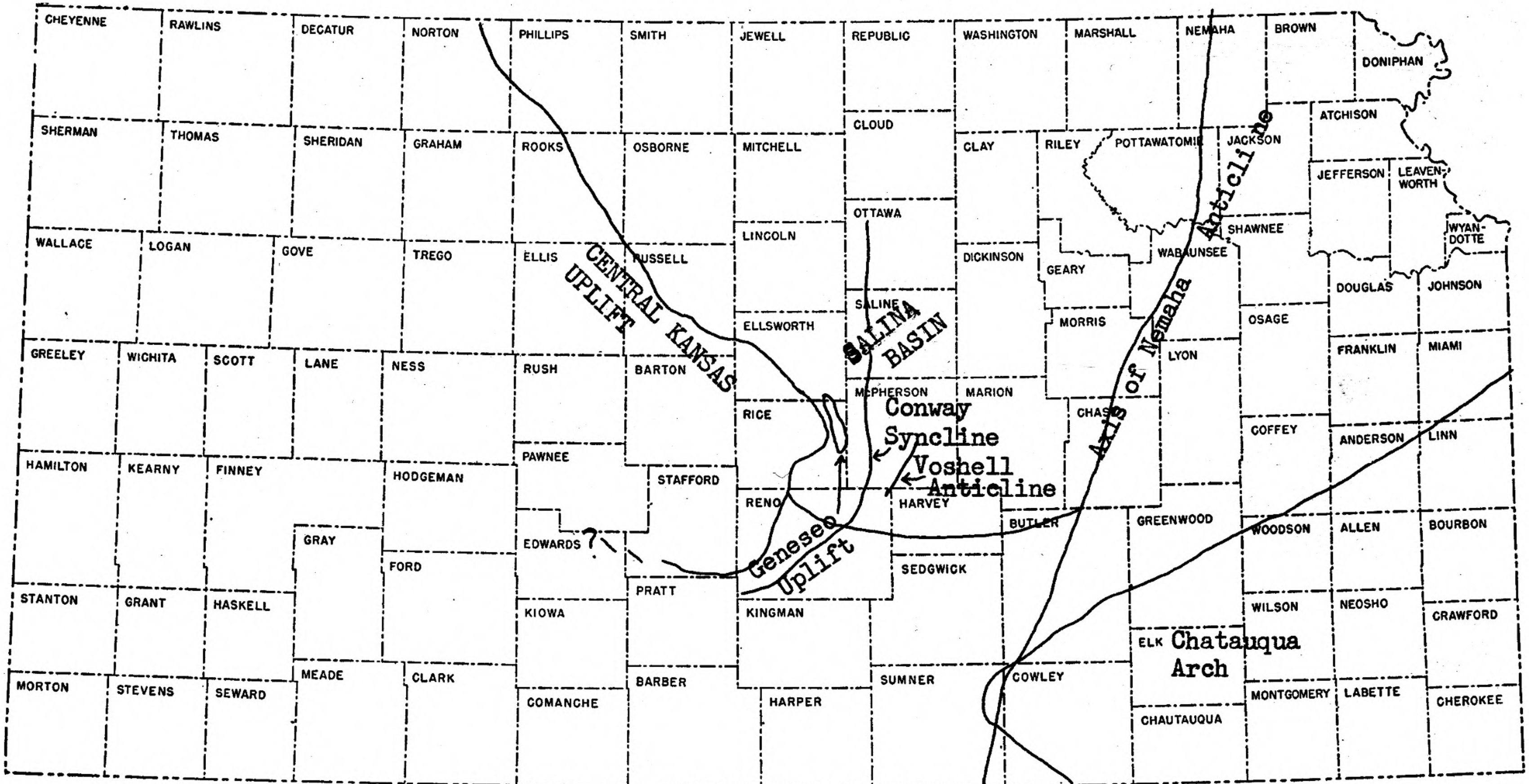


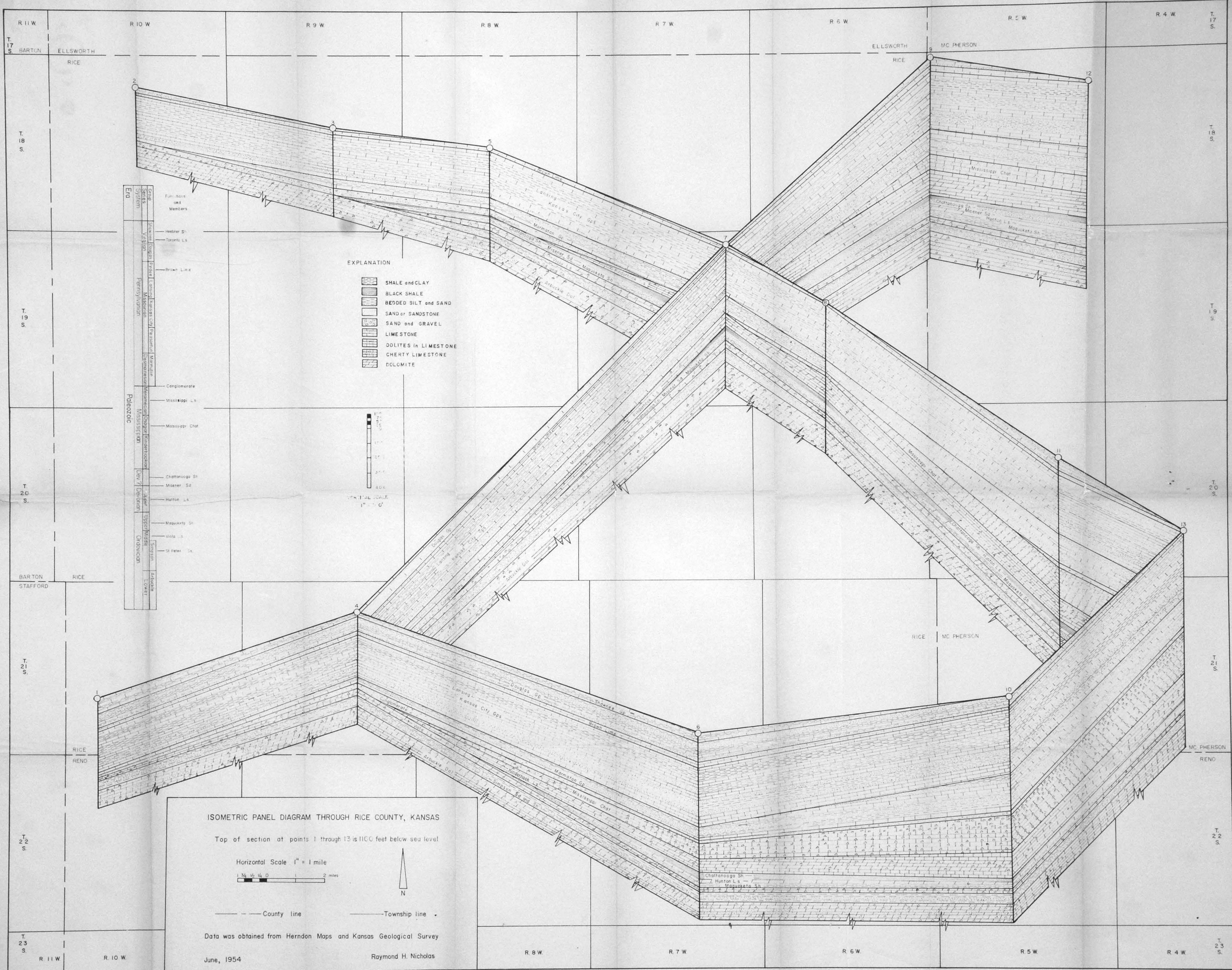
Fig. 2. Map of Rice County showing oil and gas pools.



State Geological Survey of Kansas

Fig. 3. Structural features covered by this report.

Fig. 4. Isometric panel diagram through Rice County, Kansas



R. 11 W.
R. 10 W.
R. 9 W.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
R. 4 W.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
T. 23 S.
BARTON
ELLSWORTH
RICE
MC PHERSON
STAFFORD
RENO
EXPLANATION
SHALE and CLAY
BLACK SHALE
BEDDED SILT and SAND
SAND or SANDSTONE
SAND and GRAVEL
LIMESTONE
OOLITES in LIMESTONE
CHERTY LIMESTONE
DOLOMITE
Era
System
Series
Group
Formations and Members
Paleozoic
Pennsylvanian
Mississippian
Devonian
Ordovician
Conglomerate
Mississippi Ls.
Mississippi Chat
Chattanooga Sh.
Misener Sd.
Hunton Ls.
Maquoketa Sh.
Viola Ls.
St. Peter Ss.
Brown Lime
Lansing
Kansas City Gps.
Douglas Gp.
Shawnee Gp.
Marmaton Gp.
Arbuckle Dol.
Simpson Sd. and Sh.
ISOMETRIC PANEL DIAGRAM THROUGH RICE COUNTY, KANSAS
Top of section at points 1 through 13 is 1100 feet below sea level
Horizontal Scale 1" = 1 mile
1 3/4 1/2 1/4 0 1 2 miles
N
County line
Township line
Data was obtained from Herndon Maps and Kansas Geological Survey
June, 1954
Raymond H. Nicholas

Fig. 4

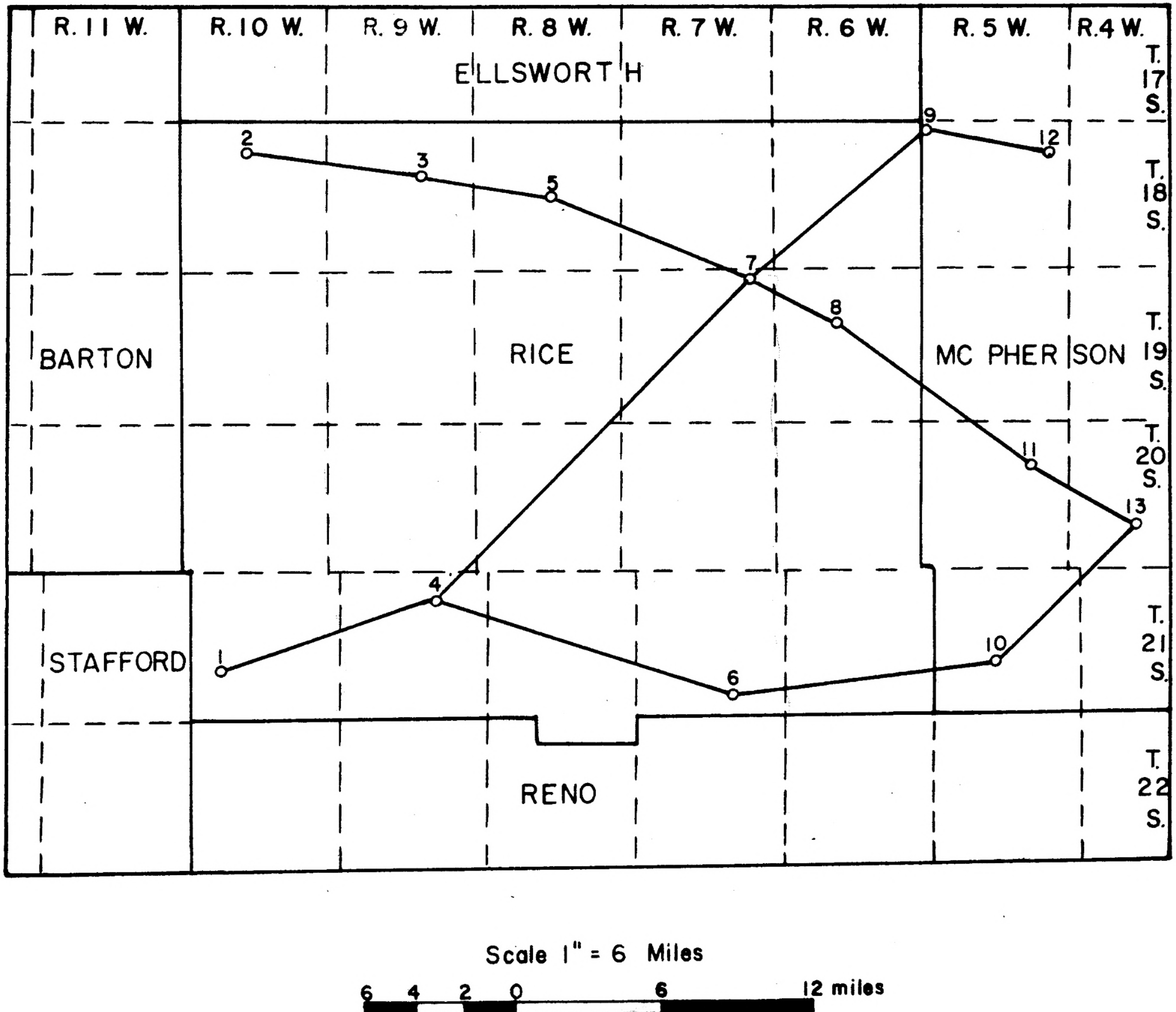


Fig. 4A. Location of wells used in Fig. 4.

Table 1. Exact locations of points used in Fig. 4.

Points	Location	Section	Township	Range
1	NW, NW, NW,	29	21S	10W
2	CNL, NE, NE,	9	18S	10W
3	SW, SW, NE,	15	18S	9W
4	NE, NE, NE,	10	21S	8W
5	NE, NE, NE,	21	18S	7W
6	CENTER NE,	34	21S	7W
7	SW, NW,	1	19S	7W
8	SW, SW, NE,	16	19S	6W
9	CW½, NW, NW,	6	18S	5W
10	NE, NE, NW,	28	21S	5W
11	SE, SE, SW,	11	20S	5W
12	NE, NE, NW,	12	18S	5W
13	SW, SW, NE,	28	20S	4W

Fig. 5. Mississippian isopach map

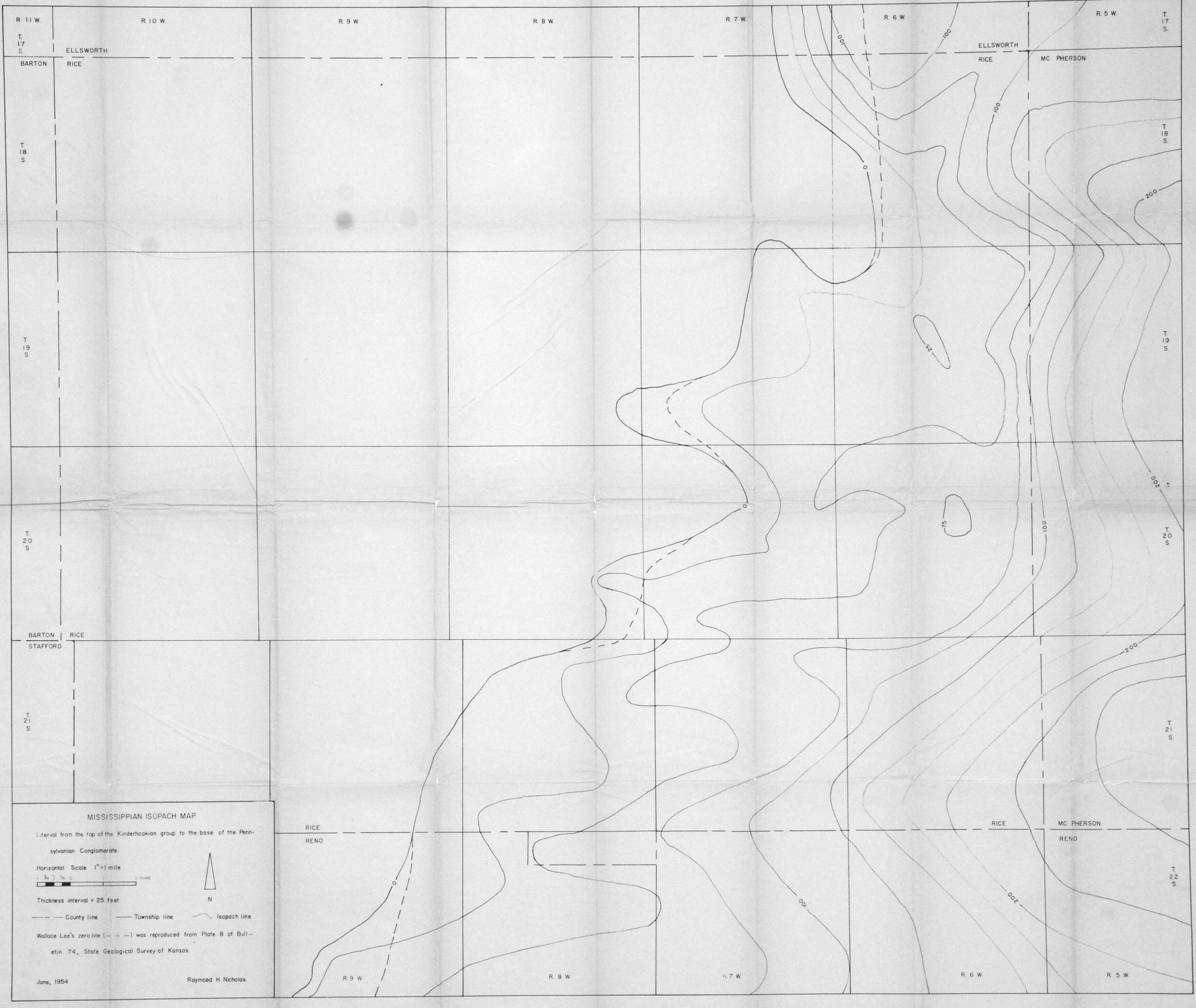

MISSISSIPPIAN ISOPACH MAP
Interval from the top of the Kinderhookian group to the base of the Pennsylvanian Conglomerate
Horizontal Scale 1" = 1 mile
Thickness interval = 25 feet
N
County line
Township line
Isopach line
Wallace Lee's zero line (— — —) was reproduced from Plate 8 of Bulletin 74, State Geological Survey of Kansas.
June, 1954
Raymond H. Nicholas
R. 11 W.
R. 10 W.
R. 9 W.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
ELLSWORTH
BARTON
RICE
MC PHERSON
STAFFORD
RENO
0
25
75
100
200

FIG. 5

Fig. 6. Map of Rice County showing contours on top of the Mississippi "Chat" and "Lime"


MAP OF RICE COUNTY SHOWING CONTOURS ON TOP OF
THE MISSISSIPPI "CHAT" AND "LIME"
County line
township line
contour line
Contour interval = 25 feet
Scale 1" = 1 mile
2 miles
N
June, 1954
Raymond H. Nicholas
R. 11 W.
R. 10 W.
R. 9 W.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
ELLSWORTH
BARTON
RICE
MC PHERSON
STAFFORD
RENO

FIG. 6

Fig. 7. Structural contour map of the Arbuckle dolomite in Rice County.

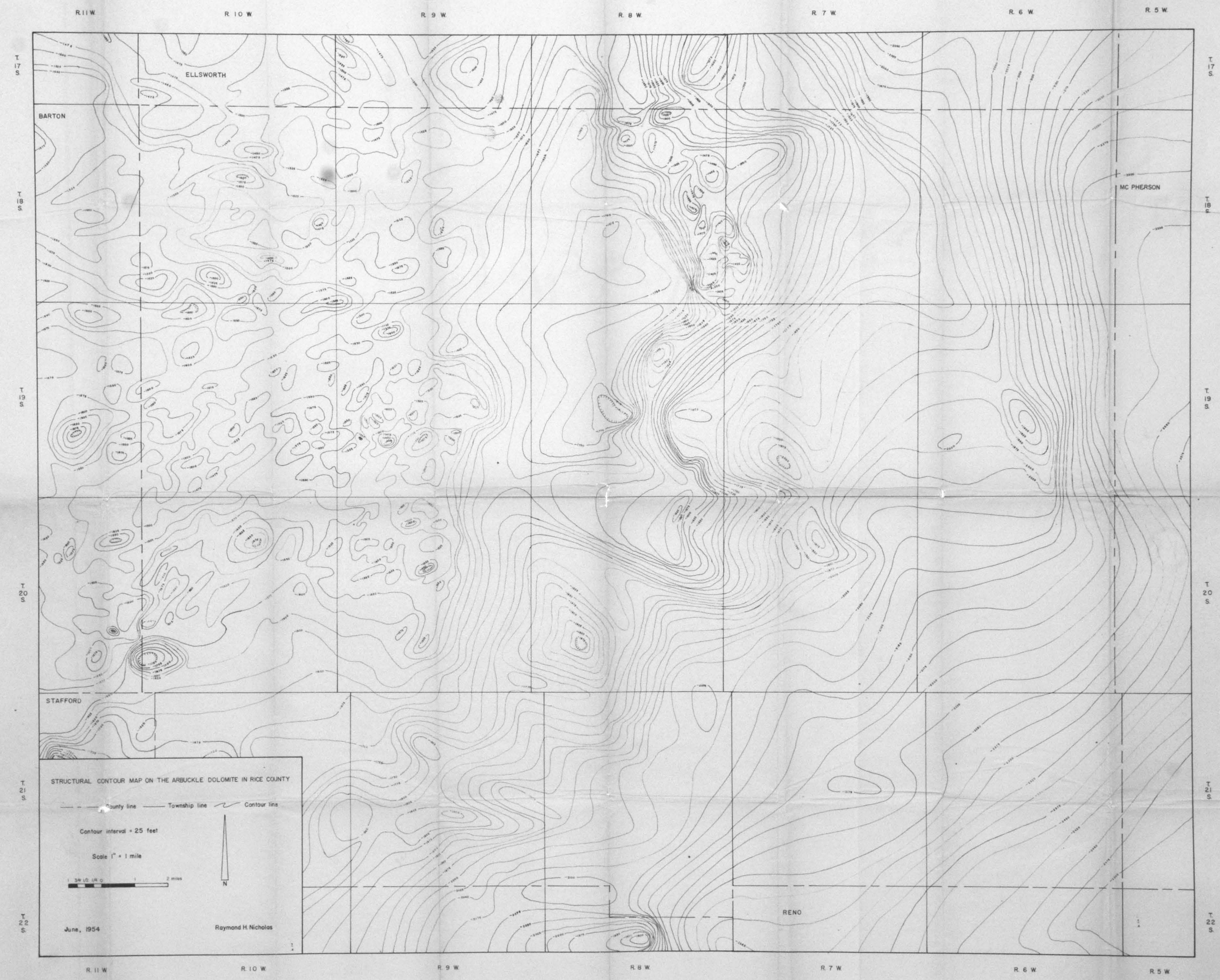

R. 11 W.
R. 10 W.
R. 9 W.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
ELLSWORTH
BARTON
MC PHERSON
STAFFORD
RENO
STRUCTURAL CONTOUR MAP ON THE ARBUCKLE DOLOMITE IN RICE COUNTY
County line
Township line
Contour line
Contour interval = 25 feet
Scale 1" = 1 mile
2 miles
N
June, 1954
Raymond H. Nicholas

FIG. 7

THE SUBSURFACE STRUCTURE AND STRATIGRAPHY RELATED TO PETROLEUM ACCUMULATION IN RICE COUNTY, KANSAS

by

RAYMOND H. NICHOLAS

B. S., Kansas State College
of Agriculture and Applied Science, 1953

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1954

ABSTRACT

Rice County, Kansas ranks fourth among Kansas counties in oil production. This study is an analysis of geological factors associated with the accumulation of petroleum in Rice County, Kansas.

An isometric panel diagram, isopach map, and structure contour maps were prepared from data afforded by numerous well logs. The diagrams and maps depict stratigraphic and structural conditions within the areas in which petroleum accumulation occurs.

Analysis of these subsurface studies reveal that four major pay horizons occur in Rice County. They are: the Lansing- Kansas City Groups and the Pennsylvanina Basal Conglomerate of Pennsylvanian age, the Mississippi "Chat" of Mississippian age, and the Arbuckle dolomite of Ordovician age. The Arbuckle dolomite is the greatest producer of the four.

Four major structural features are delineated in Rice County. They include: (1) the Central Kansas uplift, (2) the Salina basin, (3) the Geneseo uplift, and (4) the Conway syncline. The Central Kansas uplift is a high structural feature that covers the western two-thirds of the county. It was warped and truncated during several periods, the earliest of which dates back to pre- Cambrian time. Warping has occurred chiefly in post Algonkian (?), post-Canadian, post-Hunton, early Pennsylvanian, post-Missourian, and post-Cretaceous time. The largest oil fields in Rice County are located on this uplift. The Salina basin is

pre-Pennsylvanian syncline bounded on the east by the Nemaha granite ride, on the southwest by the Central Kansas uplift, and on the south by the saddle between the Chautauqua Arch, and the Central Kansas uplift. Production in the basin in Rice County is derived from stratigraphic traps and wedge outs. The Geneseo uplift is a semi-detached lobe of the Central Kansas up-lift. Several good oil fields are located on this structure. The Conway syncline is a pre-Ordovician syncline lying between the Geneseo uplift and the Voshell anticline of McPherson County.

Rice County was one of the first counties in Kansas in which gas was discovered and was the second county in Western Kansas in which oil was discovered. By 1952, Rice ranked third in acreage, fourth in cumulative production, fourth in the number of producing wells and first in estimated reserves among Kansa counties.