STRUCTURE AND STRATIGRAPHY OF STAFFORD COUNTY, KANSAS RELATED TO PETROLEUM ACCUMULATION

by

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INTRODUCTION

Purpose of Investigation

The purpose of this investigation was to determine the subsurface structure, stratigraphy, and geologic history of Stafford county, Kansas, and the relationship of these factors to petroleum accumulation in the county.

Geography and Physiography of the Area

Stafford county is located in South Central Kansas (Appendix, Fig. 1). The area is bounded on the east by Rice and Reno counties, on the south by Pratt county, on the west by Edwards and Pawnee counties, and on the north by Barton county. Stafford county contains twenty-two townships comprising 792 square miles.

The area lies entirely within the Great Bend Prairie physiographic province. The surface in much of the county is covered by wind-blown sand in which the drainage is very poorly developed. A typical sand dune topography is present over much of the county. The area is drained by Rattlesnake Creek, Peace Creek, and the North Fork of the Ninnescah Creek, all of which are tributaries of the Arkansas River.

Until 1930 the economy of Stafford county was based upon agriculture with wheat being the principal crop. In 1930 the first oil production was discovered in the county, and since that time the production of oil and gas has developed into an important industry in the county.

Procedure

Three structural contour maps, a thickness map, and a panel diagram were constructed during the course of this investigation. Structural contours were drawn on the top of the Arbuckle group, on the top of the Mississippian limestones, and on the top of the Lansing group. All available well data obtained from the Herndon maps, logs of the Kansas Sample Log Service, radioactive logs, and drillers logs were used in the construction of these maps. The Arbuckle and Lansing groups were chosen as mapping units, because they are the most important oil and gas producers in the area. The Mississippian limestone was selected for mapping, because of the manner in which the pinchout and structure of this unit is related to the minor structures and petroleum accumulations in the stratigraphic units both above and below.

A thickness map of the Viola limestone drawn by Keith Mohl, under the direction of Dr. H. V. Beck was used by the writer. The line-up of the pinchouts and the erosional windows of the Viola limestone, as revealed by this map indicates the various trends of pre-Pennsylvanian structures. A possible relation between thickening and petroleum accumulation in the Viola appears plausible from a study of this map.

The panel diagram was constructed to show the structure and stratigraphy from the top of the Topeka limestone downward. The radioactive logs and Kansas Sample Log Service logs were used wherever possible for construction of the panel diagram. The writer considered these sources to be more reliable and complete than the other information available for this purpose.

REVIEW OF LITERATURE

Numerous regional reports and studies of the geology of Central Kansas and literature pertaining to individual geologic problems in, and surrounding, the area of this investigation were available to the writer. Barwick (1928), McClellan (1930), Roth (1930), Morgan (1932), and Rich (1933) contributed much to the knowledge of regional stratigraphy in Central Kansas. Koester (1935) summarized much of the previous work and made numerous additional contributions to the knowledge of the geology of the Central Kansas uplift. Lee (1939), Lee and Merriam (1954), Merriam (1955), and Lee (1956) made substantial contributions to the knowledge of regional structure through the use of thickness maps. Keroher and Kirby (1948), Moore, et al, (1951), and many other workers have made substantial contributions to the nomenclature and identification of the rock units in Kansas.

Latta (1950) made a detailed study of the surface and subsurface geology of Barton and Stafford counties, and the relationship of the geology to ground water in the area. Imbt (1941) wrote a summary of the geology and its relationship to petroleum accumulation in the Zenith pool, which was of great value to the writer as very little information was available on the Zenith pool from the well logs. The oil and gas production of Stafford county and related information was available from numerous bulletins and circulars of the State Geologic Survey of Kansas and from the annual summaries in the American Association of Petroleum Geologists bulletins.

STRATIGRAPHY

Pre-Cambrian Rocks

The pre-Cambrian rocks in Kansas consist of granite, porphyry, gneiss, schist, quartzite, slate, and marble. In general the granites and quartzites occupy the structural highs in the basement complex (Koester, 1935). The few wells penetrating the pre-Cambrian in Stafford county have logged the basement rock as granite.

Cambrian System

Waucoban and Albertan Series. No rocks of the Waucoban or Albertan Series are recognized in Stafford county.

Croixian Series. The Lamotte (Reagan) sandstone of Croixian age is apparently present overlying the basement rocks in much of the area covered by this investigation. The Lamotte sandstone consists of rounded, poorly sorted quartz grains, which overly an arkosic facies in many of the wells drilled in Stafford county and surrounding areas. The thickest section of Lamotte sandstone drilled in Stafford county was 115 feet of sandstone and "granite wash". The sandstone apparently thins in area where the topographic highs projected above the general surface on which the Lamotte was deposited.

The Bonneterre dolomite overlies the Lamotte sandstone in at least a portion of Stafford county. The Bonneterre dolomite is a coarsely crystalline dolomite similar to the overlying Arbuckle group and is usually logged as part of the Arbuckle group in this area. The upper Cambrian Eminence dolomite found in the subsurface east of Stafford county is not recognized as such any place in Stafford county.

Ordovician System

Lower Ordovician. The Arbuckle group, consisting of the Roubidoux dolomite and the Jefferson City-Cotter dolomites, have been identified by means of insoluable residues in the subsurface of Stafford county (Keroher and Kirby, 1948). The underlying Gasconade dolomite and the Van Buren formation, also of Lower Ordovician age, are probably absent in the Stafford county area, and the Roubidoux dolomite unconformably overlies the Bonneterre dolomite or the Reagan sandstone of the Cambrian. The Arbuckle group in Stafford county is predominantly a coarsely crystalline dolomite, which contains some sandy zones. The thickness of the Arbuckle group is quite variable due to the erosional nature of the upper surface. Wells in Stafford county have penetrated from 63 to 565 feet of Arbuckle sediments in the area. Lee (1956) has indicated from 500 to 600 feet of Cambrian and Lower Ordovician rocks in the Stafford county area on a regional thickness map. The extremely thin sections of these sediments found in some wells in the area are probably located over highs in the pre-Cambrian basement.

Lower and Middle Ordovician. The Simpson group is composed of the Platteville formation and the St. Peter sandstone, both of Middle Ordovician age, and a lower unnamed unit of Lower Ordovician age. The Platteville is predominantly shale and sandy shale, while the St. Peter sandstone is a frosted well-rounded sand, somewhat lenticular in areal distribution in the area of this investigation. The underlying Simpson unit is composed of shales, sandy shale, and a lenticular dolomite, which is present overlying the Arbuckle dolomites in some wells. The Simpson dolomites are usually made up of somewhat finer crystals than the Arbuckle dolomite.

The Viola (Kimmswick) limestones and dolomite, a Middle Ordovician deposit, is present in the subsurface of Stafford county, except in the extreme northern portion of the county and on a structural high in T. 22 S., R. 11 W., where these rocks have been removed by pre-Pennsylvanian erosion (Appendix, Fig. 7). The Viola consists of dolomites and limestones containing chert. On the radioactive logs the Viola is characterized by many breaks in the neutron curve indicating porosity. Several oil pools in Stafford county produce from these porous zones in the Viola.

Late Ordovician. The Maquoketa (Sylvan) shale has been identified overlying the Viola limestones in some areas of Stafford county. Imbt (1941) identified Maquoketa rocks above the Viola limestone in the Zenith pool. The Maquoketa consists of shale, dolomitic limestone, and dolomite.

Silurian System

The Silurian System is not recognized in the Stafford county area. The Hunton limestones of Silurian and Devonian age pinch out east of the area covered by this report.

Devonian or Mississippian System

The Misener sandstone, a member of the Chattanooga shale, overlies the Viola limestone or Maquoketa shale in isolated areas of southeastern Stafford county. The lithology and distribution of the Misener sandstone in southeastern Stafford county is extremely variable. In the Zenith pool, the Misener sandstone consists of two sandstones separated by a limestone. The upper sandstone is very limited in distribution and does not exceed ten feet in thickness. The lower sandstone is more uniformly distributed in the producing area of the Zenith pool, but it does not extend as a blanket deposit outside the Zenith area. The maximum thickness of the lower sandstone in the Zenith area is twenty-eight feet. The upper Misener sand is characteristically fine grained. The lower sand is a medium-grained sand and becomes conglomeratic in the lower part in some portions of the Zenith pool (Imbt, 1941). Elsewhere, in the southeastern portion of Stafford county, the Misener is logged in isolated wells. The sand logged in these wells is apparently the basal sand of the Zenith pool.

Overlying the Misener sandstone, Maquoketa, or Viola limestones in southern Stafford county, is a shale section ranging from 90 feet to a feather edge. The shale is red to green in color and probably correlates with the "Chattanooga" shale of eastern Kansas. Lee (1956) has traced an oolitic zone at the top of the Chattanooga shale section in northeastern Kansas across the Salina basin to the east flank of the Central Kansas uplift.

The oolitic zone is probably basal Boice shale in northeastern Kansas. As the oolitic zone is not present in the area of this investigation, the writer believes the entire shale section correlates with the Chattanooga of eastern Kansas. "It is probable, although not proved, that the Boice shale is of Mississippian age and the Chattanooga shale (often miscalled "Kinderhook" shale) is of Devonian." (Moore, et al, 1951). If this is true the shale section overlying the Misener and Ordovician sediments in Stafford county is probably Devonian in age, with little or no part of the shale being Mississippian in age. The name "Kinderhook shale," has been applied to this shale section by oil company personnel, and the shale section is named the "Kinderhook shale" on many of the logs in the area.

Mississippian System

Kinderhookian Series. The Kinderhookian series is probably represented by the non-cherty limestones underlying the Osagian limestone in Stafford county. This limestone is not identified in all wells in the area, and may have been removed by the pre-Osagian erosion in part of the county. The Kinderhookian limestones were not differentiated from the overlying Osagian limestones in the preparation of Fig. 5 (Appendix).

Osagian Series. Limestones ranging from 74 feet to a feather edge are found in the southern part of Stafford county. These limestones are probably of the Burlington-Keokuk sequence. The section is composed of cherty limestone and minor amounts of dolomite in this area. The upper surface of the limestones is an erosional surface which developed during the late Mississippian and early Pennsylvanian time (Appendix, Fig. 5).

Meramacian and Chesterian Series. There are no rocks of the Mermacian or Chesterian series recognized in Stafford county.

Pennsylvanian System

Morrowan, Atokan, or Desmoinesian Series. The Pennsylvanian basal conglomerate unconformably overlies rocks ranging from the Mississippian to Ordovician systems in Stafford county. The Pennsylvanian basal conglomerate is found in contact with the Chattanooga shale, the Maquoketa shale, the Viola limestone, and the Simpson group in that order north of the Mississippian limestone pinchout. The age in which the conglomerate was deposited is unknown, however, the transitional nature of the deposit would indicate a considerable variation in time of deposition from one area to another. The Pennsylvanian basal conglomerate consists of reworked chert and other erosional debris from the underlying rocks and red and green shale in the area of this investigation. The thickness is extremely variable, but it probably ranges from 0 to 25 feet. The name "Sooy sand" or "Sooy conglomerate" has been applied to the Pennsylvanian basal conglomerate by oil company personnel. Where the sand or conglomerate zone is clean, the Pennsylvanian basal conglomerate is the reservoir for petroleum accumulation, and the impervious shales are the cap rock for these and underlying reservoirs in the Stafford county area.

Desmoinesian Series. The Marmaton group is present in the southern one-half of Stafford county overlying the Pennsylvanian basal conglomerate. The Pennsylvanian conglomerate is probably in part Marmaton in age. The transgressing Marmaton seas undoubtedly reworked the upper-most portion of the erosional debris, and deposited these sediments in much greater thickness in the topographic lows of the erosion surface. The Marmaton group is made up of alternating limestones and shales with some sandy sediments in the shale horizons. The radioactive logs show the Marmaton group to be approximately one-half limestone and one-half shale; however, sands are extremely difficult to differentiate from limestones in these logs, and some sandstone may be present. The Marmaton group is over 100 feet thick in both the southeast and southwest corners of Stafford county. The Marmaton group becomes progressively thinner to the north and pinches out approximately midway between the north and south boundries of the area covered by this report (Appendix, Fig. 5). The thinning of the Marmaton group is due to the transgressional nature of the sediments and to the erosion surface at the upper boundry of the group.

<u>Missourian Series</u>. The Pleasanton group is recognized in the basins on either side of Stafford county. A thin shale bed is thought to represent Pleasanton sediments in Pawnee county (Shapley, 1956). The Pleasanton group may be present as a shale underlying the Kansas City group in the south part of Stafford county.

The Kansas City group unconformably overlies the Marmaton group in the south one-half of Stafford county, and the Viola limestone and Simpson shale in the northern part of the county.

The Kansas City group is the first unit to completely overlap the erosion surface in this area. The Kansas City group is composed of the Bronson subgroup, the Lin subgroup, and Zarah subgroup, in ascending order; however, the alternating shales and limestones cannot be differentiated in the subsurface. The names applied to the surface outcrops in eastern Kansas are of very little value in subsurface studies of either the Kansas City group or the overlying Lansing group.

The Lansing group overlies the Kansas City group over the entire area covered by this report. A disconformity probably separates the two groups in the area, but like the other disconformities which lie in the shale horizons, it cannot be identified in the subsurface. The Lansing is predominently limestone which probably belong to the Plattsburg limestone and the Stanton limestones of the surface outcrops, separated by thin shale breaks. The Vilas shale, which separates the limestones in the outcrops, may be represented by one of the shale breaks. The Lansing group has been eroded by post-Iatan erosion in some portions of Kansas, which makes the Lansing top unreliable as a mapping horizon; however, the erosion surface is apparent only in the extreme north part of the area covered by this report. The overall thickness of the combined Lansing-Kansas City groups ranges from approximately 210 to 400 feet in this area.

The Pedee group, consisting of the Weston shale overlain by the Iatan limestone, rests upon the Stanton limestone of the Lansing group. The Iatan limestone is often logged as the Brown Lansing by drillers in the Central Kansas area. A minor disconformity may be present within the Weston shale as it thins considerably from south to north in the area.

<u>Virgilian Series</u>. The Douglas group, consisting of the Stranger formation overlain by the Lawrence shale, unconformably overlies the Pedee group in this area. The Douglas group is predominently shale with calcareous and sandy zones in the area covered by this report.

The Shawnee group unconformably overlies the Pedee group in the area of this investigation. The formations named from the outcrops are the Oread limestone, Kanawaka shale, Lecompton shale, and the Topeka limestone in ascending order. The units named from the outcrops are probably present in the subsurface, but only certain parts of the surface section are apparent on the logs of this area. The limestone formations in the outcrops are made up of limestones separated by shales. The shale formations in the outcrops thin in the subsurface, making the correlation between outcrops and subsurface extremely difficult. The Heebner shale, a member of the Oread limestone, is used as a marker bed over much of Kansas in the subsurface. The Heebner shale is a black fissel shale ranging from 5 to 10 feet thick in the area of this investigation. The thickness of the Shawnee group ranges from about 365 feet in the south part of Stafford county to approximately 300 feet in the north portion of the county. In the area near Barton-Stafford county line, the Topeka limestone is apparently eroded by post-Topeka erosion as part of the Topeka section is not present on the radioactive logs of wells drilled in that area. The unconformity at the top of the Topeka may account for most of the thinning present in the Shawnee group in this area.

The Wabaunsee group unconformably overlies the Topeka limestone. The Wabaunsee group is made up of thin limestones separated by shales with some sandy zones in the shales. The thin limestones and equally thin shales make it impossible to identify most of the 28 formations, named at the outcrops in the subsurface; however, the Severy shale at the base of the Wabaunsee group is easily picked on the radioactive logs. No commercial production has been obtained from any of the formations within the Wabaunsee group in Stafford county.

Permian System

Wolfcamp Series. The Admire group unconformably overlies the Pennsylvanian. Approximately one hundred feet of thin limestone separated by thin shales are present in the area of this investigation. The formations of the Admire group are nearly impossible to identify in the subsurface; however, the writer has located the top of the Pennsylvanian rocks on radioactive logs. Above the Pennsylvanian is a shale section which contains a sandstone in portions of the area. The sandstone may be equivalent to the Indian Cave or other upper Pennsylvanian channel sands.

The Council Grove group is made up of alternating limestones and shales; however, the individual units of the Council Grove group are thicker than those of the underlying Admire group. Several horizons within this group may be recognized readily in the well samples and on radioactive logs of wells in the area. The thickness of the Council Grove group, as determined from the radioactive logs, ranges from 350 to 410 feet.

The Chase group consists of thick cherty limestones separated by shales. Several horizons within the Chase group may be used as marker beds, as they are easily identified in the samples or on radioactive logs. The thickness of the Chase group ranges from approximately 250 feet to 340 feet in the subsurface of Stafford county.

Leonardian Series. The Sumner group overlying the Chase group is composed of evaporites, shales, and a few limestones in the subsurface. The rocks of the Sumner group tend to grade from limestones and shales at the base of the group into the evaporites higher in the section. The top of the Herington limestone is easily picked on the radioactive logs as the base of the group, and the top of the group is readily determined at the top of the stone Corral anhydrite. The Hutchinson salt, member of the Wellington shale, is present everywhere in the area. The salt member is made up of salt and anhydrite with some local thinning in the southern portion of the county, which may be due to plastic flow as described by Lee (1956). The approximate thickness of the Sumner group ranges from 100 to 1225 feet in general thinning to the north.

The Nippewalla group overlies the Sumner group conformably in the subsurface of Stafford county. The group is made up of sandstones, shales, and a few beds of gypsum, with the predominent color being red. The formations present in the area are the

Harper sandstone, Salt Plain formation, and an undetermined portion of the Cedar Hills sandstone, and Flower Pot shale which are probably completely absent in the northeastern portion of the county due to post-Cretaceous erosion. In the areas where the Cheyenne sandstone is absent, the Nippewalla group has also been subjected to post-Cretaceous erosion. The approximate range of thickness of the Nippewalla group in Stafford county is from 500 to 800 feet.

Triassic and Jurassic Systems

No rocks belonging to the Triassic or Jurassic systems have been identified in Stafford county.

Cretaceous System

Commanchean Series. The Cheyenne sandstone, a continental deposit laid down in advance of an advancing sea is the oldest Cretaceous rock present in Stafford county. A low angular unconformity separates the Cheyenne sandstone from the underlying Permian rocks. The Cheyenne sandstone has been removed from a portion of the area by post-Cretaceous erosion. The Cheyenne sandstone is composed of sandy clay, shale, and interbedded siltstone and sandstone, and ranges from a feather edge to approximately 100 feet in thickness.

The Kiowa shales overlie the Cheyenne sandstone in the western half of Stafford county and in a small area in the northeastern part of the county. The Kiowa shale is exposed at the surface in the northeastern portion of the county. Thus, it is the only bedrock exposed above the Pleistocene and Recent sediments in the area of this investigation. The Kiowa shale is predominently marine in origin and consists of shales, sandstones, and thin beds of limestone. Where the Kiowa shale is exposed at the surface, it consists of a dark-colored fossiliferous shale and a brown sandstone. The thickness of the Kiowa shale ranges from a feather edge, where it has been removed by erosion, to approximately 90 feet in the north central part of the county (Latta, 1950).

Gulfian Series. The Dakota formation is present in the extreme northwestern portion of the area of this investigation, where it overlies the Kiowa shale. The Dakota formation has been removed by erosion over the remaining part of the county. The Dakota formation consists of clays, siltstone and sandstones, and probably does not exceed 50 feet in thickness in Stafford county (Latta, 1950).

Quaternary System

Pleistocene Series. The Meade formation unconformably overlies the older rocks in Stafford county. The Meade formation is present at the surface and underlying the younger sediments over all of Stafford county. The Meade formation is made up of poorly sorted sand, gravel, and silts, some of which are loosely cemented by caliche. The deposits are an important source of ground water, and they range from more than 200 feet in thickness in the area.

Pleistocene and Recent Series. Dune sand of Pleistocene and

Recent age covers much of the surface area in Stafford county. The dune sand is composed of fine to medium-grained quartz sand and minor amounts of clay, silt, and coarse sand. The older dune sands contain a larger percentage of clay and silt than the younger sands, thus the older sands tend to be more stable and support more vegetation than the younger sands. The younger sands are clean and loose, and severe wind erosion takes place in those areas covered by the younger dune sand. The dune topography locally has a relief of more than 50 feet (Latta, 1950).

Recent Series. Consolidated marsh and beach deposits occur in a small area surrounding Big and Little Marshes in the north-eastern part of Stafford county. The marsh deposits consist of an upper 1 to 2 feet of fossiliferous, sandy silt and clay, below which are layers of poorly sorted silt, clay, and fine to coarse sand. The ridge of beach sand occurs in Big Marsh associated with an intermittant lake. Alluvium along the upper Rattlesnake Creek valley and Ninnescah Creek valley is apparently the youngest sediment in Stafford county. The alluvium occurs as a very thin veneer along the stream valleys, overlying the dune sand and the Meade formation (Latta, 1950).

STRUCTURE

Pre-Mississippian Regional Structure

North Kansas Basin. The north Kansas basin, named by Rich (1933), was a broad pre-Mississippian basin north of the Chautauqua arch and east of the Ellis arch.

Colorado Sag. Eardly (1951) named a pre-Mississippian trough trending northwest-southeast across Colorado, the Texas Panhandle, Oklahoma, and southwestern Kansas, the Colorado sag. Moore and Jewett (1942) named the area southwest of the Ellis arch and southwest of the Chautauqua arch the Southwest Kansas Basin. Merriam (1955) attempted to show a possible pre-Mississippian embayment in this area by several thickness maps, but no well-defined basin was apparent to the writer. If there was no well-defined basin in the area, it would seem that the name Colorado sag would be more appropriate for the pre-Mississippian structures lying to the southwest of the Chautauqua-Ellis axis.

Ellis and Chautauqua Arches. A pre-Mississippian structural high separated the North Kansas basin from the Colorado sag (Appendix, Fig. 2). Eardly (1951) illustrated this northwest-southeast trending structure as part of a cross structure of the Transcontinental arch. A low saddle separated the part of this structure lying in northwestern and central Kansas from the portion in southeastern Kansas. Moore and Jewett (1942) named the pre-Mississippian structural high northwest of the saddle, the Ellis arch. Barwick (1928) applied the name, Chautauqua arch, to the portion of the structure to the southeast of the saddle. The saddle between the Ellis arch and the Chautauqua arch has not been named. McClellan (1930) applied the name Chautauqua-Barton arch to the entire pre-Mississippian structural high, trending northwest-southeast, across Kansas. The terms Ellis arch and Chautauqua arch are the most consistently used in the literature, and they would appear to be the most desirable nomenclature for these structures.

Stafford county lies to the south of the main axis of the Ellis-Chautauqua pre-Mississippian highs in Kansas, with the Ellis arch lying to the northwest and the saddle separating the Ellis arch and the Chautauqua arch to the southeast. The Colorado sag was to the southwest of the area. The pre-Mississippian dips were to the southwest, the south, and the southeast in the Stafford county area due to the location of the above structures.

Later Paleozoic Regional Structures

Central Kansas Uplift. The Central Kansas uplift is a major post-Mississippian structural high, which trends at a slight angle to the grain of the pre-Mississippian Ellis-Chautauqua structure (Appendix, Fig. 2). The Central Kansas uplift deformation probably followed a pattern which was dictated by a pre-Cambrian grain. The Central Kansas uplift may have been the result of a continued movement of a portion of the Ellis arch which was modified by northeast to southwest trending structures in late Mississippian and early Pennsylvanian time. The name Russell arch was originally applied to this structure by Denison (1926), however, Barwick (1928) applied the name Barton arch to the same structure. Morgan (1932) and Koester (1935) publicized the name Central Kansas uplift, which has been more widely accepted than the previously proposed names. The structure is generally referred to as the Central Kansas uplift in recent geologic literature.

Hugoton Embayment. The name Hugoton embayment was used by Maher and Collins (1948) for the embayment extending from the Andarko basin into southwestern Kansas (Appendix, Fig. 2). McClellan (1930) and Moore and Jewett (1942) applied the name Dodge City basin to the same general structure. The writer prefers the name Hugoton embayment, because the structure is not a true basin, and because the structure is closely related to the Andarko basin to the south. Although the Hugoton embayment is considered a post-Mississippian structure, an embayment extending from the Colorado sag was present in the same general area in pre-Mississippian times.

Andarko Basin and the Northern Basin Shelf. The Andarko basin and the associated Hugoton embayment are closely associated with the regional dip of the Paleozoic rocks in southern and south central Kansas. The name Northern basin shelf was used by Wheeler (1947) to describe a shelf-like flattening of the Mississippian and Pennsylvanian rocks, which was located between the Andarko basin and the Central Kansas uplift (Appendix, Fig. 2).

Sedgwick Basin. The Sedgwick basin is a post-Mississippian basin-like structure lying east of the Northern basin shelf, southeast of the Central Kansas uplift, south of a structural high which separates it from the Salina basin, and west of the Nemaha anticline and fault (Appendix, Fig. 2). Moore and Jewett (1942) named the structure the Sedgwick basin. The Sedgwick basin is probably an embayment related to the Andarko basin to the south.

Salina Basin. The Nemaha ridge divides the pre-Mississippian North Kansas basin into two distinct basins, the Salina basin to the west and the Forest City basin to the east (Appendix, Fig. 2). The name Salina basin was applied to the basin west of the Nemaha ridge by Barwick (1928).

Minor Structures

Rush Rib. Koester (1935) named a structural and topographic high extending from Graham county across Trego, Ellis, Rush, and Barton counties into southeastern Stafford county, the Rush rib (Appendix, Fig. 2). The northwesterly trend of the Rush rib nearly paralleled the axis of the pre-Mississippian Ellis arch. The structure was apparent on the Arbuckle structure map (Appendix, Fig. 4), as a nose extending through T. 21 S., R. 11 W. into T. 22 S., R, 11 W. The Viola thickness map indicated a thinning along this same northwest-southeast trend. The Lansing structure map (Appendix, Fig. 6) does not indicate a prominent structure along the Rush rib trend, therefore, the Rush rib is considered to be at least pre-Lansing in age, and probably pre-Mississippian in age in Stafford county. The Kowalsky, southwest, and the Snider, south, pools produce oil from the Simpson pays and the Arbuckle dolomite in local domes on the Rush rib in Stafford county.

Pawnee Rib. Koester (1935) named "the broad area in Pawnee county in which the 'Siliceous lime' underlies the Pennsylvanian--" the Pawnee rib. Jewett (1951) wrote "A pre-Mississippian structure in Pawnee county, which may be regarded as part of the Ellis arch, is called Pawnee rib." Shapley (1956) concluded, "From all available evidence today, the Pawnee rib was probably used in the same sense as the term Central Kansas uplift is used today." The writer could find no well-defined structural trend in Stafford county, which might be an extension of the so-called Pawnee rib; however, the Pawnee rib is illustrated on Fig. 2 (Appendix) in the position illustrated by Jewett (1951).

Ellsworth Anticline. Koester (1934) called a structure extending from the vicinity of Ellsworth through R. 8, 9, and 10, and beyond the southern limits of Rice county, the Ellsworth anticline. McClellan extended the Ellsworth anticline across Stafford county (Welch 1951). The writer has extended the anticline to the southwest across Stafford county as shown on Fig. 2 (Appendix). The axis of the anticline, as shown by the writer, is to the east of the axis shown by McClellan in the southern one-half of Stafford county. The presence of the structure in the position shown by the writer is indicated by the following: 1. The Viola limestone and dolomite is absent on local highs along the anticlinal trend due to pre-Pennsylvanian erosion (Appendix, Fig. 7). 2. A structural high is apparent along the trend shown on both the Arbuckle and Lansing structure maps (Appendix, Fig. 4 and 6). 3. The position of the Mississippian limestone pinchout indicates a structural high along the trend at the time of the pre-Marmaton erosion (Appendix, Fig. 5).

Pratt Anticline. The largest minor structure extending into Stafford county is the Pratt anticline, which trends northeast-southwest through Barber, Pratt, and Stafford counties (Appendix, Fig. 2). The Pratt anticline extends into Stafford county along the same trend as the Ellsworth anticline and probably is merely a southwestward extension of the Ellsworth anticline of Koester (1935). The position of the fold in Stafford county is determined by the same criteria used to locate the Ellsworth trend in Stafford county. Merriam (1955) using thickness maps, determined the major movement of the Pratt anticline to be between the end of Viola deposition and the end of Lansing deposition. The writer does not have the necessary thickness maps of the county to determine whether the structure of the Lansing map (Appendix, Fig. 6) is due to post-Lansing movement or due to differential compaction. The possibility exists that a fault with some vertical displacement may be present along the Ellsworth-Pratt anticlinal trend in the subsurface.

GEOLOGIC HISTORY

Pre-Cambrian Era

The pre-Cambrian geological history is but little known; however, both igneous and metamorphic rocks have been recognized from well cuttings, and the relationships of these rocks give some indication of the major pre-Cambrian events. Walters (1946) in a study of the buried pre-Cambrian hills of Barton county concluded, "It is probable, but unproved, that the intrusion of the granitic igneous rocks caused the metamorphism of the gneiss, schists, and quartzites." In pre-Cambrian time batholithic intrusions probably cut pre-existing rocks and metamorphosed these rocks to form the gneiss, schists, and quartzites. Extended erosion followed which lasted into the Cambrian period.

Paleozoic Era

The Waucoban and Albertan epochs of the Cambrian were represented by erosion of the underlying basement rocks. The surface was possibly peneplained with a few monadnocks of resistant rocks projecting above the general surface. The Croixan seas transgressed, reworked the erosional debris, and deposited the Lamotte (Reagan) sandstone. The Lamotte sandstone grades upward into the overlying Bonneterre dolomite, indicating continuous deposition through Bonneterre time. An exception to the continuity of deposition may have occurred over any buried hills, such as those found by Walters (1946) in Barton county. The possibility exists that the Lamotte and possibly the Bonneterre were not deposited over basement highs at the time of deposition. Post-Bonneterre erosion removed any post-Bonneterre sediments that may have been deposited, and the Bonneterre was subjected to erosion before the Ordovician rocks were deposited in the area.

In Lower Ordovician the Roubidouix formation and the Jefferson City-Cotter sequence was deposited over the area, before erosion removed a portion of the sediments. A thickness map by Lee (1956) shows an elongate trend of thickening extending across Stafford county. The thickening of the Cambro-Ordovician Arbuckle sediments along this trend indicates a synclinal trough was probably developed during the deposition of the Reagan and Arbuckle in the area. The first folding along the Ellis arch trend probably took place during Lower Ordovician time, and the pre-Simpson erosion may have been responsible for the sinkholes and drainage developed on the Arbuckle in the northern portion of Stafford county where the Arbuckle was not subjected to post-Mississippian erosion (Appendix, Fig. 4).

The seas returned to the Central Kansas area during Lower Ordovician and reworked the Arbuckle debris on the erosion surface. The erosional debris was apparently concentrated in the sink holes of the Arbuckle erosion surface, thus, tending to level the surface on which the Lower Ordovician member of the Simpson group was deposited. The St. Peter sandstone, member of the Simpson group, was deposited over the area; followed by a period of erosion, which removed part of the St. Peter prior to the deposition of the Platteville formation. The Platteville grades upward into the overlying Viola limestones and does not indicate extended erosion in the area of this investigation. Lee (1956) found a hiatus existed between the Upper Simpson beds and the Viola but very little topography developed on the erosion surface. The Viola limestones were deposited over the area and followed by an erosion which resulted in considerable disection of the Viola limestones before the Maquoketa was deposited. Considerable uplift must have occurred prior to the deposition of the Marmaton. The Maquoketa deposition apparently filled the erosional lows in the Viola (Lee, 1956). In the Stafford county area the Maquoketa was found in portions of the county which were apparently lows on the Viola erosion surface. The writer believes the post-Viola and pre-Maquoketa erosion and associated solution cavities may account for at least a part of the extremely porous zones found in the Viola.

The Silurian part of the Hunton was probably deposited over the area, followed by an interval of non-deposition or erosion. The entire sequence of Devonian and Silurian and Devonian limestones, and much of the underlying Maquoketa shale was removed by pre-Chattanooga erosion. The Viola limestone was again subjected to weathering during the pre-Chattanooga erosion over much of Stafford county. The Chattanooga was then deposited, overlying the Viola limestone and scattered remanents of the Maquoketa. The remanents of the Maquoketa apparently were left in the places where the Maquoketa had been deposited in the topographic lows of the Viola. The writer believes the Chattanooga is Devonian in age, and the post-Chattanooga erosion, which followed essentially divided the Devonian and Mississippian rocks in the area.

The Boice shale of northeastern Kansas may have been deposited and removed by post-Boice erosion. The Kinderhookian limestones were then deposited, followed by another erosion cycle which probably removed a portion of the Kinderhookian limestones from the area of this investigation before the overlaying Osagian limestones were deposited over the entire area. A period of erosion followed which probably extended into Meramac time. The Upper Meramac rocks are present in the Salina basin and the Hugoton embayment, and a part of the Meramac series was probably deposited over Stafford county. The Chesterian epoch was a time of uplift and deformation, which extended through the Morrowan epoch of the Pennsylvanian.

The folding which occurred from Late Mississippian into Early Pennsylvanian times followed the general northeast-southwest trend. The northeast-southwest trending structures may result from some faulting but this cannot be proved. These structures as a whole had their beginnings in pre-Mississippian time, but the major deformation occurred in Early Pennsylvanian time, predominantly in the Morrowan epoch of the Pennsylvanian.

The Cherokee seas began to cover Kansas from the southwest in Demoinesian time, but apparently did not cover the Pratt anticline to the south of Stafford county (Merriam, 1955). If the Cherokee seas advanced up the Central Kansas uplift into Stafford county, only the extreme southwestern portion of the county received Cherokee deposits. A portion of the Pennsylvanian basal conglomerate may be Cherokee in age. As the seas continued to transgress, the Marmaton group was deposited upon the erosion surface, overlaping the Cherokee sediments. The Marmaton group was subjected to post-Marmaton erosion, which removed the upper portion of the group, leaving the Marmaton sediments as a wedge extending into Stafford county from the south. The seas which deposited the Pleasanton sediments then moved over the Central Kansas area, but did not advance as far up the Central Kansas uplift as the Marmaton seas. The Pleasanton sediments were probably deposited in extreme southwestern Stafford county as a shale which could not be differentiated from the underlying Marmaton with the information available on the area. The seas continued to over-lap the higher areas of the Central Kansas uplift as the Kansas City group was deposited. Shortly after the Kansas City deposition began the seas covered all of the Stafford county area. Slight fluctuations of the seas during Kansas City and Lansing deposition caused the sediments to be cyclic in nature. The fluctuations of the seas and many other factors controlling sedimentation during Kansas City and Lansing time, were more uniform than in the area of outcrop in eastern Kansas, as the limestones are thicker and the shale partings are thinner in the subsurface than in the outcrops.

The Pedee group was deposited before the seas again retreated from the higher portions of the area. The Pedee group is absent in the extreme northern portion of Stafford county due to post-Iatan erosion. The nearly complete Pedee section in the southern part of the county, which is much lower on the flanks of the Central Kansas uplift, may indicate the uplift stood above the surrounding area during the erosion of the Pedee group. The thickness maps of Merriam (1955) and Lee (1956) indicate no deformation of the Ellsworth-Pratt anticline trend after the Lansing was deposited although the movement of the Central Kansas uplift extended into Late Pennsylvanian time.

The Virgilian series was deposited over the entire area as the seas returned to cover the Central Kansas uplift. The alternating limestones and shales, along with some sandstones were deposited as the seas fluctuated somewhat in depth. The Douglas group and the Shawnee group were deposited before the seas retreated enough for the erosion of the Topeka limestone at the top of the Shawnee group. The Topeka limestone was subjected to more erosion near the Central Kansas uplift in northern Stafford county, than on the flanks of the uplift in the southern part of the county. The Wabaunsee group was then deposited over the area before an erosional break ended Pennsylvanian time. The seas returned to the area during the Wolfcamp epoch and the marine limestones and shales of the Admire group, Council Grove group, and the Chase group were deposited over the Central Kansas area. The inlet from the sea was restricted during Late Wolfcamp time, and the seas became shallower as the deposits became more clastic in nature. In Leonard time the climate became progressively more arid, and the sediments deposited were predominantly shale and evaporites. The Hutchinson salt was deposited in a nearly circular basin which was not effected by the structures that had existed previously. The central Kansas area was tilted to the southwest toward the Hugoton embayment during Permian time. The uppermost Permian sediments in the area were probably deposited in extremely arid conditions, these sediments extended into Gaudalupe time.

Mesozoic Era

The Central Kansas area remained above sea level throughout the Triassic and Jurassic periods. Merriam (1955) found the entire Hugoton embayment was tilted to the northwest during Jurassic time. Erosion of the Permian sediments lasted until Early Cretacious, when the Commachean series were deposited in the area. The Cheyenne sandstone was deposited as a continental and Littorial deposit, as the Commachean seas transgressed over the area. The Kiowa shale of marine origin was then deposited before the seas retreated. In Gulfian time the seas covered the area for the last time, and the basal Dakota sandstone was deposited as the seas moved over the Kiowa erosion surface. Before the seas retreated from the area for the last time, the Colorado group, which overlies the Dakota group, was then deposited over the area followed by an unknown amount of Montana group rocks. Near the end of the Cretaceous period the entire area was tilted to the northwest, and subject to erosion.

Cenozoic Era

Erosion of the Cretaceous and Permian strata occurred during most of the Tertiary period. The Ogallala formation of Pliocene system may have been deposited over part of the Stafford county area, then removed by erosion. The Meade formation was deposited over the eroded Cretaceous and Permian rocks during Pleistocene time, as sediments from the Rocky Mountains, and Western Kansas were carried into the area. During Late Pleistocent a dune topography began to develop as wind-blown sands were carried over the area. The wind-blown sands continued to move over the area throughout Recent time.

OIL AND GAS PRODUCTION IN STAFFORD COUNTY

Prior to 1930, five unsuccessful tests for oil and gas had been drilled in Stafford county. Midwest Exploration Company (Standolind Oil and Gas Company) drilled the first commercial oil well in the county in 1930, when the discovery well of the Richardson field was completed. The well was completed in the "Siliceous lime" (Arbuckle) although gas was encountered in a sand lense at a shallower level, thought to be in the Severy shale. The discovery well was shut in. Adverse financial conditions of the depression were responsible for delay in the development of the Richardson field, and no new fields were discovered until 1932.

Three additional producing wells were drilled in 1932 as the Richardson field was extended. Exploration for petroleum was revived with the discovery of the Gates field on a seismic high in 1933. The Drach, Max, Mueller, and Zenith fields were discovered by 1938. As of 1955 the Richardson, Gates, Drach, Max, Mueller, and Zenith fields had not been exceeded in areal extent or in total number of producing wells by any fields discovered after 1938. Each of these six fields had produced a cumulative total of more than five million barrels of oil by 1955. The development of these fields resulted in a peak in drilling activity in 1939, which was not exceeded until 1949.

The number of producing oil fields in Stafford county continued to increase as drilling activity continued at a reduced pace through World War II. Following World War II, the use of the reflection seismograph, and improved completion techniques resulted in a continuous increase in the drilling of oil and gas wells in Stafford county. The peak in drilling activity was reached in 1953, when 400 tests were drilled and 203 producing oil wells and one gas well were discovered. Since 1953 activity has decreased in Stafford county; however, the county remains seventh in oil production for counties in Kansas in 1955. Tables 1 and 2 (Appendix) list the oil and gas fields of Stafford county as of 1955.

THE RELATIONSHIP OF STRUCTURE AND STRATIGRAPHY TO PETROLEUM ACCUMULATION

Arbuckle Production

The Arbuckle production in Stafford county is concentrated in the area north of the -2,000 contour line on the Arbuckle structure map (Appendix, Fig. 4), and the larger Arbuckle accumulations are found where the top of the Arbuckle group is above the -1,800 contour line. Pre-Simpson erosion of the area above the -1,800 contour line resulted in the development of a karst topography on the underlying Arbuckle rocks, indicated in Fig. 4. Good permeabilities and porosities are apparently associated with the solution of the limestones and dolomites in the areas where the karst topography is present on the Arbuckle surface. Very little indication of a pre-Simpson karst topography is found south of the -2,000 contour, and very little Arbuckle production is found south of this line. Apparently the factor that controls Arbuckle production in Stafford county is the porosity and permeability, developed during pre-Simpson weathering and erosion. Structure is probably also a factor in the accumulation of petroleum in the Arbuckle rocks; however, many good structures to the south of the -2,000 contour line do not contain commercial accumulations of oil and gas in the Arbuckle.

The Arbuckle production is usually associated with the pre-Simpson topographic highs in the area lying within the -1,800 contour line. The larger Arbuckle accumulations in this area are within closed highs indicated on Fig. 4; however, the smaller accumulations within this area do not always show closure and are probably trapped by porosity and permeability pinchouts. Closure responsible for Arbuckle production below the -2,000 contour line is shown on Fig. 4. The porosity and permeability in the Arbuckle group in the area south of the -2,000 contour line is possibly the result of fractures associated with well developed structural highs.

Simpson Production

The production from the St. Peter sandstone of the Simpson group overlies the Structural highs of the Arbuckle surface (Appendix, Fig. 4). The lenticular development of the sandstone within the shales of the Simpson group determines the suitability of this horizon as a reservoir rock. Only those areas in which a well-developed, clean sand is found produce oil in commercial quantities from the St. Peter sandstone.

Viola Production

Petroleum accumulation in the Viola limestones appears to be restricted to Ranges 11, 12, and 14 west of townships 24 and 25 south; however, two pools from which commercial production is obtained from the Viola interval are located north of this general area. The area of greatest Viola production underlies the Chattanooga shale, which pinches out to the north of the Mississippian limestone pinchout shown on Fig. 5 (Appendix). Closure was lacking on both the Arbuckle structural map and the

Lansing structural map (Appendix, Fig. 4 and 5) in several of the areas of Viola production; however, anticlinal trends are indicated in these areas. The Viola thickness map (Appendix, Fig. 7) indicates a general thickening of the Viola in practically every area from which Viola oil or gas is produced (Appendix, Fig. 7). This thickening of the Viola is not uniform in the various areas of Viola production. The porous zones in the Viola limestones parallel the bedding planes. A study of the radioactive logs indicate that these porous zones occur over a considerable area. The Zenith field is an example of a stratigraphic and structural trap in which the porous zones of the Viola pinch out against the Chattanooga shale. The two areas which produce from the Viola interval north of the Chattanooga pinchout are located on structural highs in T. 22 S., R. 14 W. Some Viola production is associated with similar structural highs south of the Chattanooga pinchout. A possible criteria for future Viola production may be the location of areas in which the Viola interval is locally thickened, within the limits of anticlinal trends.

Mississippian Production

Mississippian oil production has been reported from three pools in Stafford county. The Richland and Rattlesnake West pools produce minor amounts of petroleum from permeability and porosity pinchouts in the Mississippian limestones. No closure is indicated on Fig. 5 (Appendix) in the areas of these accumulations. Kinderhook oil and gas production is reported from the

Farmington pool in T. 24 S., R. 15 W.; however, this production is from a sand at the base of the so-called "Kinderhook". This sand is probably equivalent to the Misener sandstone, and is possibly Devonian in age rather than Mississippian. Lee (1939) found porous zones developed in the Mississippian limestones to a depth of 100 feet below the top, but very little petroleum production has occurred in the upper 30 feet of these limestones. The fact that much of Stafford county is underlain by less than thirty feet of Mississippian limestone may account for the lack of prolific production from this interval.

Pennsylvanian Basal Conglomerate Production

Several oil and gas fields in Stafford county have produced some oil and gas from the Pennsylvanian basal conglomerate. With one exception these accumulations were found in structural highs, where a clean sand or conglomerate zone had developed in this horizon. The Satterlee pool in T. 24 S., R. 14 W. is structurally low on each of the horizons contoured by the writer, the oil produced from this pool was possibly accumulated in a lenticular sand or conglomeritic zone overlain by impervious shales.

Lansing and Kansas City Production

Only the Arbuckle group has exceeded the Lansing and Kansas City groups in total production of petroleum in the area of this investigation. The Lansing and Kansas City groups produce commercial quantities of petroleum from porous limestone intervals within the group, associated with structural highs shown on the

Lansing structural contour map (Appendix, Fig. 6). In many of the fields producing from this interval only one or two of the individual limestones have an accumulation of petroleum present. The stratigraphic level at which production is found varies from one reservoir to another. In many fields the Lansing structures and petroleum accumulations were found to be superimposed over similar structures and accumulations in the Arbuckle group; however, pre-Mississippian structures, such as the Rush rib show little similarity between the Arbuckle and Lansing structures. These pre-Mississippian structures usually lack Lansing-Kansas City production, while very good accumulations were found in the Arbuckle group.

CONCLUSIONS

The location of Stafford county on the southern flank of the Central Kansas uplift was apparently favorable to the updip migration of petroleum from the basin to the south. Minor structural highs and stratigraphic pinchouts were responsible for localizing the accumulation of petroleum. Erosion of the underlying rocks during several intervals of geologic time was responsible for the development of pinchouts, porosity and erosional highs associated with the petroleum accumulation in the Arbuckle, Viola, and Mississippian rocks. Conditions at the time of deposition were responsible for the development of petroleum reservoirs in the Simpson group, the Misener sandstone, Pennsylvanian basal conglomerate, and the Lansing and Kansas City groups. The future potential of Stafford county is apparently limited to the discovery of small structural and stratigraphic traps as the area has been extensively drilled in the past. New techniques of completion and production may make possible the development of some accumulations, which were not considered of commercial quantity in the past.

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APPENDIX

Table 1. Producing oil fields in Stafford County, Kansas

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Oil Production bbls. Cumulative	Producing Wells	Producing Horizon
Ahnert ('41)	26-22-13	no runs	47,473	1	Arbuckle
Bart-Staff* ('51)	4-21-14	29,039	176,999	3	Arbuckle
Bayer ('51)	16-21-14	no report	1,505		Lans.--K.C.
Bedford ('40)	21-23-12	47,656	1,697,252	13	Arbuckle
Brenn ('54)	19-23-13	44,213	52,640	8	Lans.--K.C.
Brock ('44)	12-23-12	19,235	401,636	10	Arbuckle
Bryon ('51)	9-21-12	2,313	26,753	1	Arbuckle
Byron Southeast ('51)	10-21-12	7,087	42,884	4	Arbuckle
Centerview ('54)	28-24-13	9,127	17,944	1	Arbuckle
Cephas ('53)	10-25-14	78,213	233,432	14	Viola
Cephas North ('54)	35-24-14	15,072	17,403	2	Lans.--K.C.
Chase-Silica* ('31)	32-19- 9	65,956	362,042	16	Arbuckle
Clarksburg (revived) ('55)	36-22-13	6,943	6,943	2	Lans.--K.C.
Cleveland ('53)	21-23-14	6,826	23,254	1	Lans.--K.C.
Cleveland South ('53)	28-23-14	no report	783		Lans.--K.C.
Cochlin ('51)	19-22-11	5,538	32,757	2	Arbuckle
Crissman ('52)	16-23-14	40,574	193,244	11	Lans.--K.C.
					Simpson
					Arbuckle
Crissman North ('52)	9-23-14	no runs	1,807	1	Lans.--K.C.
Curtis ('42)	6-22-13	51,425	1,109,447	7	Lans.--K.C.
		93,754		16	Arbuckle
Dell ('50)	7-21-13	6,968	101,388	5	Lans.--K.C.
Dell East ('51)	5-21-13	44,396	426,966	8	Lans.--K.C.
		37,743		7	Arbuckle
Dell Northeast ('51)	5-21-13	4,115	18,767	2	Lans.--K.C.
					Arbuckle
Diamond ('53)	8-22-13	217	9,172	1	Lans.--K.C.
Drach ('37)	12-22-13	261,314	6,000,227	51	Arbuckle
Drach West ('38)	14-22-13	Combined with Gates			
Duggan ('51)	30-21-11	13,920	151,012	8	Lans.--K.C.
					Penn. congl.
					Simpson
					Arbuckle

Table 1. (Cont.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Oil Production bbls. Cumulative	Producing Wells	Producing Horizon
Farmington ('43)	34-24-15	25,830	1,151,206	14	"Kinderhook"
					Arbuckle
Farmington Northeast ('55)	26-24-15	2,344	2,344	1	Arbuckle
Fischer ('38)	31-21-12	10,820	409,525[illegible]	6	Arbuckle
Fischer Northwest ('48)	36-21-13	101,856	2,437,504	12	Lans.--K.C.
		218,973		27	Arbuckle
Frey ('50)	7-21-14	93,812	648,384	12	Arbuckle
Gates ('33)	27-21-13	635,743	5,044,276	115	Lans.--K.C.
					Penn. congl.
					Viola
					Arbuckle
German Valley ('51)	4-22-12	5,309	40,247	2	Arbuckle
Glen ('54)	14-23-14	5,851	13,647	1	Lans.--K.C.
Gray ('46)	11-24-13	2,375	50,791	3	Lans.--K.C.
Green Ridge ('53)	30-23-14	3,625	10,043	1	Lans.--K.C.
Green Valley ('53)	2-23-14	3,227	19,555	2	Lans.--K.C.
Grow ('49)	16-21-13	29,818	415,195	12	Lans.--K.C.
					Arbuckle
Grunder ('43)	11-25-15	no runs	24,727	1	Lans.--K.C.
Hahn ('53)	21-22-13	5,589	13,745	2	Lans.--K.C.
Happy Valley ('52)	15-23-13	1,729	9,371	1	Arbuckle
Happy Valley Northeast ('55)	11-23-13	9,303	9,303	4	Arbuckle
Harter ('50)	30-24-13	4,723	79,511	4	Lans.--K.C.
					Simpson
					Arbuckle
Hazel ('42)	21-21-13	102,460	789,405	25	Lans.--K.C.
					Arbuckle
Hazel West ('50)	20-21-13	6,897	821,814	2	Lans.--K.C.
		152,452		21	Arbuckle
Helene ('52)	16-22-12	1,878	24,495	3	Arbuckle
Heyen ('43)	24-22-12	30,371	609,832	14	Arbuckle
Hickman ('51)	27-21-14	5,294	774,469	19	Lans.--K.C.
		100,976		2	Simpson
Hickman South ('52)	34-21-14	9,062	27,436	1	Lans.--K.C.

Table 1. (Cont.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Cumulative	Producing Wells	Producing Horizon
Hudson ('52)	33-22-12	no report	none		Lans.--K.C.
Hufford ('48)	33-21-13	70,511	853,250	9	Lans.--K.C.
		47,924		7	Arbuckle
Jordan ('36)	15-25-14	35,391	904,017	9	Lans.--K.C.
Kachelman ('50)	7-25-13	13,601	18,556	2	Lans.--K.C.
					Viola
		2,767		2	Arbuckle
Kelly ('48)	35-23-12	no report	5,204		Arbuckle
Kenilworth ('47)	15-22-13	37,094	456,089	11	Lans.--K.C.
					Arbuckle
Kennil ('54)	4-23-13	Abandoned during 1955			Arbuckle
Kipp ('37)	27-25-14	9,630	669,013	6	Lans.--K.C.
Kipp North ('54)	23-25-14	9,494	12,138	1	Lans.--K.C.
Kipp Northeast ('46)	23-25-14	16,429	230,877	3	Lans.--K.C.
Knoche ('51)	8-24-12	no report	992		Viola
Koelsch ('52)	24-24-14	60,298	187,705	11	Lans.--K.C.
Koelsch Southeast ('52)	25-24-14	109,740	412,449	16	Simpson
					Arbuckle
Kowalsky* ('41)	32-20-11	38,270	87,568	6	Lans.--K.C.
Kowalsky Southwest ('50)	6-21-11	27,955	173,898	7	Simpson
					Arbuckle
Leesburgh ('38)	12-25-13	32,664	2,574,127	15	Simpson
					Arbuckle
Leo ('50)	7-21-13	8,532	77,811	3	Lans.--K.C.
					Arbuckle
Lincoln ('51)	29-21-14	31,470	161,101	4	Lans.--K.C.
Lincoln Northwest ('52)	29-21-14	8,149	26,225	4	Simpson
					Arbuckle
McCandless ('44)	30-25-13	45,994	915,841	9	Lans.--K.C.
		32,636		6	Simpson
McGinty ('50)	13-21-14	796	11,557	1	Lans.--K.C.
McGinty Northwest ('51)	14-21-14	2,654	27,396	1	Lans.--K.C.
Macksville East ('54)	14-24-15	11,208	22,340	2	Viola

Table 1. (Cont.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Cumulative	Producing Wells	Producing Horizon
Max ('38)	35-21-12	46,030	6,607,181	10	Lans.--K.C.
		3,690		1	Simpson
		420,940		76	Arbuckle
Max North ('55)	27-21-12	218	218	1	Arbuckle
Max South ('50)	15-22-12	no runs	9,282	1	Lans.--K.C.
Merle ('49)	32-23-13	12,988	312,275	13	Lans.--K.C.
Mopac ('54)	30-24-11	41,342	45,472	6	Viola
Mt. View ('52)	29-22-13	10,538	42,203	1	Lans.--K.C.
		1,319		1	Arbuckle
Mueller ('38)	29-21-12	18,621	6,088,6498	4	Lans.--K.C.
		526,167		89	Arbuckle
Mueller West ('49)	24-21-13	3,855	32,489	3	Arbuckle
Nellie ('48)	28-22-14	217	21,759	1	Lans.--K.C.
Neola ('48)	15-25-11	2,335	31,941	2	Viola
Newell ('53)	7-25-11	16,867	36,857	3	Lans.--K.C.
					Viola
North Star ('52)	27-24-12	54,393	269,581	7	Viola
		21,298		3	Simpson
North Star North ('53)	21-24-12	no runs	1,309	1	Arbuckle
O'Connor ('48)	8-24-15	2,771	26,107	3	Lans.--K.C.
Oscar ('49)	24-22-14	18,775	168,274	8	Lans.--K.C.
					Viola
					Arbuckle
Oscar North ('51)	14-22-14	107,974	382,701	12	Arbuckle
Oscar South ('53)	26-22-14	18,768	80,712	2	Lans.--K.C.
		24,679		3	Arbuckle
Oscar West ('52)	22-22-14	197,729	576,980	23	Lans.--K.C.
Pleasant Grove ('52)	26-22-12	29,363	123,075	6	Lans.--K.C.
Pleasant Grove South ('55)	35-22-12	no report	none		Arbuckle
Prairie Home ('49)	2-21-13	no report	14,940		Arbuckle
Prairie Home South ('53)	11-21-13	3,467	17,799	1	Lans.--K.C.
Pritchard South ('51)	3-21-14	1,619	14,043	1	Lans.--K.C.
Pritchard Southeast* ('53)	2-21-14	18,255	48,268	2	Arbuckle
Pundsack ('47)	19-21-13	138,329	1,218,124	21	Lans.--K.C.
		110,056		20	Arbuckle

Table 1. (Cont.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Oil Production bbls. Cumulative	Producing Wells	Producing Horizon
Pundsack North ('50)	18-21-13	11,802	87,411	4	Arbuckle
Pundsack Northwest ('50)	24-21-14	no report	5,031		Lans.--K.C.
Radium ('53)	7-22-14	no runs	1,043	1	Lans.--K.C.
					Viola
Radium Townsite ('53)	5-22-14	49,261	97,137	6	Arbuckle
Radke ('53)	25-23-14	2,862	11,088	1	Lans.--K.C.
Radke East ('54)	24-23-14	4,530	6,059	1	Lans.--K.C.
Rattlesnake ('38)	13-24-14	7,664	205,641	4	Lans.--K.C.
Rattlesnake Southeast ('54)	13-24-14	18,407	32,886	2	Lans.--K.C.
Rattlesnake Southwest ('50)	14-24-14	9,189	84,722	2	Lans.--K.C.
Rattlesnake West ('44)	11-24-14	11,492	157,165	7	Lans.--K.C.
					Mississippian
Richardson ('30)	36-22-12	401,732	13,119,694	71	Lans.--K.C.
					Arbuckle
Richland ('44)	27-24-14	no report	186,258		Mississippian
					Arbuckle
Riley ('40)	28-23-11	1,825	143,273	2	Lans.--K.C.
Rose Valley ('52)	36-25-13	6,505	28,878	2	Lans.--K.C.
					Viola
Rothgarn ('43)	10-21-13	11,562	323,343	10	Lans.--K.C.
					Arbuckle
Rothgarn Southeast ('50)	14-21-13	8,348	170,309	1	Lans.--K.C.
		29,027		4	Arbuckle
St. John ('35)	23-24-13	41,701	2,692,562	16	Lans.--K.C.
					Arbuckle
St. John North ('52)	20-23-13	3,416	23,639	1	Lans.--K.C.
St. John Northwest ('52)	20-23-13	16,195	33,335	4	Lans.--K.C.
		3,776		1	Arbuckle
St. John Townsite ('44)	33-23-13	13,485	430,879	10	Lans.--K.C.
					Arbuckle
Sandago ('47)	12-21-12	7,406	156,748	5	Arbuckle
Sand Hills ('44)	19-21-11	2,798	62,926	1	Arbuckle
Saterlee ('54)	31-24-14	413	2,566	1	Penns. congl.

Table 1. (Cont.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Oil Production bbls. Cumulative	Producing Wells	Producing Horizon
Saundra ('46)	14-21-12	26,407	280,536	11	Lans.--K.C.
					Arbuckle
Seevers ('54)	6-25-13	25,253	30,947	3	Lans.--K.C.
Shaeffer ('41)	3-21-13	74,546	500,759	10	Lans.--K.C.
					Penn. congl.
					Simpson
					Arbuckle
Shepherd ('51)	16-22-11	43,703	268,363	8	Arbuckle
Shepherd North ('54)	9-22-11	16,611	32,243	2	Lans.--K.C.
		1,760		1	Penn. congl.
Shepherd South ('53)	21-22-11	6,009	23,909	2	Arbuckle
Silver Bell ('49)	10-22-13	6,913	70,706	3	Lans.--K.C.
					Arbuckle
Sittner ('37)	33-21-12	19,508	726,019	14	Lans.--K.C.
					Arbuckle
Slade ('53)	23-25-12	155	3,739	1	Lans.--K.C.
Sleeper (851)	22-22-11	no runs	14,796	2	Penn. congl.
Smallwood ('51)	2-22-14	96,831	676,941	18	Lans.--K.C.
		30,834		6	Arbuckle
Snider ('36)	3-21-11	18,268	498,703	2	Simpson
Snider South ('38)	16-21-11	77,380	1,431,680	9	Simpson
		7,994		1	Arbuckle
Spangenberg ('43)	21-22-12	no runs	84,508	1	Arbuckle
Stafford ('40)	15-24-12	49,060	3,607,368	24	Viola
					Arbuckle
Starr ('50)	4-21-14	29,610	80,413	5	Arbuckle
Strobel ('52)	9-22-14	16,831	74,997	4	Lans.--K.C.
					Arbuckle
Strobel Northwest ('52)	8-22-14	5,410	32,364	2	Simpson
					Arbuckle
Sutton ('54)	21-22-14	8,469	12,334	1	Lans.--K.C.
Syms East ('47)	21-21-12	1,892	16,216	2	Arbuckle
Syms Southeast ('52)	27-21-12	8,739	43,227	3	Arbuckle
Taylor ('52)	16-21-14	1,380	16,681	2	Simpson

Table 1. (Concl.)

Field and Year of Discovery	Location Discovery Well	Oil Production bbls. 1955	Oil Production bbls. Cumulative	Producing Wells	Producing Horizon
Taylorville ('53)	29-25-12	7,535	20,666	1	Viola
Van Lieu ('43)	20-24-13	no report	206,063	3	Arbuckle
Van Winkle ('50)	23-21-14	1,282	13,701	1	Lans.--K.C.
Van Winkle Southeast ('50)	20-21-14	7,185	66,644	2	Lans.--K.C.
Wendelburg ('51)	19-23-11	1,549	17,123	1	Arbuckle
Widener ('54)	26-21-12	31,545	60,672	7	Arbuckle
Wood ('53)	33-22-14	10,804	34,069	4	Simpson Arbuckle
Zenith-Peace Creek* ('37)	23-24-11	299,739 Includes Reno County	39,023,831	175	Lans.--K.C. Viola
Pools or fields abandoned			65,100		
Total Stafford County		6,564,369	114,676,859§	1,450	

* Field extends into adjacent county or counties

§ Corrected cumulative

Table 2. Gas fields and gas production in Stafford County, Kansas

Field and Year of Discovery	Location Discovery Well	Gas Production Cu. Ft. 1955	Gas Production Cu. Ft. Cumulative	Producing Horizon
Bradbridge* ('48)	6-24-15	no report	none	Arbuckle
Farmington ('48)	27-24-15	Incl. with Macksville	774,387	Mississippian
Farmington West ('52)	6-25-15	no report	none	Penn. sand
Gates ('50)	26-21-13	no report	266,956	Lans.--K.C.
Hill ('52)	11-23-12	no report	none	Lans.--K.C.
Knocke ('51)	8-24-12	no report	1,208,546	Viola
Macksville ('47)	3-24-15	854,295	7,894,391#	Lans.--K.C.
O'Connor ('47)	16-24-15	no report	none	Arbuckle
Zenith-Peace Creek* ('37)	23-24-11	no report		Viola
Total Stafford County		854,295	9,892,805	

* Field extends into adjacent county
\# Corrected cumulative

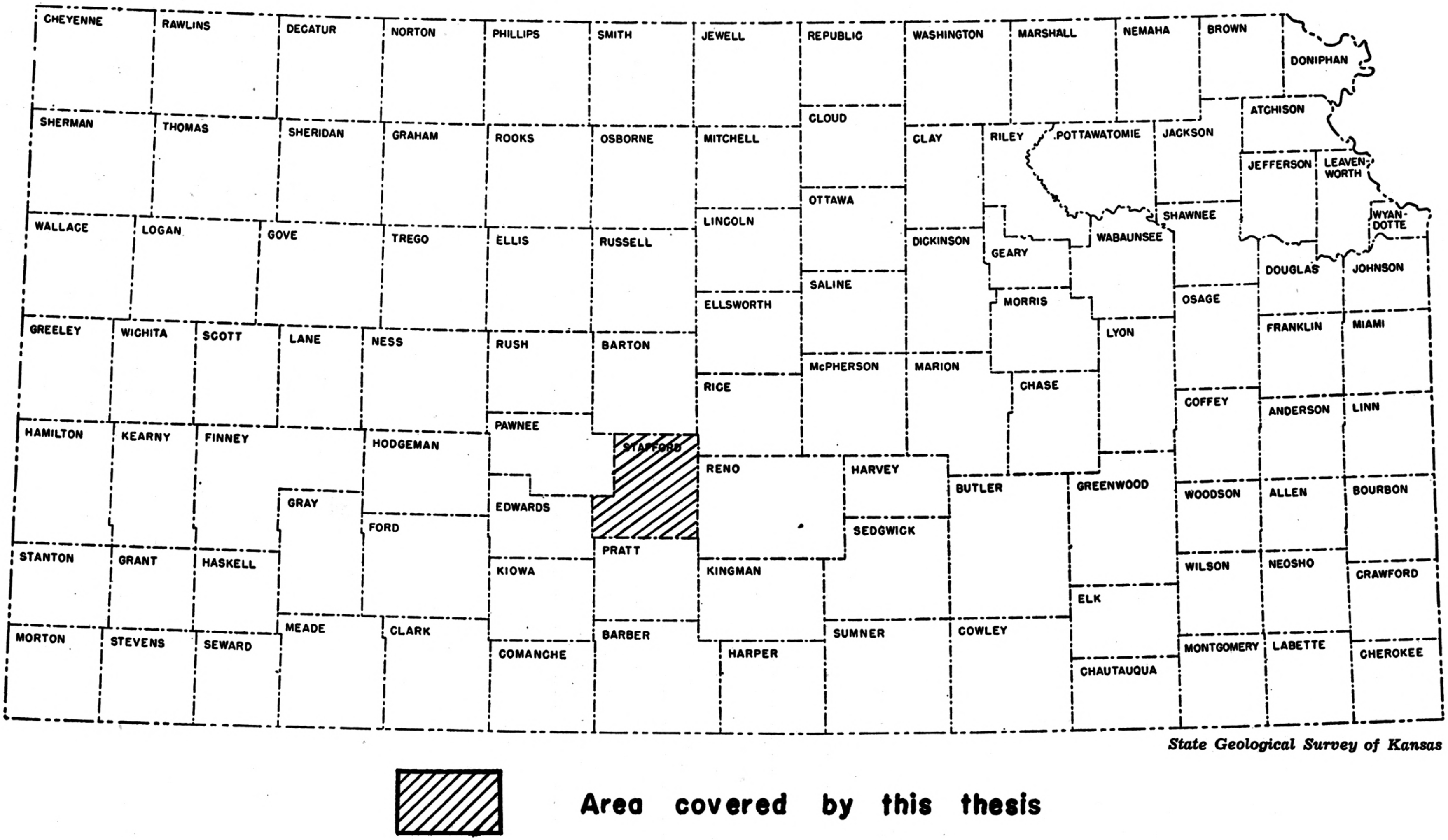
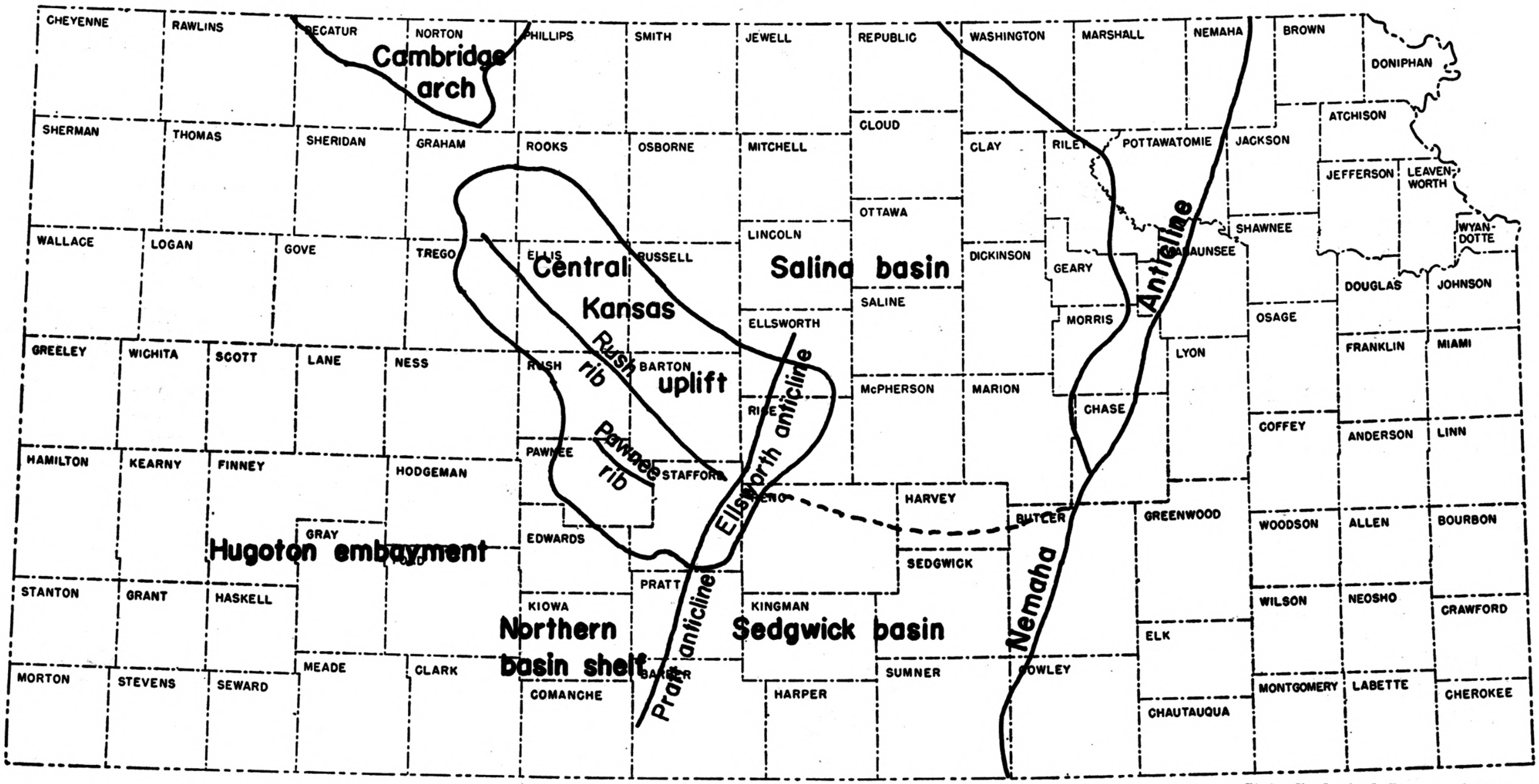


Fig. 1. Location of the area covered by this investigation



State Geological Survey of Kansas

Fig. 2. Geographical location of major and minor structures

Fig. 3. Map showing oil and gas pools in Stafford County, Kansas

Fig. 4. Structure contours drawn on the Arbuckle group, Stafford County, Kansas

(In accompanying plate box)

Fig 4

STRUCTURAL CONTOUR MAP
ON THE TOP OF THE ARBUCKLE
STAFFORD COUNTY, KANSAS

County line

Township line

Contour line

Contour interval = 20 feet

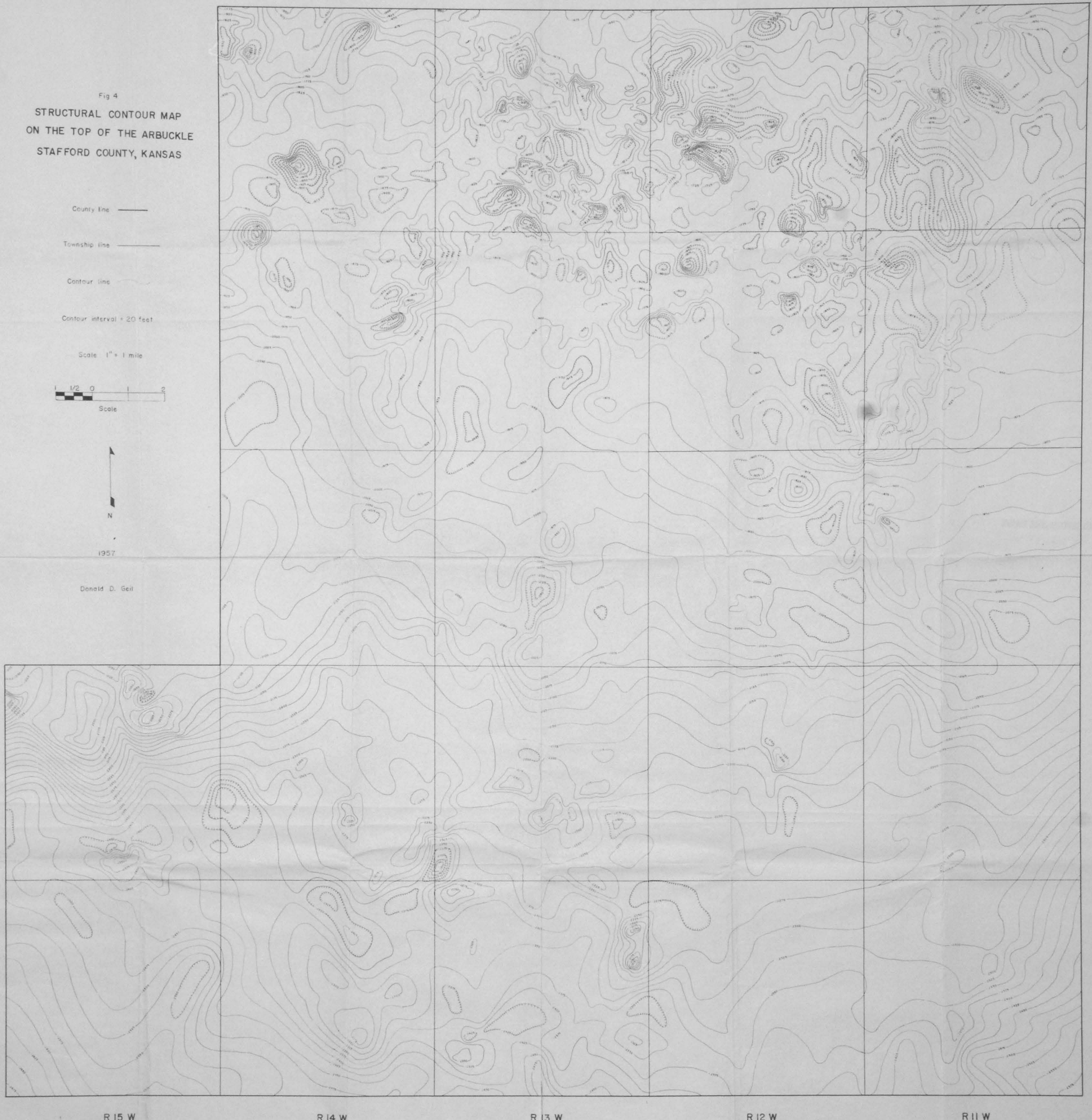
Scale 1" = 1 mile

1/2 0 1 2
Scale

N

1957

Donald D. Geil



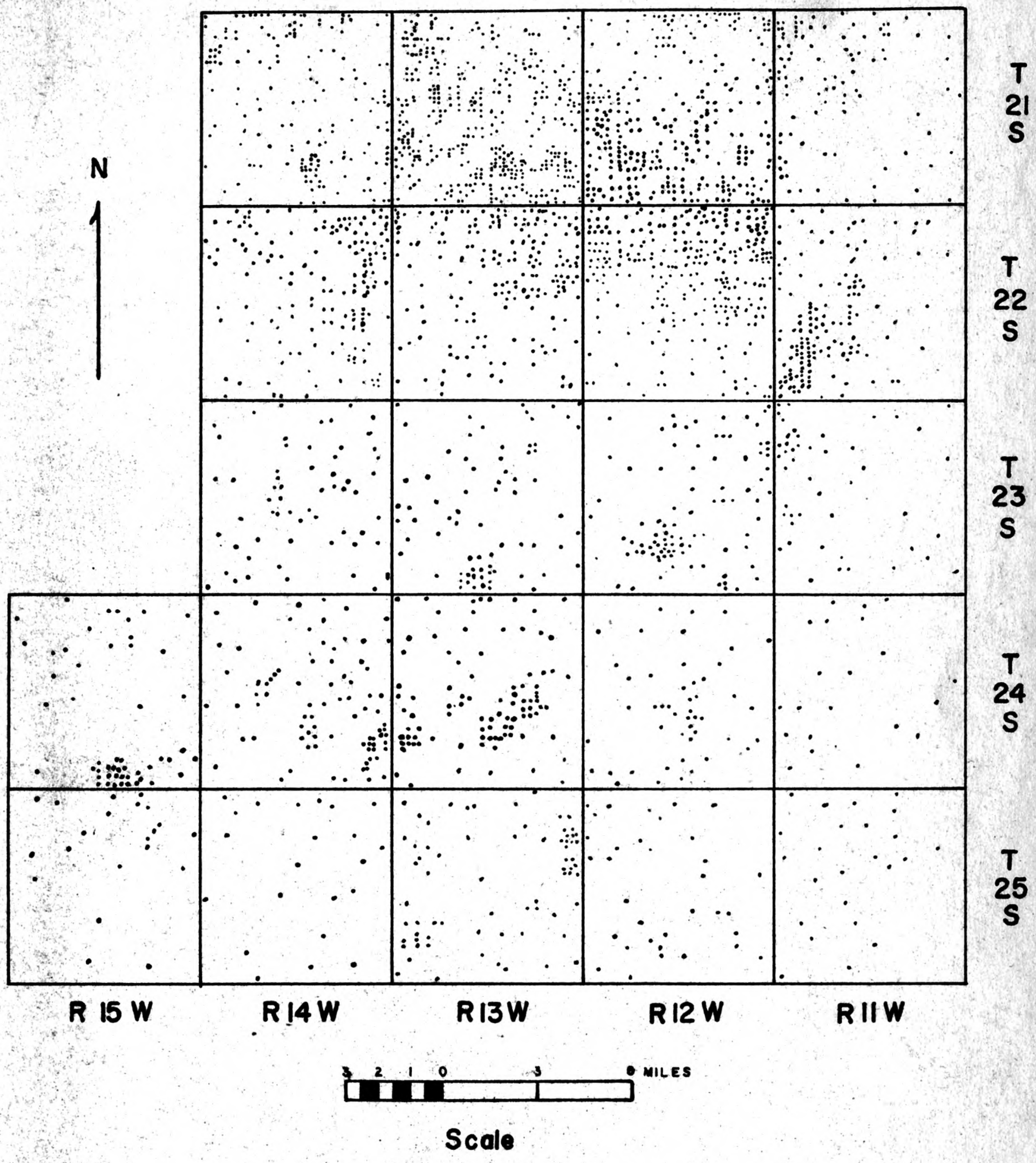


Fig. 4A. Map of Stafford County, Kansas showing points used for drawing contours on the Arbuckle group

Fig. 5. Structure contours drawn on the Mississippian limestones, Stafford County, Kansas

(in accompanying plate box)

Fig 5

STRUCTURAL CONTOUR MAP
ON THE TOP OF THE MISSISSIPPIAN
STAFFORD COUNTY, KANSAS

County line

Township line

Contour line

Contour interval = 20 feet

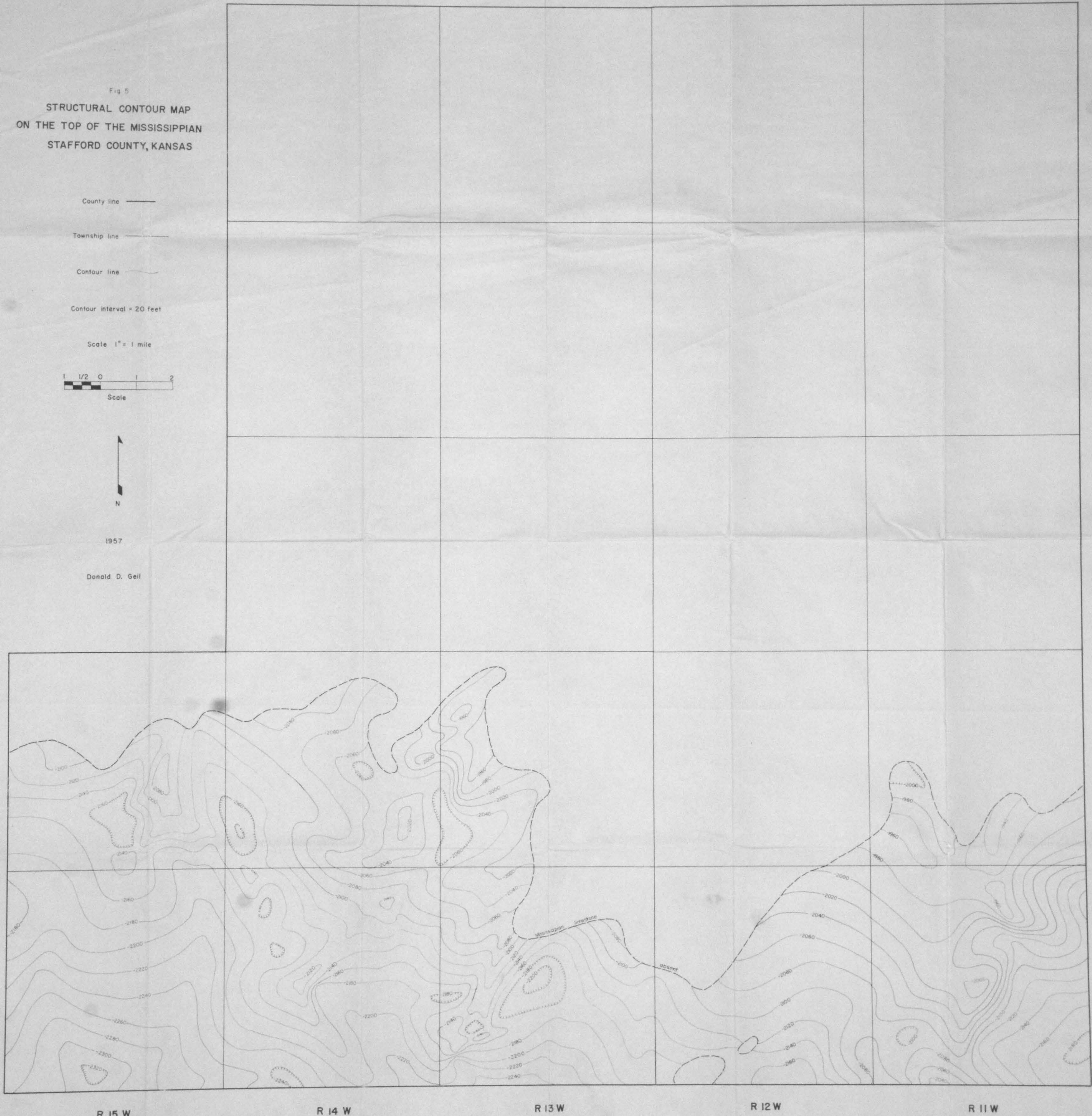
Scale 1" = 1 mile

1 1/2 0 1 2
Scale

N

1957

Donald D. Geil



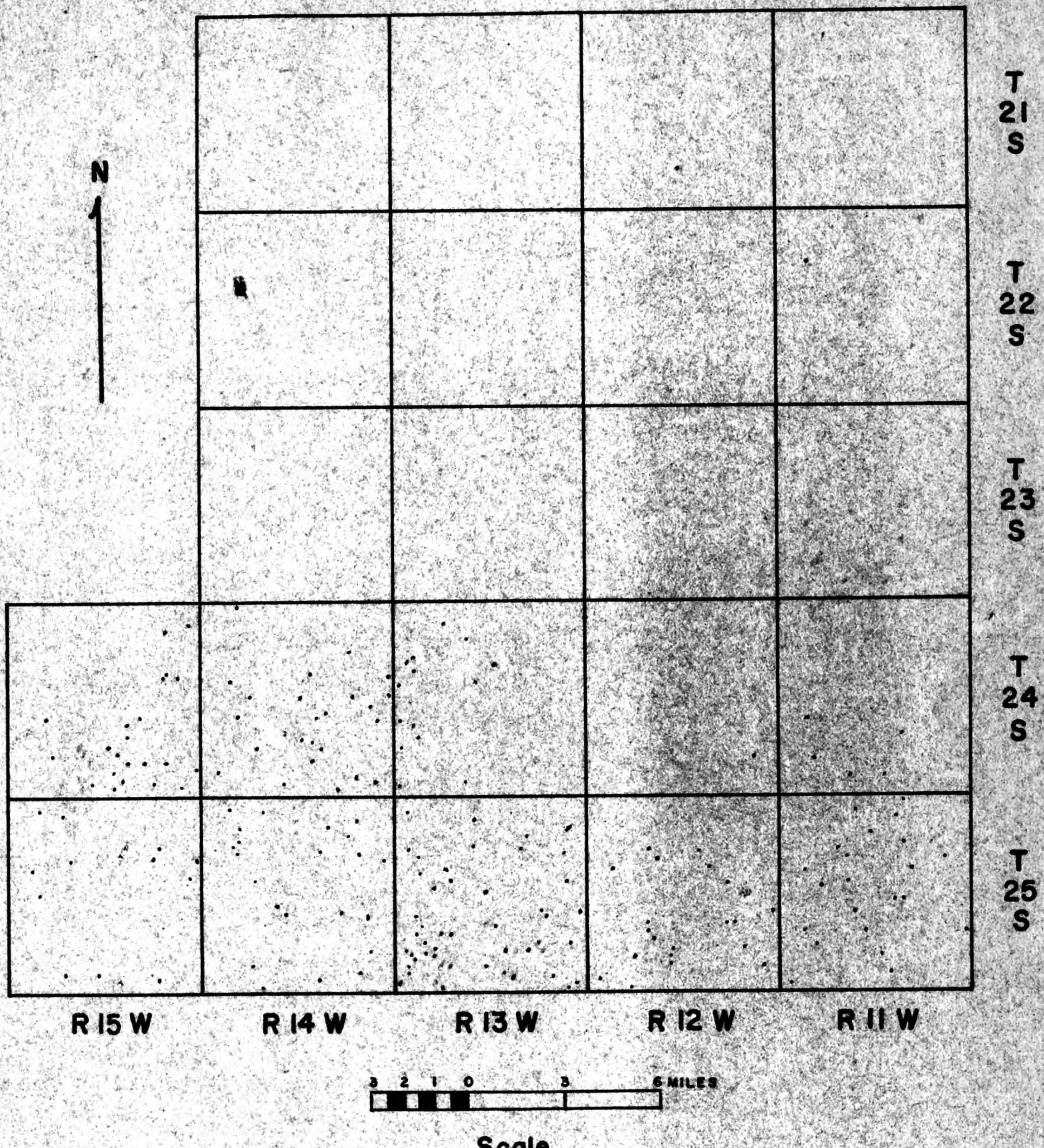


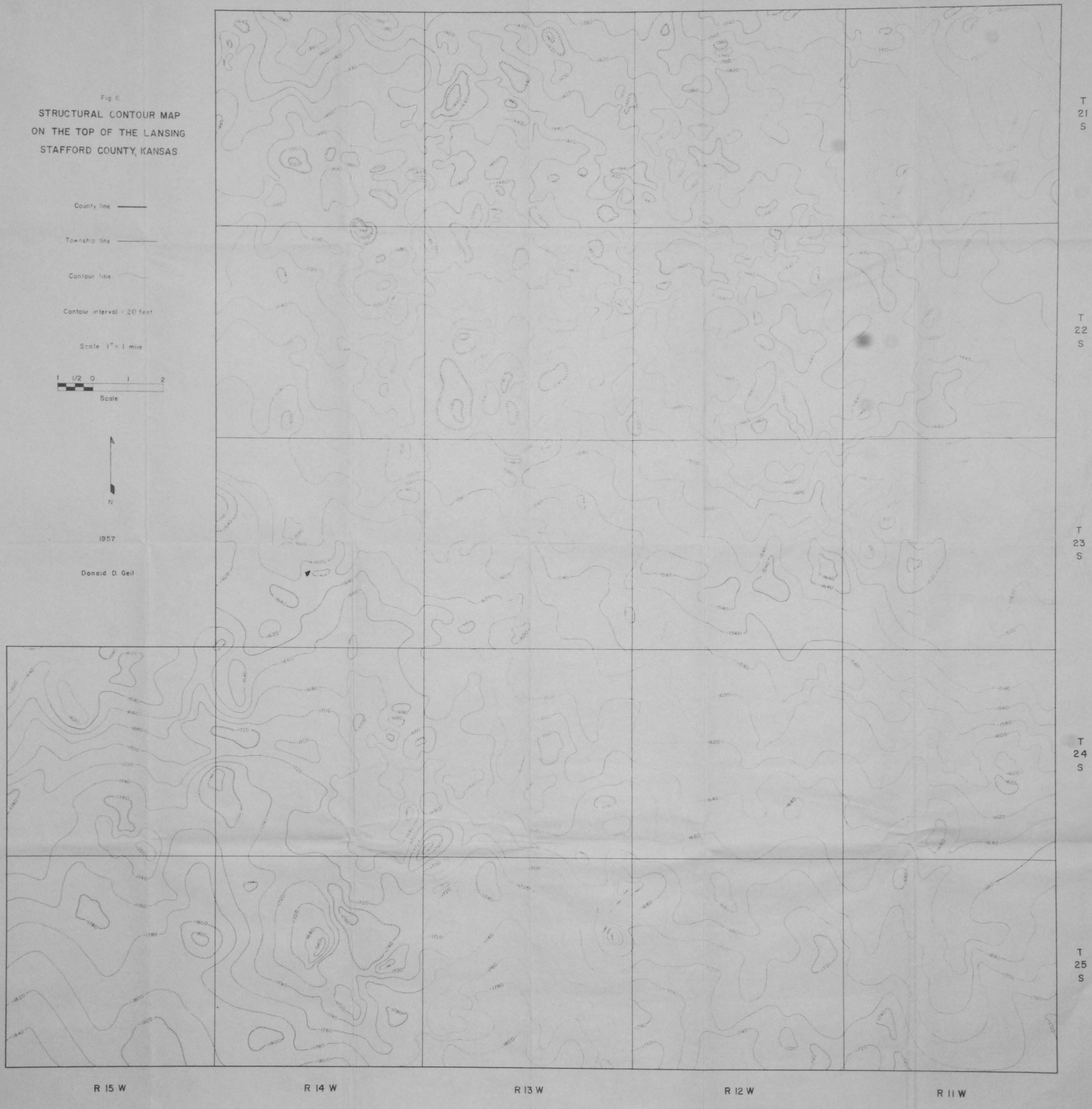
Fig. 5A. Map of Stafford County, Kansas showing points used for drawing contours on the Mississippian limestones

Fig. 6. Structure contours drawn on the Lansing group, Stafford County, Kansas

(in accompanying plate box)

Fig. 6

STRUCTURAL CONTOUR MAP
ON THE TOP OF THE LANSING
STAFFORD COUNTY, KANSAS



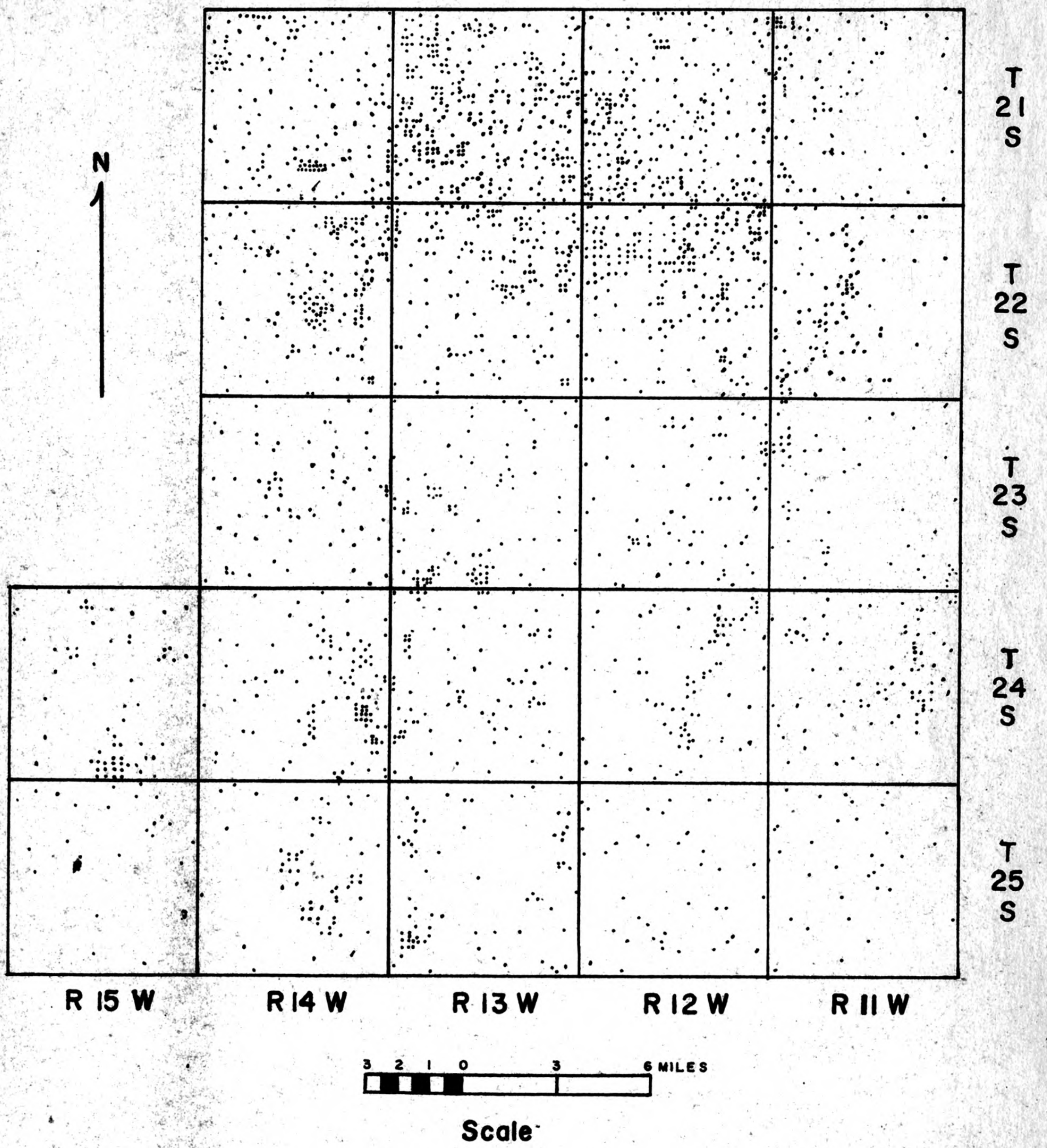


Fig. 6A. Map of Stafford County, Kansas showing points used for drawing contours on the Lansing group

Fig. 7. Thickness map of the Viola limestone, Stafford County, Kansas

(in accompanying plate box)

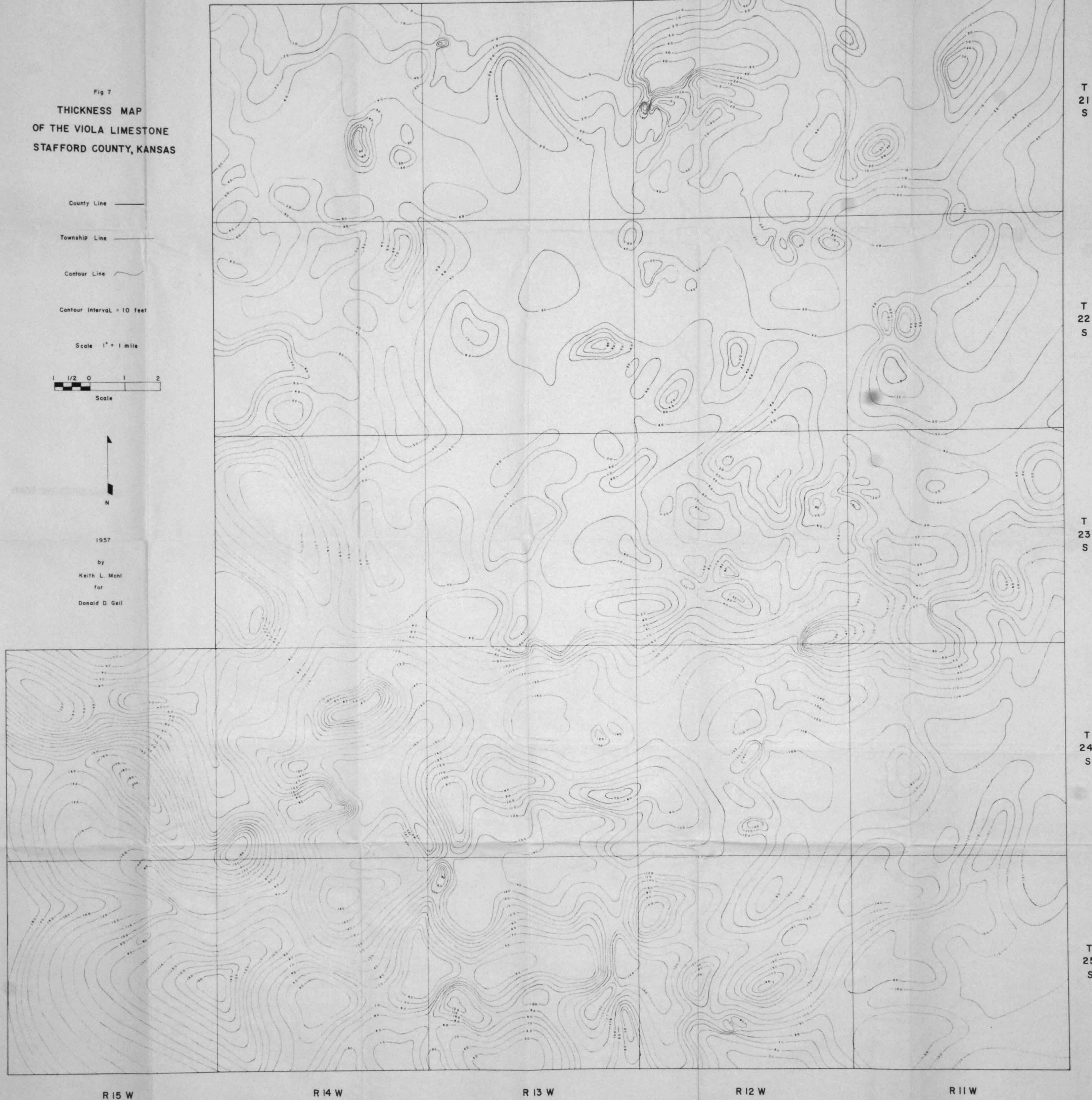


Fig 7
THICKNESS MAP
OF THE VIOLA LIMESTONE
STAFFORD COUNTY, KANSAS
County Line
Township Line
Contour Line
Contour IntervaL = 10 feet
Scale 1" = 1 mile
1 1/2 0 1 2
Scale
N
1957
by
Keith L. Mohl
for
Donald D. Geil
T 21 S
T 22 S
T 23 S
T 24 S
T 25 S
R 15 W
R 14 W
R 13 W
R 12 W
R 11 W

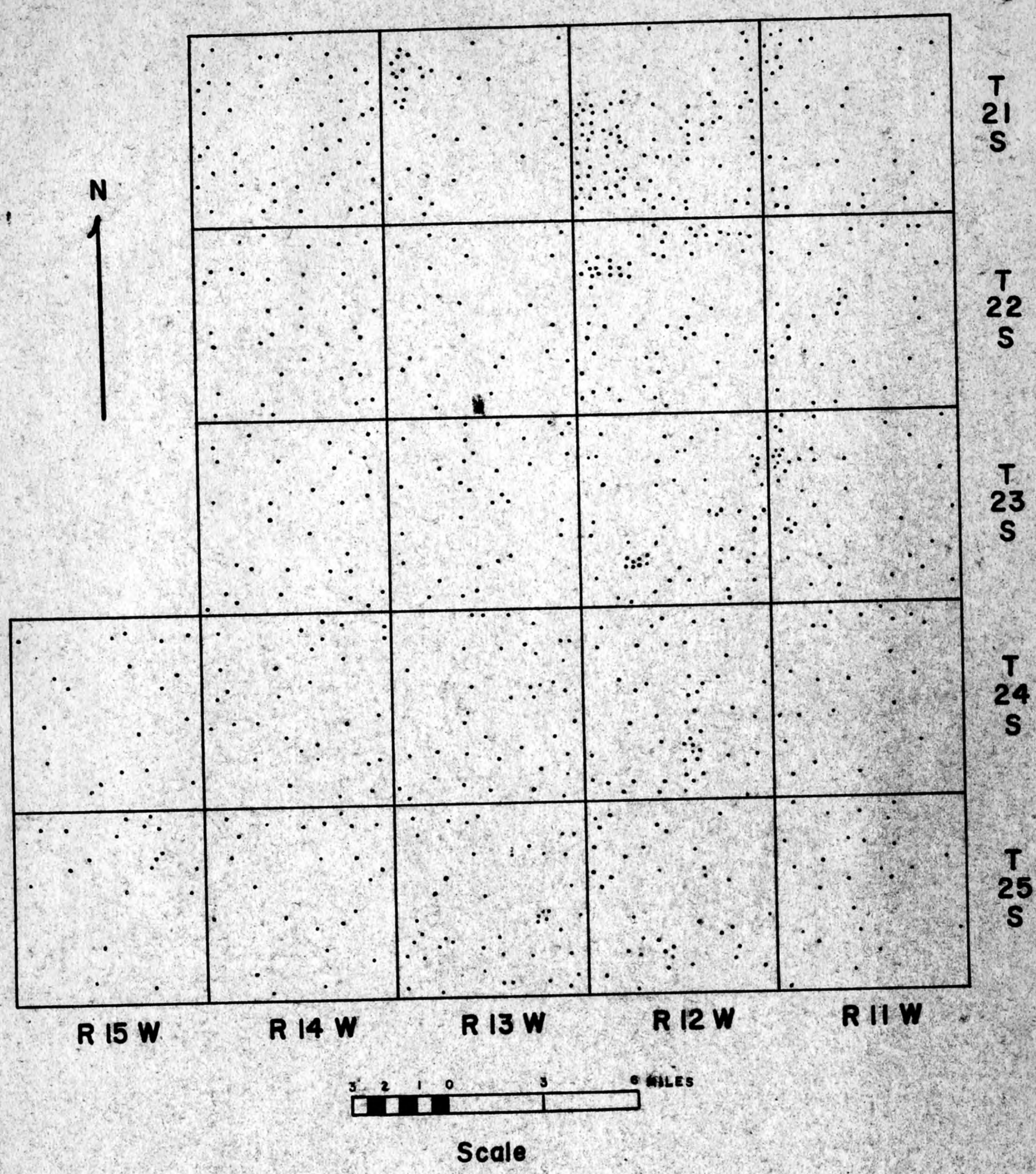


Fig. 7A. Map of Stafford County, Kansas showing points used for drawing Viola thickness lines

Fig. 8. Panel diagram of Stafford County, Kansas
(in accompanying plate box)

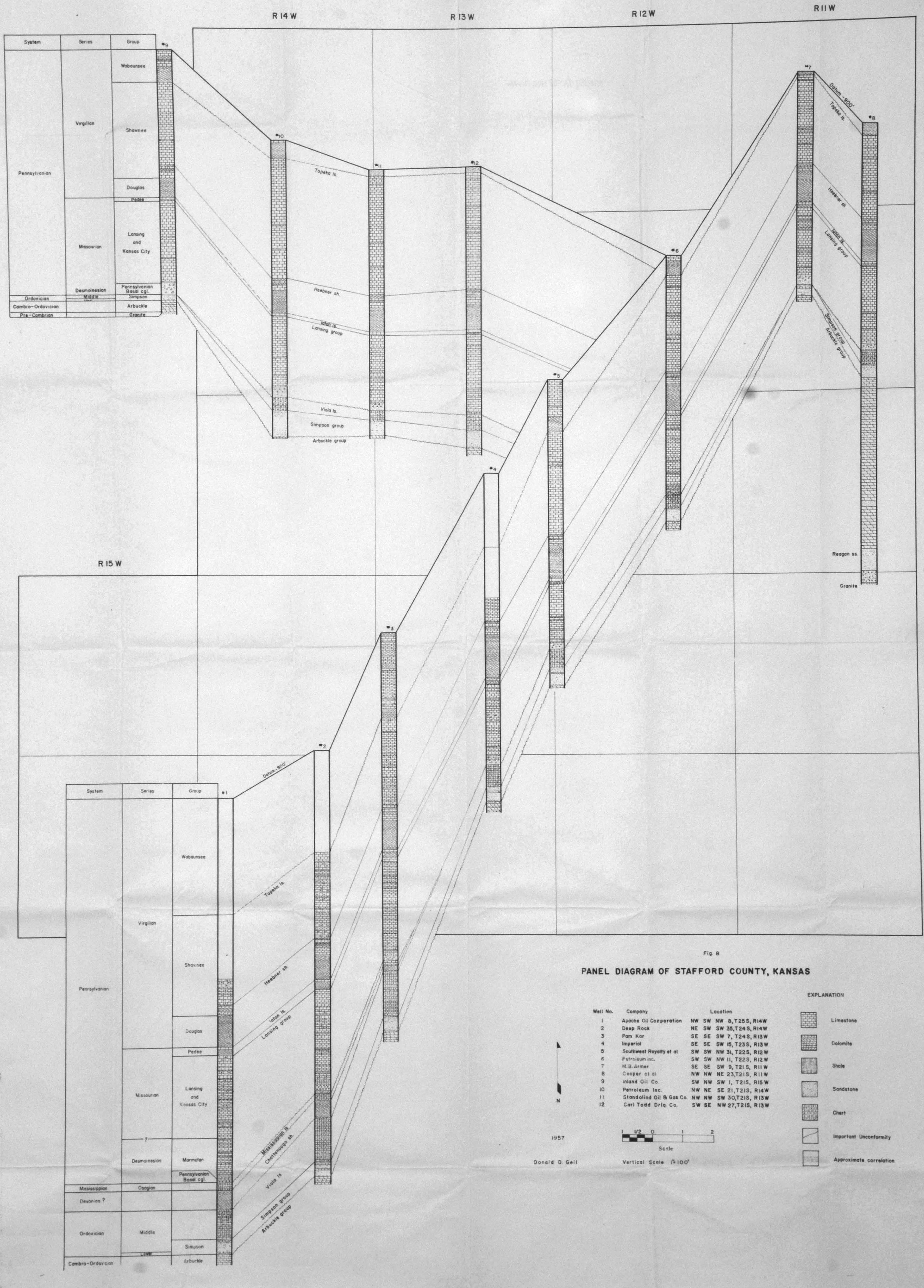


Fig. 8

PANEL DIAGRAM OF STAFFORD COUNTY, KANSAS

Well No.	Company	Location
1	Apache Oil Corporation	NW SW NW 8, T25S, R14W
2	Deep Rock	NE SW SW 35, T24S, R14W
3	Pam Kar	SE SE SW 7, T24S, R13W
4	Imperial	SE SE SW 15, T23S, R13W
5	Southwest Royalty et al	SW SW NW 31, T22S, R12W
6	Petroleum Inc.	SW SW NW 11, T22S, R12W
7	M.B. Armer	SE SE SW 9, T21S, R11W
8	Cooper et al	NW NW NE 23, T21S, R11W
9	Inland Oil Co.	SW NW SW 1, T21S, R15W
10	Petroleum Inc.	NW NE SE 21, T21S, R14W
11	Standolind Oil & Gas Co.	NW NW SW 30, T21S, R13W
12	Carl Todd Drlg. Co.	SW SE NW 27, T21S, R13W

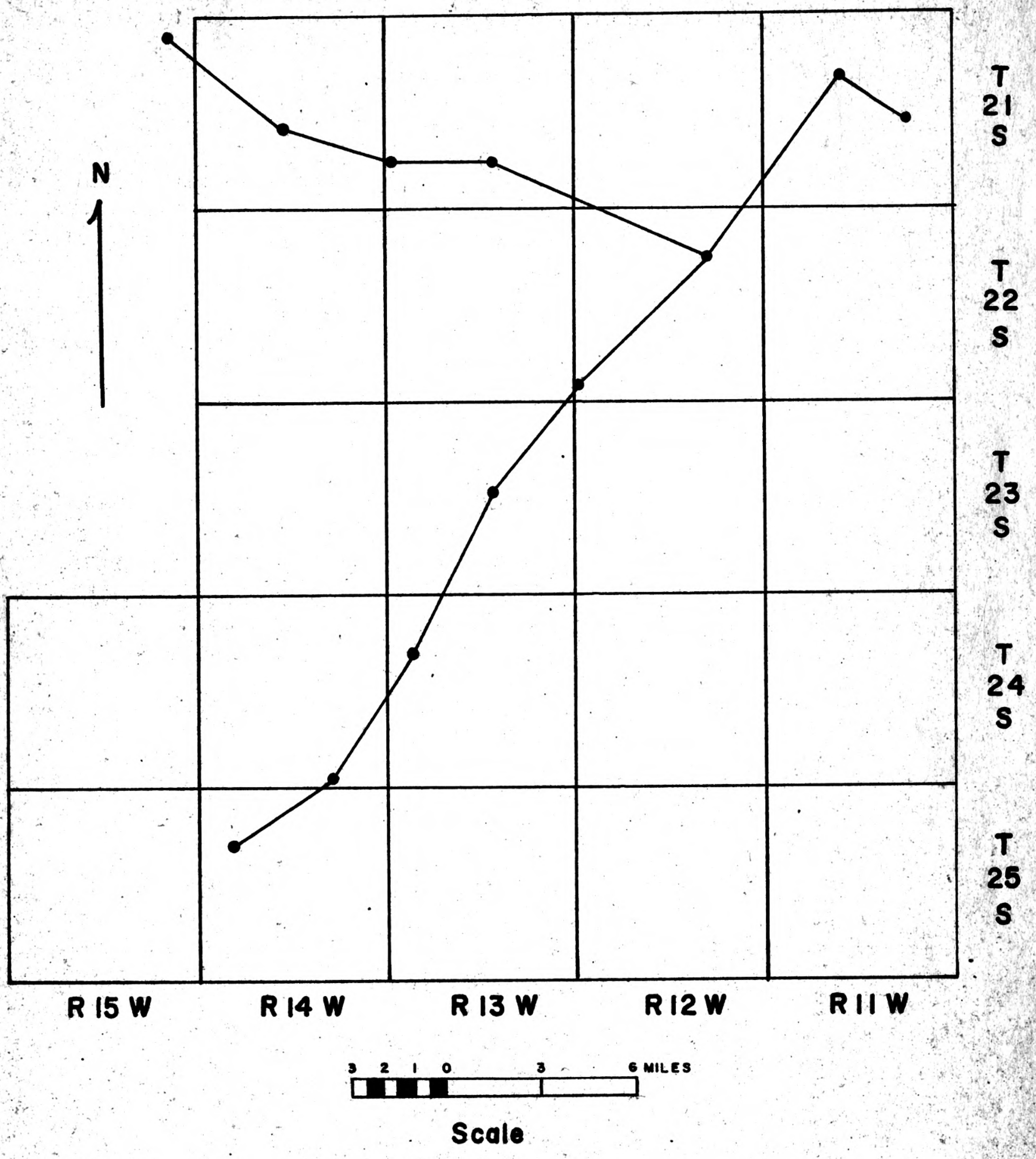


Fig. 8A. Map of Stafford County, Kansas showing points used for construction of panel diagram

STRUCTURE AND STRATIGRAPHY OF STAFFORD COUNTY, KANSAS RELATED TO PETROLEUM ACCUMULATION

by

DONALD DEAN GEIL

B. S., Kansas State College
of Agriculture and Applied Science, 1954

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

1957

The purpose of this investigation was to determine the subsurface structure, stratigraphy, and the geologic history of Stafford county, Kansas and the relationship of these factors to petroleum accumulation. Stafford county is an area of twenty-two townships located in south-central Kansas.

Three structural contour maps, a thickness map, and a panel diagram were constructed using all available subsurface data. These maps were then used to determine the relationship of the geology of the area to petroleum accumulation.

Three minor structures extend into Stafford county from adjacent areas. These minor structures are superimposed upon the southward extension of the Central Kansas uplift into the county. The Rush rib is a pre-Mississippian structure, which extends across the northeastern corner of the county. The Ellsworth and Pratt anticlines are younger structures, which apparently join to form a continuous northeast-southwest trending structural high. Oil accumulations associated with structural closure are found only in pre-Mississippian rocks over the Rush rib, while both pre-Mississippian and post-Mississippian rocks have accumulations of petroleum in closed structures over the Ellsworth-Pratt anticlinal trend.

Several periods of erosion effected the area; however, post-Arbuckle, post-Maquoketa, and post-Osagian erosional periods were the most important in relation to petroleum accumulation. These periods of erosion and the associated solution of the limestones and dolomites were responsible for the porosity and permeability developed in the Arbuckle, Viola, and Mississippian reservoir rocks. The porosity and permeability found in the reservoirs in the St. Peter sandstone, Pennsylvanian basal conglomerate, and the Lansing and Kansas City groups were the result of favorable sedimentation conditions at the time of deposition.

Since 1953, drilling activity in Stafford county has been declining; however, Stafford county remained the seventh largest oil producing county in Kansas in 1955. The future potential of the area is apparently limited to the discovery of small structural and stratigraphic traps.