

THE SUBSURFACE GEOLOGY OF THE GREENWOOD FIELD AREA LOCATED IN
MORTON COUNTY, KANSAS AND BACA COUNTY, COLORADO

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1956

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

1958

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INTRODUCTION

Purpose of Investigation

The purpose of this work was to determine the relationship between structure, stratigraphy and petroleum accumulation in the Greenwood Field Area located in Morton County, Kansas and Baca County, Colorado.

Area Covered by This Report

The Greenwood Field Area is located in southwestern Kansas and southeastern Colorado and is bordered on the south by Oklahoma (Fig. 1, Appendix). Most of the area lies between parallels 37° and $37^{\circ} 24'$ north latitude and meridians $101^{\circ} 53' 35''$ and $102^{\circ} 09' 36''$ west longitude. The Greenwood Field Area covers approximately 400 square miles in western Morton County, Kansas and 210 square miles in eastern Baca County, Colorado.

The area is in the High Plains section of the Great Plains physiographic province. It comprises a comparatively flat, nearly featureless plain interrupted by the valleys of the Cimarron river and its tributaries and by an extensive area of sand dunes south of the Cimarron river (McLaughlin, 1942). About 60 percent of the area is upland that is predominantly flat, but locally has broad mounds and depressions. More than 30 percent of the area is covered by dune sand of which 60 percent has a typical sand-dune topography. In some places the sand dunes form relatively steep, irregular hills, and other places broad rises and depressions that locally give the area a hummocky topography. The highest

points in the area are in the northwestern and southwestern parts and the lowest point is in the northeastern part. The Cimarron river enters the area from the west and flows diagonally across the southern part in a northeasterly direction. Most of the tributaries of the Cimarron are north of the river and flow north-eastward in a direction roughly parallel to the direction of flow of the Cimarron.

The Greenwood Field Area is structurally located on the western flank of the Hugoton embayment (Fig. 2, Appendix). It is the lower portion of a northeast-southwest structural trend that reaches maximum relief at Keys dome in Cimarron county, Oklahoma. This trend parallels the Sierra Grande uplift to the west and the Las Animas arch to the northwest.

Procedure

Gas production in the Greenwood field is from the Wabaunsee, Shawnee and Lansing-Kansas City groups. For this reason structural contour maps were prepared on the Topeka limestone (Shawnee group) and the Lansing group (Lansing-Kansas City groups). An isopach map from the top of the Topeka limestone to the top of the Lansing group was constructed to show any relationship of thinning or thickening to gas accumulation.

A structural contour map on top of the Keys sand was prepared to show the structural relationship of this basal Morrowan sand to oil and gas production from the Sparks, Boehm, Taloga, Elkhart and Interstate fields (Fig. 3, Appendix). These fields all produce from zones in the Morrow. Taloga gets some of its production

from the Cherokee Group which overlies the Morrow. The Keys sand rests unconformably on the underlying Mississippian, usually Chester. An isopach map was constructed to show the irregular thickness of the Keys sand and to indicate any Mississippian positive or negative areas. Few wells, other than those in the areas of Sparks, Boehm, Taloga, Elkhart, Interstate and one unnamed field have been drilled deeper than the lower part of the Lansing-Kansas City group, thus there is questionable control on the Keys sand beyond these areas.

Two cross sections were prepared to show subsurface structure and stratigraphic variation of the Paleozoic rocks in the Greenwood field area. Electric well logs were used in constructing the cross sections. Information used in constructing the maps was obtained from electric well logs, scout notes and Hernden Maps.

Previous Work

McLaughlin (1942) reported on the geology and ground-water resources of Morton County, Kansas. Maher and Collins prepared a series of reports dealing with the structure and stratigraphy of the Hugoton embayment and associated structures in Colorado, Kansas and Oklahoma (Maher, 1945, 1947, 1948, 1953, 1953a; Collins, 1947; Maher and Collins, 1949, 1952, 1953).

A study of the Keys gas field was made by Wagner (1955). Information concerning the location and production data of oil and gas fields in Kansas has been published by Goebel and others (1957).

STRATIGRAPHY

Quaternary and Tertiary Systems

Quaternary sediments consist of thin deposits of loess in about two-thirds of the area north of the Cimarron river and thin deposits of dune sand in about three-fourths of the area south of the Cimarron river. The dunes vary from a few inches to approximately 75 feet in thickness. The sand is made up of fine to medium well-rounded quartz grains and fragments of caliche. Recent alluvium, consisting mainly of subrounded sand with smaller amounts of gravel, silt and clay has been deposited in the valleys of the Cimarron river and its tributaries. The loess and dune deposits overlies undifferentiated Pleistocene sediments and the Ogallala formation. McLaughlin (1942) included the undifferentiated Pleistocene sediments with the Ogallala formation because the Pleistocene sediments could not be distinguished from the Ogallala (Pliocene) and because the Pleistocene may be absent in some places.

The Ogallala formation consists of calcareous silt, sand, gravel and clay. The silt is made up almost entirely of pale gray, pink and red quartz grains, which are angular to sub angular in shape. The sand consists of rounded grains of quartz and some magnetite. It is mostly very fine grained, but may range from very fine to coarse. The gravel is fine to coarse and is made up of quartz, feldspar, and other material derived from igneous rocks. The thickness of the Ogallala ranges from a few feet in the northwestern part to over 500 feet in the southeastern part (McLaughlin, 1942).

Cretaceous System

The Cretaceous rocks found in the Greenwood field area are those that underlie the Graneros shale elsewhere in western Kansas (McLaughlin, 1942).

Gulfian Series. Cockrum Sandstone. The Cockrum sandstone is thought to be the equivalent of the Dakota sandstone and is a local name. It consists mostly of light buff or brown, fine grained sandstones containing clay and lesser amounts of shale and siltstone. The Cockrum sandstone crops out along a tributary of the North Fork of the Cimarron river and is present only in the western half of the area covered by this report. It varies in thickness from a few feet to about 150 feet.

Comanchean Series. Kiowa Shale. The Kiowa shale underlies most of the northern third of Morton County, Kansas and the northern half of Baca County, Colorado. It consists of dark-gray or dark-bluish-gray thin-bedded shale containing small amounts of sand and brown clay. The Kiowa shale is relatively uniform in thickness, ranging from 35 to 85 feet with the greater thickness to the west (McLaughlin, 1942).

Cheyenne Sandstone. The Cheyenne sandstone underlies the northwestern part of the report area, being absent to the southeast. It is a white to yellow quartz sandstone of medium to coarse grain and contains some shale. In some areas it is conglomeratic near the base. The Cheyenne sandstone has very irregular bedding and ranges from a few feet to over 100 feet in thickness (McLaughlin, 1942).

Jurassic System

Morrison Formation. Thin beds of blue-green clay and marl and blue-green, light-gray and brown sandstone have been encountered between the Cheyenne sandstone and the Triassic (?) redbeds. These beds are thought to correlate with the Morrison formation. They pinch out a few miles east of the Colorado-Kansas line in Morton County (McLaughlin, 1942).

Triassic System

Undifferentiated redbeds, thought to be Triassic in age crop out at two places along the Cimarron valley in Morton County; at Point Rock, on the north side of the river in sec. 12, T. 34 S., R. 43 W., and on the south side of the river in sec. 5, T. 34 S., R. 42W. These redbeds are made up of red siltstone; buff, red and white sandstone; and a small amount of gypsum. The siltstone is thin and unevenly bedded. It is maroon when freshly exposed and weathers to pink or light red. The sandstone is massive and fine grained, and is white, gray, tan, brown and red in color. The total thickness of the Triassic redbeds is not known due to the difficulty in defining the boundary between the Triassic redbeds and the Permian redbeds (McLaughlin, 1942). Logs from test wells in Morton county indicate that the Triassic underlies the western half of the county and is deposited unconformably upon the Permian.

Permian System

The Permian is approximately 2500 feet thick in the Greenwood

field area and is predominantly clastic with some evaporites. The Permian rocks in the Hugoton embayment consist of an upper evaporite and siltstone facies and a lower carbonate facies. The upper evaporite and siltstone facies change to a dominantly sandstone and siltstone facies in a westward direction and the lower carbonate facies changes into arkose and siltstone facies (Maher, 1953). The Day Creek dolomite (Guadalupe age), Blaine anhydrite (Leonard age) and Stone Corral anhydrite (Leonard age) are easily recognized in well cuttings and on electric well logs and act as good subsurface markers. The Sumner and Chase groups which are present as evaporites and carbonates further to the east have changed to clastics and lost their identity.

Limestones and dolomitic limestones encountered at 2200 feet and below are thought to be the equivalent of the Neva. These beds are easily picked on electric well logs. The base of the Permian is questionably picked 150 to 250 feet below the Neva.

Guadalupian Series. Rocks of Guadalupe age consist of red beds of shale, siltstone and fine grained sandstone overlying the Day Creek dolomite, which is composed of finely crystalline anhydrite, finely granular dolomite, and white coarsely crystalline limestone beds (Maher and Collins, 1952). The Whitehorse sandstone lies below the Day Creek dolomite and consists of redbeds of shale, siltstone and sandstone.

Leonardian Series. Nippewalla Group. The Nippewalla group includes beds of red shale, sandstone, and evaporite beds overlain by the Blaine formation. The Blaine formation consists of white and pink finely crystalline anhydrite separated by thin

beds of red shale, dolomite and salt (Maher and Collins, 1952).

Sumner Group. The Sumner group includes the Stone Corral formation, The Ninnescah shale, and the Wellington formation. The Stone Corral formation is made up of white finely granular anhydrite and buff finely granular dolomite. This formation marks the top of the Sumner group. The Ninnescah shale and Wellington formation consist of undifferentiated red sandy shales interbedded with some dolomitic limestones.

Wolfcampian Series. The Wolfcampian series is divided into the Chase, Council Grove and Admire groups in descending order. They consist mostly of undifferentiated red shaly sandstones, dolomitic sandstones, shales, sandy limestones and oolitic limestones. The Neva limestone in the Council Grove group is easily recognized on electric well logs. The Permian is thought to rest unconformably on the underlying Virgil beds.

Pennsylvanian System

The Pennsylvanian rocks in the Greenwood field area consist of the Virgilian series, the Missourian series, the Desmoinesian series, the Atokan series and the Morrowan series and range from 2000 to 2500 feet in thickness.

Virgilian Series. **Wabaunsee Group.** The Wabaunsee groups consist of cream colored finely crystalline and gray oolitic limestones with intermittent gray limy shales. In many places the unconformity between the Wabaunsee and the underlying Shawnee group is marked by a red shale or gray limy fine-grained sandstone.

Shawnee Group. The Shawnee group is made up of gray to buff finely crystalline limestone interbedded with gray limy shales, red and maroon shales and oolitic limestones. The Topeka limestone marks the top of the Shawnee group and is buff to light gray, dense to finely crystalline and occasionally oolitic. The Shawnee group rests unconformably on the Douglas group.

Douglas Group. The Douglas group is composed of finely crystalline limestones, oolitic limestones, gray limy shale and red sandy shale. Rocks of Pedee age may have been mistakably identified as Douglas in age. An unconformity is considered to be present between the Virgil and underlying Missouri.

Missourian Series. Lansing-Kansas City Group. The Lansing-Kansas City group consists of buff, white and brown dense to crystalline and chalky limestones which are occasionally oolitic. They are interbedded with gray, greenish-gray and green shales. Fine to very fine calcareous, slightly glauconitic sands grading into siltstones or sandy limestones have been found near the base of this group (Wagner, 1955). Because of the impracticability separating the Lansing-Kansas groups on the basis of lithology, they are referred to as the Lansing group in this report. The Missourian appears to rest unconformably on the underlying Desmoinesian.

Desmoinesian Series. Marmaton Group. The Marmaton group averages 225 feet in thickness and includes brown dense to crystalline limestones with interbedded gray, dark gray to black and green shales. An arkosic sand or slightly arkosic limestone is present at the base. An unconformity may be present between the

Marmaton and the underlying Cherokee shales (Wagner, 1955).

Cherokee Group. Rocks of Cherokee age range from 150 to over 300 feet in thickness. They reach their maximum thickness in the northeastern part of the Greenwood field area. The upper part of the group consists of dark gray to black silty micaceous shale. The lower portion is comprised of fine to coarse calcareous glauconitic and slightly arkosic sands, arkosic limestones and limestones with thin interbedded dark gray shales. The Cherokee rests unconformably on the Atokan (Merriam, 1955).

Atokan Series. Beds thought to be Atokan in age are composed of brown to black crystalline to dense cherty and siliceous limestones and interbedded black shales. Coarse calcareous arkosic sand has frequently been found near the base (Wagner, 1955). The Atoka rests unconformably on Morrow beds. It ranges from 150 to 200 feet in thickness and pinches out to the northwest of the Greenwood field area (Maher and Collins, 1952).

Morrowan Series. The Morrow is between 400 and 500 feet thick and includes gray, dark gray, black and green shales, sands and limestones. The sandstones are fine to quite coarse, calcareous, glauconitic and sometimes arkosic. The limestones are brown, fine to coarsely crystalline, slightly glauconitic and frequently sandy. Both the sandstones and limestones have lenticular characteristics in the Greenwood field area. The Keys sand which is basal Morrow rests unconformably on the underlying Mississippian, usually Chester. It is composed of fine to coarse calcareous and glauconitic material and is subject to rapid lateral variations in thickness and lithologic properties.

The presence of this sand over a wide area indicates that it is a blanket type deposit. Wagner (1955) suggests that any thinning of the Keys sand may be an indication of a pre-existing Mississippian high which was not completely beveled by erosion.

Mississippian System

Rocks of Mississippian age range from 800 to 1000 feet in thickness in the area covered by this report. They consist chiefly of limestones and dolomites, some of which are cherty or oolitic. The Emergency Export Corporation drilled the only well in the area that penetrated the entire Mississippian section. This well was located in the NW NW Section 12, T 34 S, R 43 W and bottomed in the Arbuckle limestone.

Chesterian Series. Beds of Chester age vary in thickness from a few feet to over 100 feet and have been reported absent in some of the wells in the Keys gas field to the south-west and the Richfield area to the east. The Chester according to Wagner (1955) is composed of white to cream crystalline limestones, brownish-red and green siltstones, and red and green shales. Rocks of this series lie unconformably on the Ste. Genevieve limestone and are overlain unconformably by Pennsylvanian rocks (Maher and Collins, 1949).

Meramecian Series. The Ste. Genevieve limestone is cream to brown, oolitic and sandy and occurs at the top of the series. The St. Louis limestone underlies the Ste. Genevieve and according to Maher and Collins (1949) is composed of beds of buff to cream-colored finely crystalline limestone and dense limestone

interspersed with beds of dolomite. The Spergen and Worsaw limestones are found at the bottom of the series. They consist of brown crystalline cherty limestones, gray and brown dolomites and dolomitic limestones (Wagner, 1955). The Meramecian series averages 600 feet in thickness and is thought to rest unconformably on Osagian strata.

Osagian Series. The Osage is comprised of brown and gray crystalline cherty dolomites and ranges between 100 to 200 feet in thickness. A minor unconformity separates the Osage from the underlying Kinderhook (Maher and Collins, 1949).

Kinderhookian Series. This series averages 100 feet in thickness and is composed of brown, buff and gray cherty dolomites and limestones with coarse rounded sands and green waxy shales (Wagner, 1955). The Kinderhookian series rests unconformably on beds of Ordovician age.

Ordovician System

The Ordovician system is separated from the Mississippian system by a major unconformity. The Viola limestone marks the top of Ordovician rocks in the Greenwood field area. It is made up of gray, buff and cream-colored fine to coarsely crystalline dolomite. The upper part of the Viola is characterized by white and cream-colored granular to dense chert (Maher and Collins, 1949). The Emergency Export Corporation drilled through 100 feet of Viola and approximately 10 feet of Simpson in their well located in the NW NW Section 12, T 34 S, R 43 W. The Simpson group which according to Maher and Collins (1949) is hard to

differentiate from the overlying Viola in southwestern Kansas is thought to be represented by dolomitic sandstone interbedded with gray to buff sandy dolomite and varicolored shales. In the Keys area the base of the Simpson is marked by a very fine quartzitic glauconitic sand (Wagner, 1955). The Simpson is an unconformable deposit between the Viola limestone and the Arbuckle group.

Cambro-Ordovician System

Arbuckle Group. The total thickness of this group is not known in the Greenwood field area, however, it was reported to be over 700 feet thick in the Keys area and consisted of buff to white crystalline slightly cherty dolomites. The age of the Arbuckle group is upper Cambrian and lower Ordovician.

Cambrian System

The Cambrian System is represented by the Lamotte sandstone which lies unconformably on the Pre-Cambrian surface (Maher and Collins, 1949). The Arbuckle group was reported to lie on the Pre-Cambrian granite in the Keys dome area which suggests the Lamotte sandstone may be locally absent and also pinch out to the west.

Pre-Cambrian Rocks

The basement rocks consist of granite, schist, quartzite, gneiss, slate and marble, with red or pink granite predominating from the Greenwood field area to the west (Maher and Collins, 1949).

MAJOR STRUCTURES

Hugoton Embayment

The Hugoton embayment is located in western Kansas, southwestern Colorado and the panhandles of Oklahoma and Texas (Fig. 2, Appendix). The embayment is a large synclinal shelf-like extension of the Anadarko basin of Oklahoma. It is delineated structurally on the southwest by the Amarillo uplift; on the west by the Sierra Grande uplift; on the northwest by the Las Animas arch; on the northeast by the Cambridge arch and Central Kansas uplift; and on the east by the Pratt anticline.

Marginal positive areas and conditions existing in the Anadarko basin controlled the extent of inundation and deposition in the embayment. Initial downwarp probably occurred during pre-Cambrian time and deposition began with the invasion of late Cambrian seas. The embayment is expressed mostly in Paleozoic rocks with only slight structural modification during Mesozoic and Tertiary time. (Merriam, 1956).

Sierra Grande Uplift

The Sierra Grande uplift is located on the western edge of the Hugoton embayment and occupies most of Union County, New Mexico and Las Animas County, Colorado. The uplift is expressed at the surface in cretaceous rocks and is classified by Eardly (1951) as a Laramide structure that has undergone previous movement. Rocks of Permian age have been reported to rest directly on the pre-Cambrian granite on the southern portion of this uplift. Mississippian onlap is present on the eastern flank of the uplift.

Onlap of Ordovician and Cambrian beds may be present, but it is not clearly evident. The Sierra Grande uplift was a positive feature in Mississippian time and possibly earlier. It has undergone several movements in Paleozoic as well as Mesozoic time (Maher and Collins, 1949).

Las Animas Arch

The Las Animas arch is an anticlinal feature trending northeast from the Sierra Grande uplift across eastern Colorado and northwestern Kansas. Mississippian and Pennsylvanian movements associated with the ancestral Rockies appear to have initiated the Las Animas arch which merges with the Sierra Grande uplift. Maher and Collins (1949) have suggested pre-Pennsylvanian separation of these two features by a trough extending in a southeastward direction from the vicinity of the Canyon City embayment. Considerable movement since the beginning of Mesozoic time is indicated by the present structural attitude of Cretaceous and older rocks.

MINOR STRUCTURES

Keys Dome

The Keys dome located in Cimarron County, Oklahoma is the highest portion of a northeast-southwest structural trend extending across Cimarron County, Oklahoma into southwestern Morton County, Kansas (Fig. 2, Appendix). This feature shows some evidence of uplift between Arbuckle and Mississippian time with increased uplift in early Pennsylvanian time. Rocks of Chester age (upper Mississippian) appear to flank the dome on all sides

but are locally missing on the top (Wagner, 1955). A structural contour map on top of the Keys sand (Fig. 10, Appendix) indicates that anticlinal features similar to the Keys dome only smaller in extent are present in the Greenwood field area.

GEOLOGIC HISTORY

Paleozoic Era

Initial downwarp of the Hugoton embayment is thought to have occurred during pre-Cambrian time and the depositional history began with the invasion of late Cambrian seas (Merriam, 1955). These seas deposited the Lamotte sandstone on the pre-Cambrian surface and overlapped it with dolomite beds of the Arbuckle group. The distribution, thickness, and stratigraphic relation of the Lamotte sandstone to other rocks suggest that it was derived mainly from the north.

During Middle Ordovician time the Simpson group and the Viola limestone were deposited. The Simpson group lies above the Arbuckle dolomite and consists of sand and shale. This group is overlapped by the Viola limestone which consists of a series of limestones and dolomites with some chert.

Rocks of Silurian and Devonian age have not been recognized in the area covered by this report. If deposited, they were removed by erosion subsequent to the deposition of the overlying Mississippian strata.

Mississippian seas advanced from the Anadarko basin and deposited 800 to 1000 feet of limestones, dolomites and shales unconformably on the underlying Viola limestone.

The Kinderhookian (lower Mississippian) was deposited first, followed by Osagian, Meramecian and Chesterian (upper Mississippian). Encroaching and receding seas are suspected of causing unconformities between the series. Withdrawal of the seas at the end of Chesterian time resulted in the beveling of Chesterian beds on top of the Keys dome and other smaller structures in the surrounding area.

The Pennsylvanian system unconformably overlies rocks of Mississippian age and ranges from 2000 to 2500 feet in thickness. Encroaching seas of early Morrow-time laid down the Keys sand which was a blanket like deposit. Maher (1953) suggested that this basal sand may have been derived from a southeastern source. Morrow seas began a slow retreat after depositing thick marine limestones. This slow recession left mainly black and green shales in a dominantly lagoonal environment (Maher, 1953). Major uplifting took place near the end of Morrow time creating prominent source areas to the west.

Atokan seas deposited mostly dense and cherty limestones with some shale. These were overlapped by the Cherokee shale and Marmaton group of the Desmoinesian series. The seas withdrew at the end of Desmoines time and permitted some erosion of rocks of Desmoines age before Missouri time.

The source areas developed by tectonic movement at the end of Morrow time were probably so worn down by Missouri time that fewer clastics were produced (Maher, 1953). Gentle upwarping near the end of Missouri time caused the seas to temporarily retreat and initiated the Las Animas arch.

Little tectonic movement is discernible between Virgil and

Permian time. Deposition consisted mostly of limestone with some shale.

Permian strata is approximately 2500 feet thick in southeastern Colorado and southwestern Kansas. Deposition from the early Wolfcampian seas was similar to that of the Missouri seas with alternating limestones and shales. The carbonate facies changed to clastic as the beds of upper Wolfcampian and Leonardian age were being deposited, thus causing some of the more discernible limestone beds which lie to the east to lose their identity. The Stone Corral anhydrite and dolomite, the Blaine anhydrite and the Day Creek dolomite of middle and late Permian retained their evaporite characteristics and were separated by beds of sandstones, siltstones and mostly red shales. Although there was structural accentuation of the Las Animas arch to the northwest during Permian time, the pre-Cambrian positive areas and the present site of the Sierra Grange uplift were buried and were no longer controlling factors on the southwestern side of the Hugoton embayment (Maher, 1945). The withdrawal of Permian seas brought about a complete change in geological conditions. Marine sedimentation ceased leaving way to subaerial erosion accompanied by continental sedimentation (Merriam, 1955).

Mesozoic Era

Undifferentiated redbeds of questionable Triassic age were deposited in southwestern Kansas. These beds are assumed to be mostly continental in origin and consist of red siltstone; red, buff and white sandstones; and some gypsum.

During the Jurassic period the Greenwood field area was part of a large land mass upon which fluvialile Morrison beds were laid down. Much of these beds were removed by subsequent erosion (McLaughlin, 1942).

In early Cretaceous time the sandstones of the Cheyenne formation were deposited. Twenhofel (1924) suggested that the Cheyenne formation was deposited in shallow seas or by streams. Invasion of the sea followed with deposition of the dark very fossiliferous Kiowa shale. Sandstones and clays were laid down probably under both fluvialile and near-shore conditions at the beginning of late Cretaceous time. These beds are called the Cockrum sandstone and have been suggested to be the equivalent of the Dakota sandstone. Erosion during late Cretaceous and early Tertiary time probably removed any late cretaceous marine sediments which may have been deposited in the area (McLaughlin, 1942).

Cenozoic Era

Tertiary Period. The Laramide revolution which began in late Cretaceous time was followed by a long period of erosion that lasted until late Tertiary (Pliocene) time. During late Tertiary and early Quaternary (Pleistocene) time sediments from the west were carried eastward by streams and deposited as the Ogallala formation and undifferentiated Pleistocene beds. These beds were deposited on the eroded surface of Permian and Mesozoic rocks (McLaughlin, 1942).

Quaternary Period. Similar conditions to those of Pliocene time existed during the early part of the Quaternary period. A blanket of loess was deposited over much of the area north of the

Cimarron river by dust storms. Dune sand was laid down in the area south of the Cimarron river. Erosion during the Quaternary period removed some of the Tertiary cover and in some places exposed the underlying Mesozoic rocks. Alluvium was deposited by the Cimarron river and some of its tributaries which were developed during Quaternary time (McLaughlin, 1942).

DISCUSSION AND CONCLUSIONS

The Greenwood gas field which lies to the west of the Hugoton area was discovered in 1951. Gas is produced from the Wabaunsee, Shawnee and Lansing-Kansas groups in this field (Tables 1 and 2, Appendix). The Boehm field (Fig. 3, Appendix) also discovered in 1951 encountered both oil and gas from formations of Morrow age. In 1954 the Interstate and Sparks fields were discovered. Prolific oil pays were encountered from the Morrowan in the Interstate pool. The Sparkes field produces both oil and gas which is also from Morrowan strata. Discoveries from the Morrow continued in 1955 as the Elkart gas field and Taloga oil and gas field were brought in. Some oil is produced from the Cherokee formations in the Taloga field. Figure 3 (Appendix) shows the limits of the expanded Greenwood gas field and the location of an unnamed field (Morrow production) discovered in 1957.

Greenwood Field Production

Gas production in the Greenwood field is from the Wabaunsee, Shawnee and Lansing-Kansas groups. The combined thickness of these groups averages about 1000 feet with the most prolific gas pay coming

from the middle zones. Structural contour maps on the Topeka limestone and Lansing group (Figs. 7 and 8, Appendix) indicate that structural closure is not responsible for the accumulation of gas in the Greenwood field. The increasing dip of the formations into the Hugoton embayment is indicated by the closeness of the contour lines on the eastern side of the area. Some of the structures which are responsible for Morrow production are reflected on these two structural contour maps.

An isopach map between the top of the Topeka limestone and the Lansing group (Fig. 9, Appendix) shows a gradual thickening of the formations to the east and northeast. This thickening into the Hugoton embayment is probably the result of differential compaction; however, slight regional uplift may also have been partly responsible. The lack of any sudden thinning or thickening of the isopached formations suggests that the area was relatively flat at the time of deposition and that no local positive areas existed.

The stratigraphic trap that is responsible for the accumulation of gas in the Greenwood field is considered to be the result of the loss of permeability. The writer believes that the loss of permeability is due to an east to west carbonate to non-carbonate facies change, which is characteristic of the Paleozoic limestones and dolomitic limestones in southwestern Kansas and southeastern Colorado. Although hardly discernible on electric well log characteristics, the change from a limestone to a shaly limestone is much easier to recognize from well cuttings.

Morrow Production

A structural contour map (Fig. 10, Appendix) on the Keys sand shows that structural closure with the possibility of some faulting is responsible for most of the accumulation of oil and gas in Morrowan strata. Cross sections A and B (Figs. 13 and 14, Appendix) show the relationship of stratigraphy and structure to oil and gas accumulation. These cross sections indicate that many of the deeper structures in the Greenwood field area may not be recognized at shallower depth.

An isopach map of the Keys sand (Fig. 11, Appendix) shows the irregular thickness of this basal Morrowan sand and suggests that it was deposited on an uneven Mississippian erosional surface. There is very little correlation, however, between the thinning and thickening of the Keys sand and structural highs.

Future Potential

The future potential for oil and gas production in the Greenwood field area is good. Several areas of possible expansion still exist for gas production from the Wabaunsee, Shawnee and Lansing Kansas City groups.

Strata of Morrowan age has been virtually untested in the central and western part of the area covered by this report. Figure 10 (Appendix) shows a questionable high area located in the northern part of T 33 S, R 43 W and the southern part of T 32S, R 43 W. It is very probable that small structures such as Boehm and Taloga may exist in this area. Probable faulting along the

eastern flank of the area (Figs. 10 and 14, Appendix) could be responsible for trapping petroleum and merits geologic investigation.

The Emergency Export Corporations's well located in section 12, T 34 S, R 43 W is the only one in the Greenwood field area that has penetrated rocks of middle and lower Mississippian, Ordovician and Cambro-Ordovician age. Before these formations can be truly evaluated, it will be necessary to drill more deep wells.

ACKNOWLEDGMENT

The writer is indebted to Dr. Joseph R. Chelikowsky, Head of the Department of Geology and Geography, for his advice and suggestions while preparing this thesis and for criticisms and suggestions while editing the thesis. Sincere thanks are also expressed to Dr. Charles P. Walters, Associate Professor of Geology, for his advice and suggestions while preparing this thesis. Thanks are also extended to Pan American Petroleum Corporation for furnishing electric well logs and scout tickets used in preparing this thesis.

LITERATURE CITED

- Collins, J. B.
Subsurface geologic cross section from Trego County, Kansas, to Cheyenne County, Colorado: Kansas Geol. Survey, Oil and Gas Investi. No. 5, Prelim. Cross. Sec., 1947, 1-8 pp.
- Eardley, A. J.
Structural geology of North America. New York: Harper and Brothers, 1951, 383-384 pp.
- Garlough, J. L., and G. L. Taylor.
Hugoton gas field, Grant, Haskell, Morton, Stevens, and Seward Counties, Kansas, and Texas County, Oklahoma: Stratigraphic Type Oil Fields, Am. Assoc. Petro. Geologists, 1941, 78-104 pp.
- Geobel, E. D. and others.
Oil and Gas Developments in Kansas during 1956, State Geol. Survey of Kansas, Bull. 128, 1957, 104-105, 195, 231 pp.
- Lee, Wallace, and D. F. Merriam.
Preliminary study of the structure of western Kansas: Kansas Geol. Survey, Oil and Gas Investi. No. 11, Maps and Cross secs., 1954, 1-23 pp.
- Maher, J. C.
Structural development of Las Animas arch, Lincoln, Cheyenne, and Kiowa Counties, Colorado: Am. Assoc. Petro. Geologists Bull., Vol. 29, No. 11, 1945, 1663-1667 pp.
- Maher, J. C.
Subsurface geologic cross section from Scott County, Kansas, to Otero County, Colorado: Kansas Geol. Survey, Oil and Gas Investi. No. 4, Prelim. Cross Sec., 1947, 1-11 pp.
- Maher, J. C.
Hugoton embayment of Anadarko basin in southwestern Kansas, southeastern Colorado, and Oklahoma panhandle: Am. Assoc. Petroleum Geologists Bull., Vol. 32, No. 5, 1948, 813-816 pp.
- Maher, J. C.
Subsurface geologic cross section from Baca County to Yuma County, Colorado: Kansas Geol. Survey, Oil and Gas Investi. No. 6, Prelim. Cross Sec., 1948, 1-11 pp.
- Maher, J. C.
Permian and Pennsylvanian rocks of southeastern Colorado: Am. Assoc. Petro. Geologists Bull., Vol. 37, No. 5, 1953, 913-939 pp.
- Maher, J. C.
Paleozoic history of southeastern Colorado: Am. Assoc. Petro. Geologists Bull., Vol. 37, No. 11, 1953a, 2475-2489 pp.

Maher, J. C., and J. B. Collins.

Pre-Pennsylvanian geology of southwestern Kansas, southeastern Colorado, and Oklahoma panhandle: U. S. Geol. Survey, Oil and Gas Investi., Prelim. Map 101, 1949, sheets 1-4.

Maher, J. C., and J. B. Collins.

Correlation of Permian and Pennsylvanian rocks from western Kansas to the Front Range of Colorado: U. S. Geol. Survey, Oil and Gas Investi., Chart OC 46, 1952, sheets 1-3.

Maher, J. C., and J. B. Collins.

Permian and Pennsylvanian rocks of southeastern Colorado and adjacent areas: U. S. Geol. Survey, Oil and Gas Investi., 1953, Map OM 135.

McCoy, A. W.

Tectonic history of the Denver basin. Am. Assoc. Petrol. Geologists Bull. Vol. 37, 1953, 1873-1893.

McLaughlin, T. G.

Geology and Ground-Water Resources of Morton County, Kansas, State Geol. Survey of Kansas, Bull. 40, 1942, 13-16, 69-90 pp.

Merriam, D. F.

Structural development of the Hugoton embayment, Proc 4th. Subsurface Symposium, Univ. of Oklahoma, Norman., 1955, 81-97 pp.

Merriam, D. F.

Hugoton Embayment commands fresh look. Oil and Gas Journal, Vol. 54, No. 44, 1956, 82-86 pp.

Moore, R. C., and others.

The Kansas Rock Column, State Geol. Survey of Kansas, Bull. 89, 1951, 132 p.

Twenhofel, W. H.

Geology and invertebrate paleontology of the Commanchean and "Dakote" formations of Kansas, Kansas Geol. Survey, Bull. 9, 1924, 135 p.

Wagner, R. C.

The Keys Gas Field, The Panhandle Geonews, Vol. 2, No. 3, 1955, 4-14 pp.

APPENDIX

Table 1. Gas Production of Greenwood Field Area During 1956

Pool and Location of Discovery Well	Discovery Year	Area Acres	Gas Production, M cu. ft		No. Wells	Producing zone ft.	
			during 1956	to end 1956		Name	Depth
Boehm 14-33-42W	1951	2,400	2,153,662	6,090,065	6	Morrowan	4,872
Elkhart 11-35-43W	1955	640	126,010	201,265	1	Morrowan	4,558
Greenwood Gas Area 14-33-42W	1951	98,280	35,432,972	83,182,535	200	Wabaunsee Shawnee Lans.-K.C.	2,777 3,069 3,534
Sparks 34-30-42W	1954	12,000	1,779,406	1,779,406	12	Morrowan	5,397
Taloga 34-34-42W	1955	1,200	8,883,580	9,199,397	15	Morrowan	4,428

Table 2. Oil Production of Greenwood Field Area During 1956

Pool and Location of Discovery Well	Discovery Year	Area Acres	Oil Production, bbls during 1956 to end 1956	No. Wells	Producing zone ft. Name	Depth
Boehm 14-33-42W	1951	120	6,205	5	Morrowan	
Interstate 29-34-43W	1954	1,960	305,171	56	Morrowan	4,210
Sparks 34-30-42W	1954	80	786	3	Morrowan	5,254
Taloga 34-34-42W	1955	600	25,119	5	Morrowan	4,428

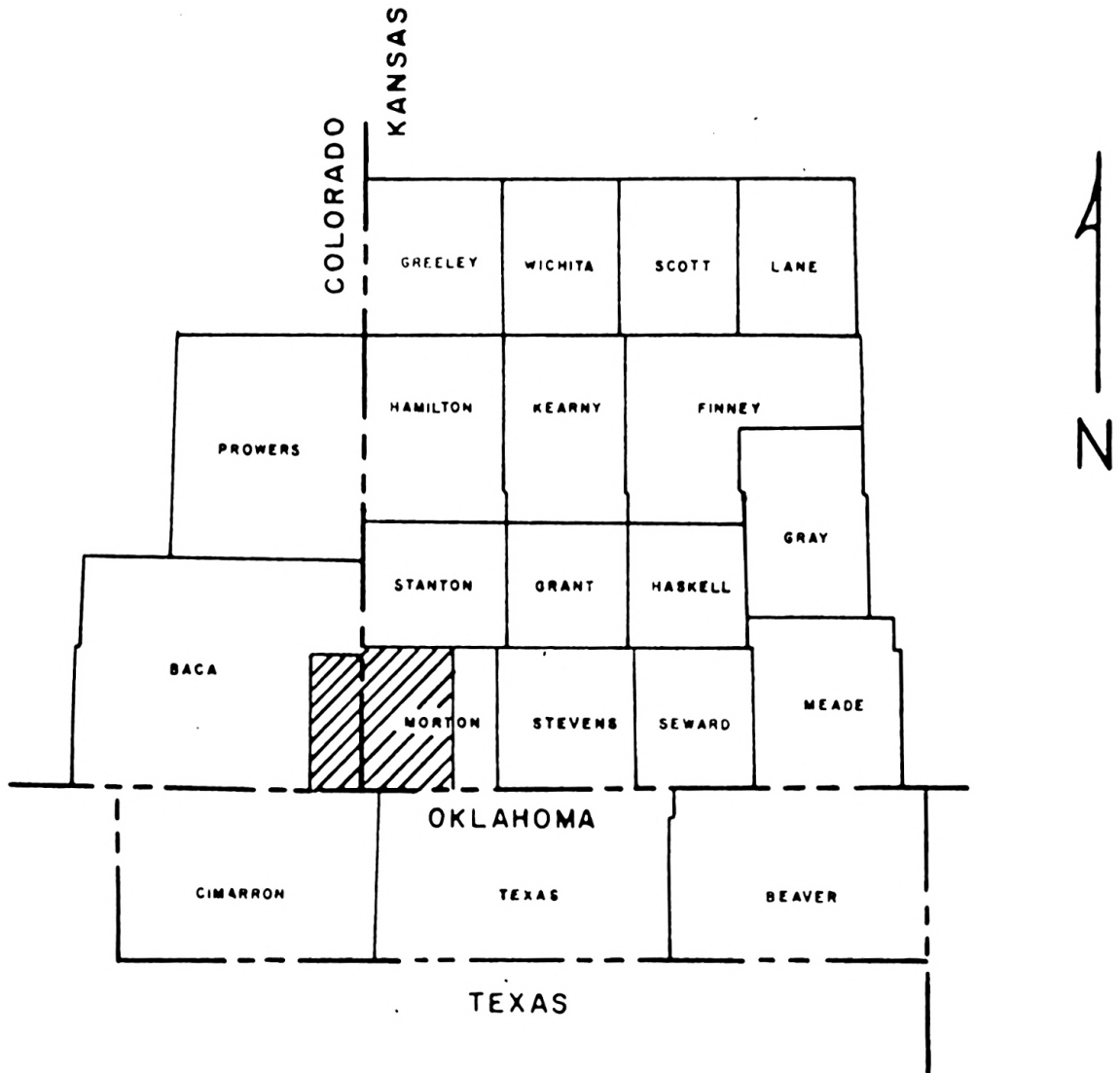


Fig. 1. Location of area covered by this report.

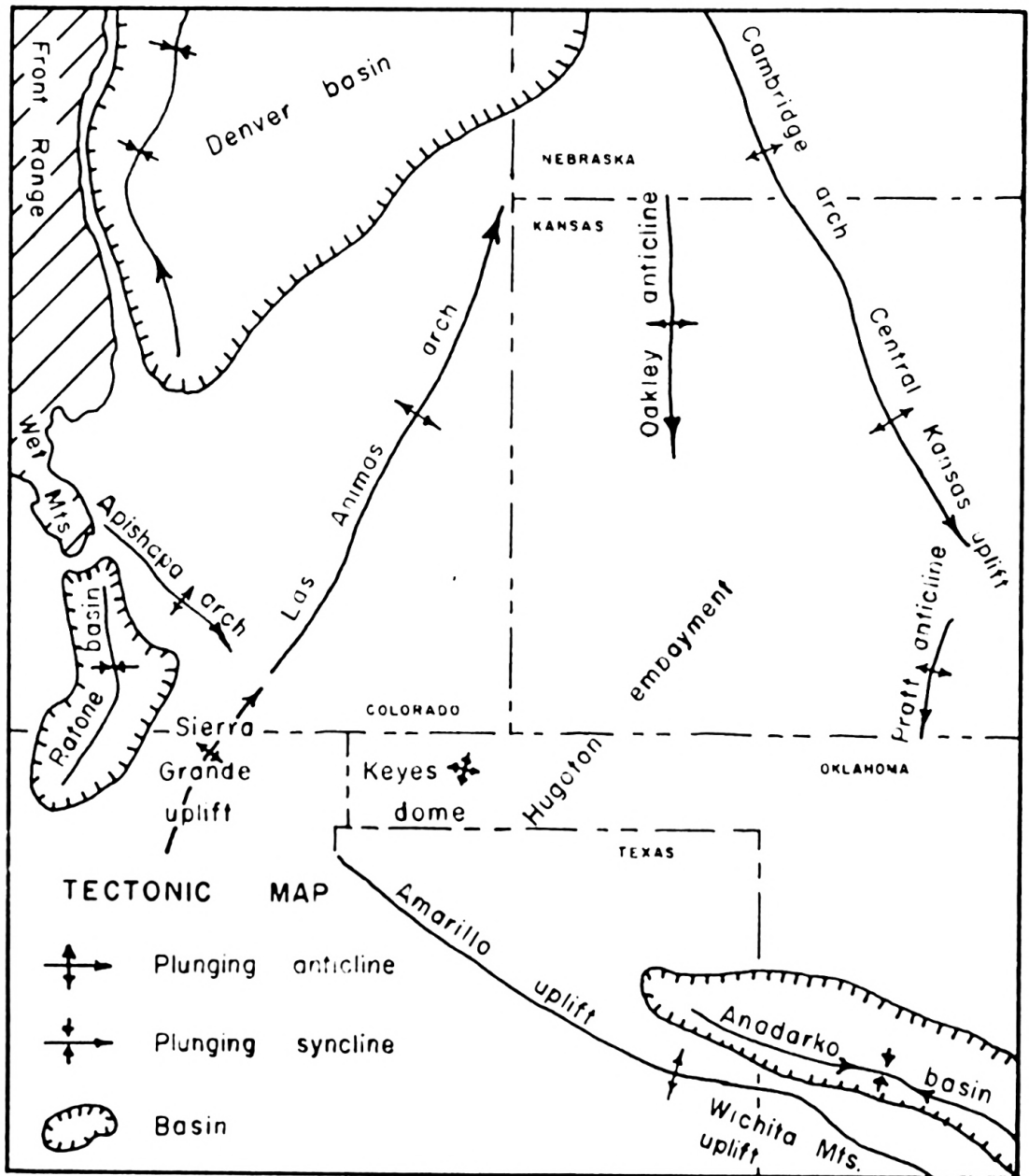


Fig. 2. Geographical distribution of major structures.

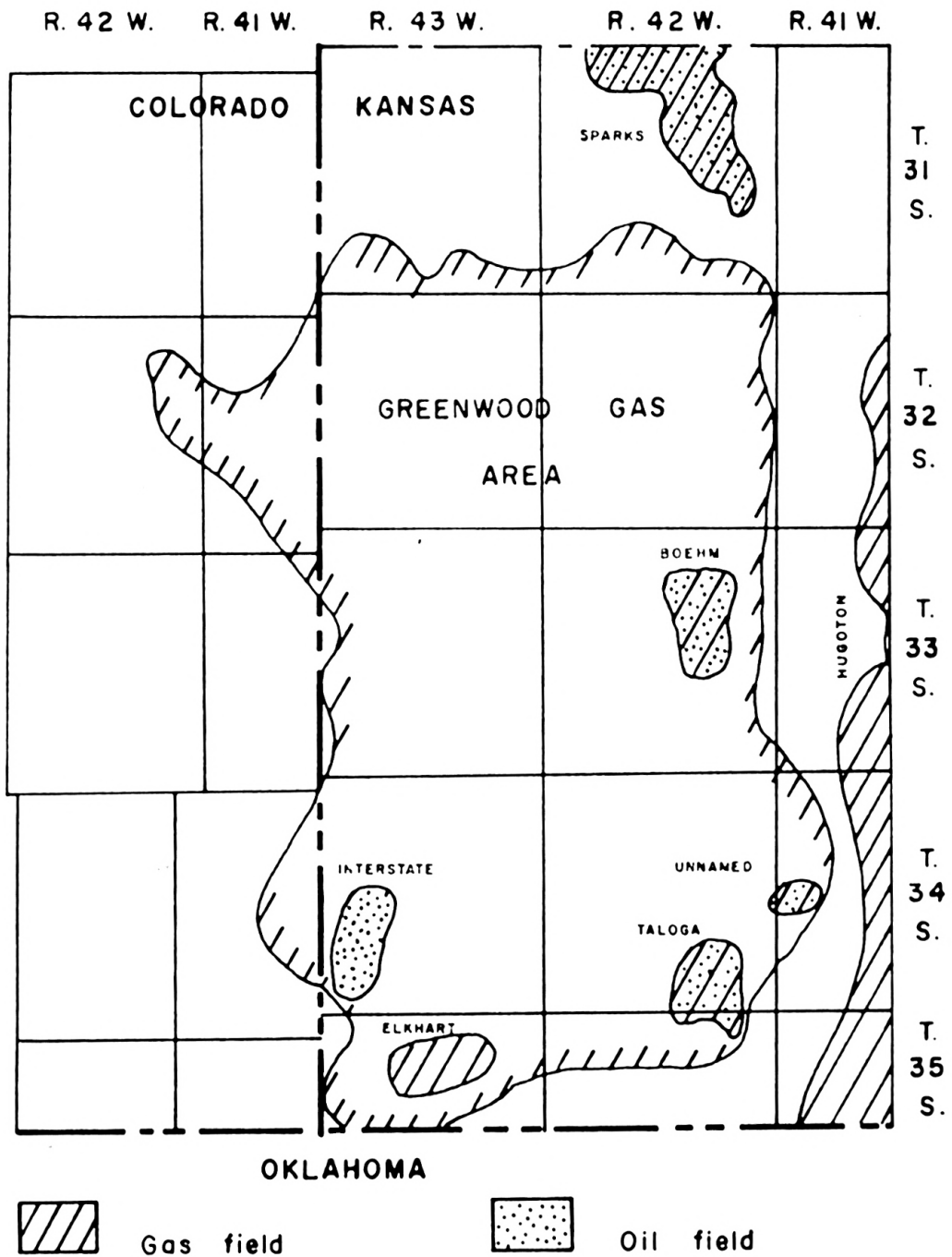


Fig. 3. Map of the Greenwood field area showing oil and gas pools.

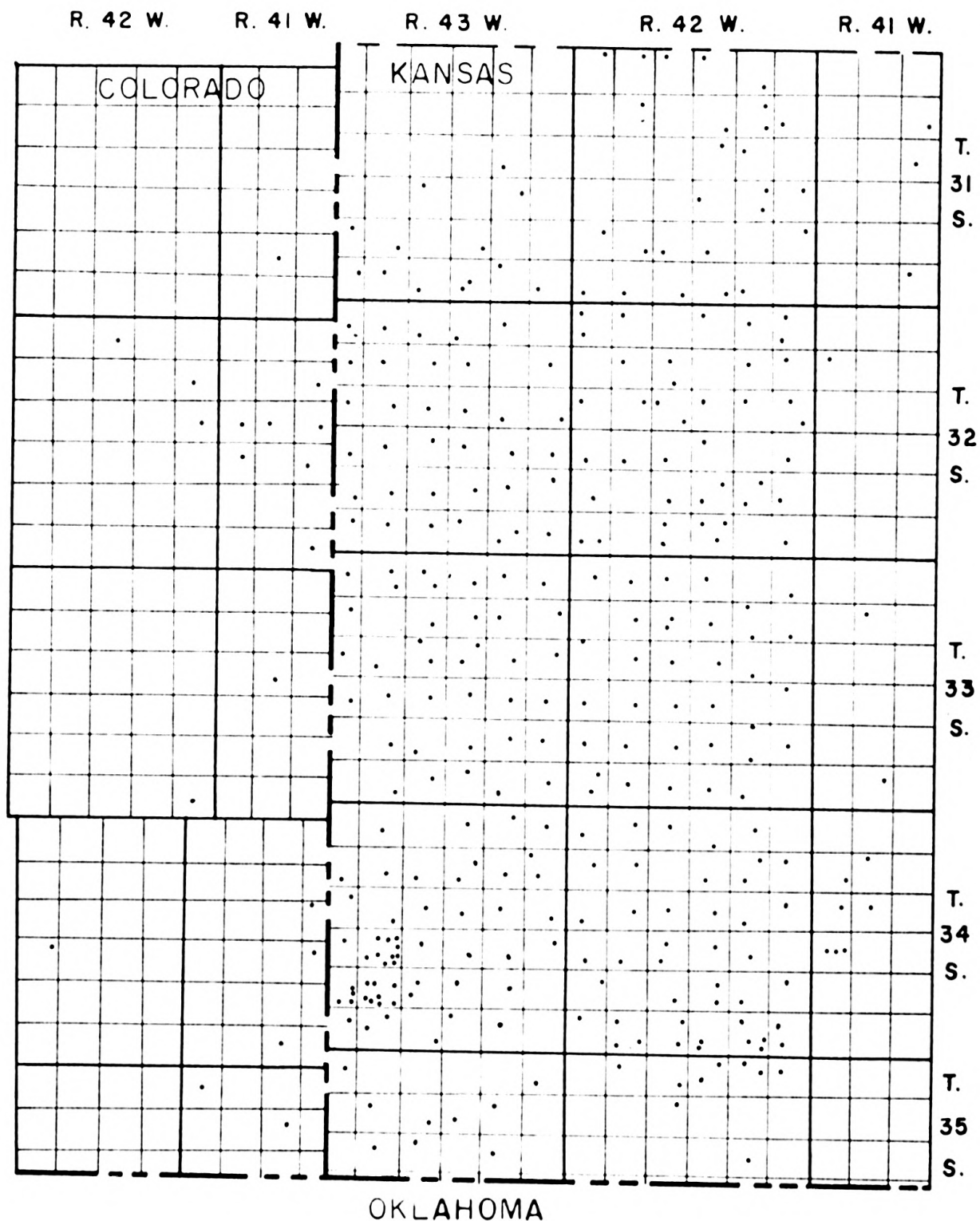


Fig. 4. Map of the Greenwood field area showing the location of wells used to construct the Topeka contour map, the Lansing contour map and the isopach map between the Topeka and the Lansing.

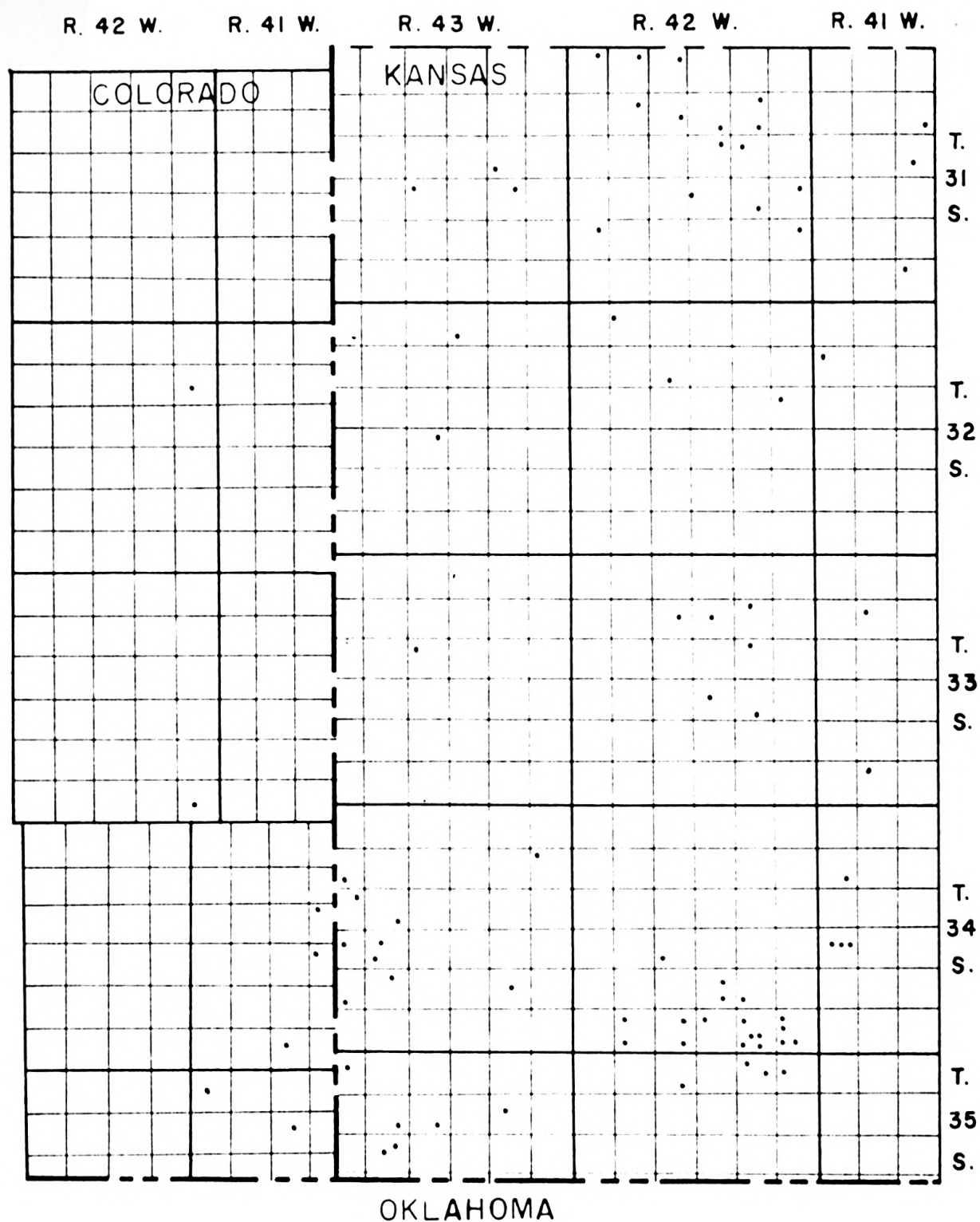


Fig. 5. Map of the Greenwood field area showing the location of wells used to construct the Keys contour map.

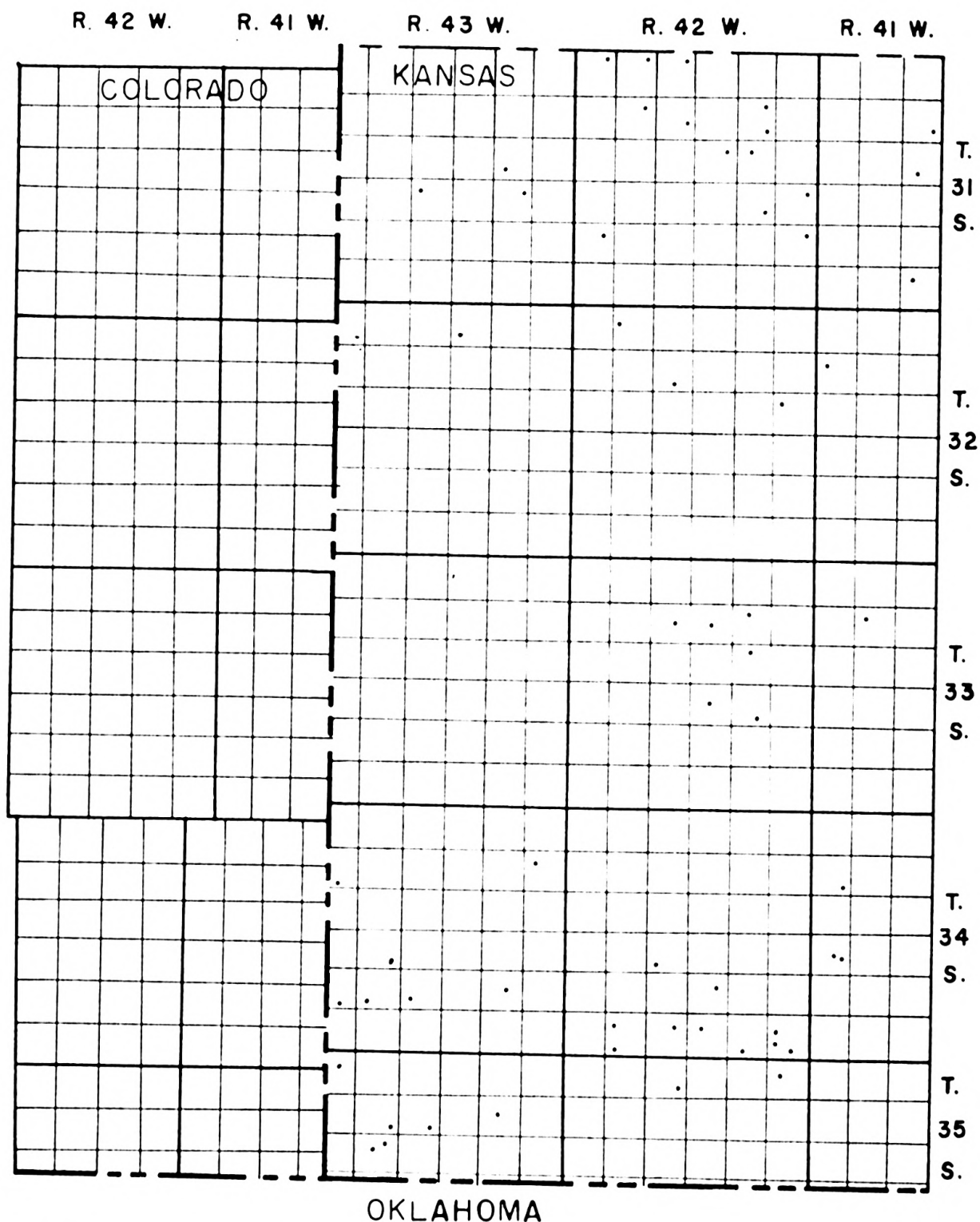


Fig. 6. Map of the Greenwood field area showing the location of wells used to construct an isopach map of the Keys sand.

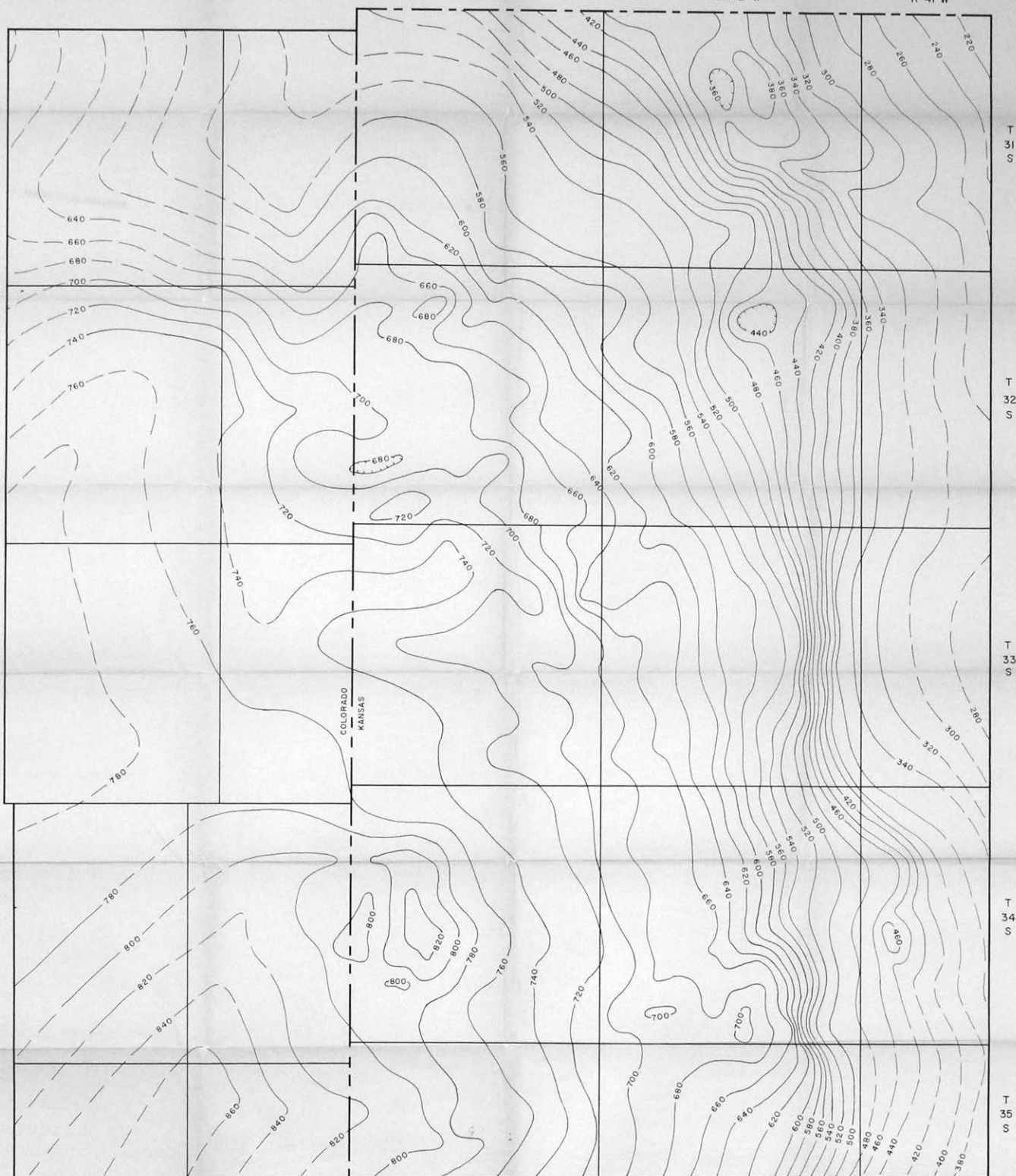
R 42 W

R 41 W

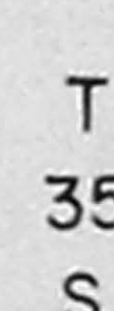
R 43 W

R 42 W

R 41 W



R 41 W



1958

FIGURES 9 TO 11 INCLUSIVE
(in accompanying plate box)

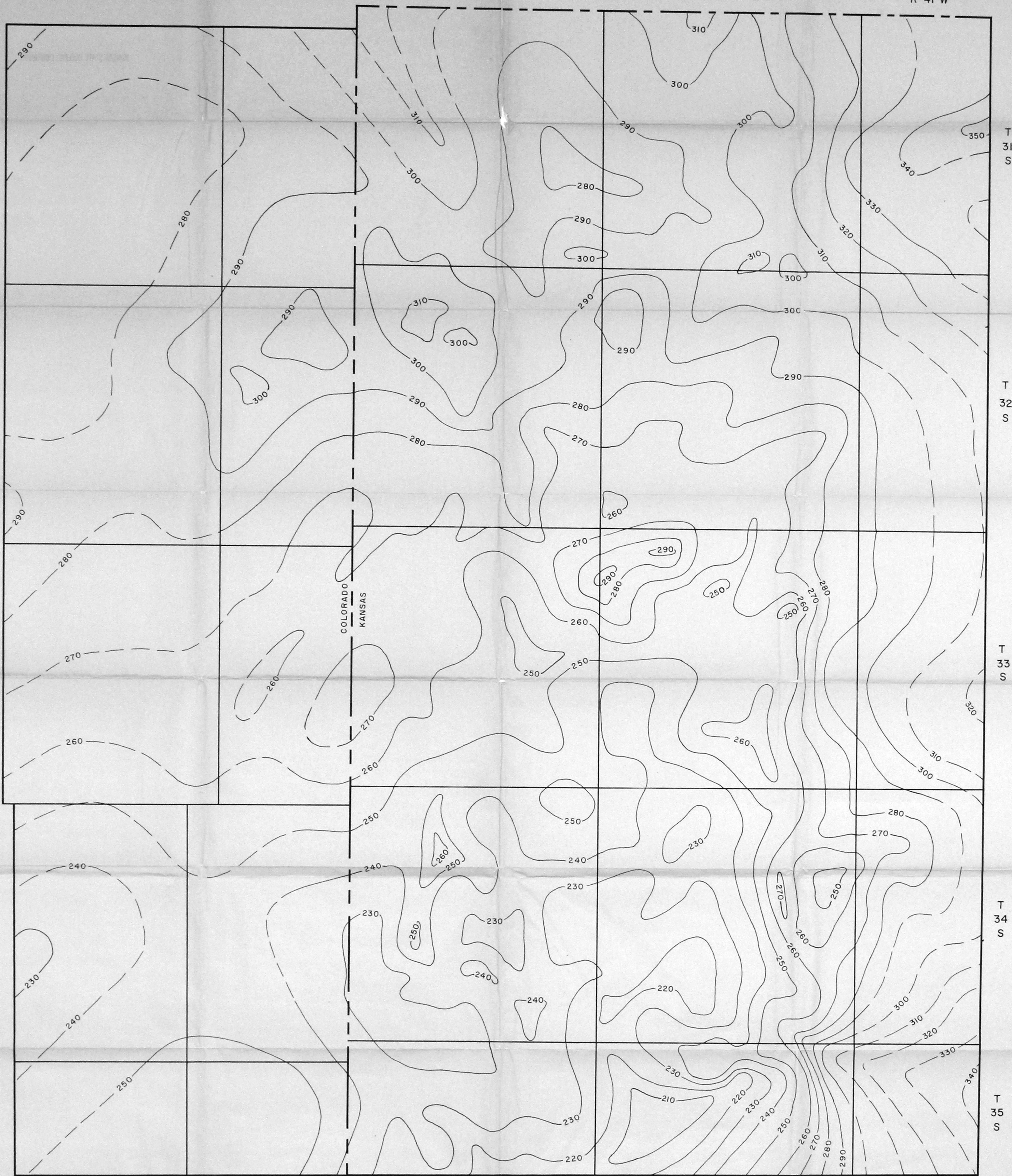
R 42 W

R 41 W

R 43 W

R 42 W

R 41 W



ISOPACH MAP FROM THE TOP OF THE TOPEKA TO THE TOP OF THE LANSING

GREENWOOD FIELD AREA

MORTON COUNTY, KANSAS - BACA COUNTY, COLORADO

0 1 2 3 4 miles

SCALE

N

STATE LINE

COUNTY LINE

TOWNSHIP LINE

DATUM PLANE: SEA LEVEL

CONTOUR INTERVAL: 10 feet

PAUL M. STRUNK

1958

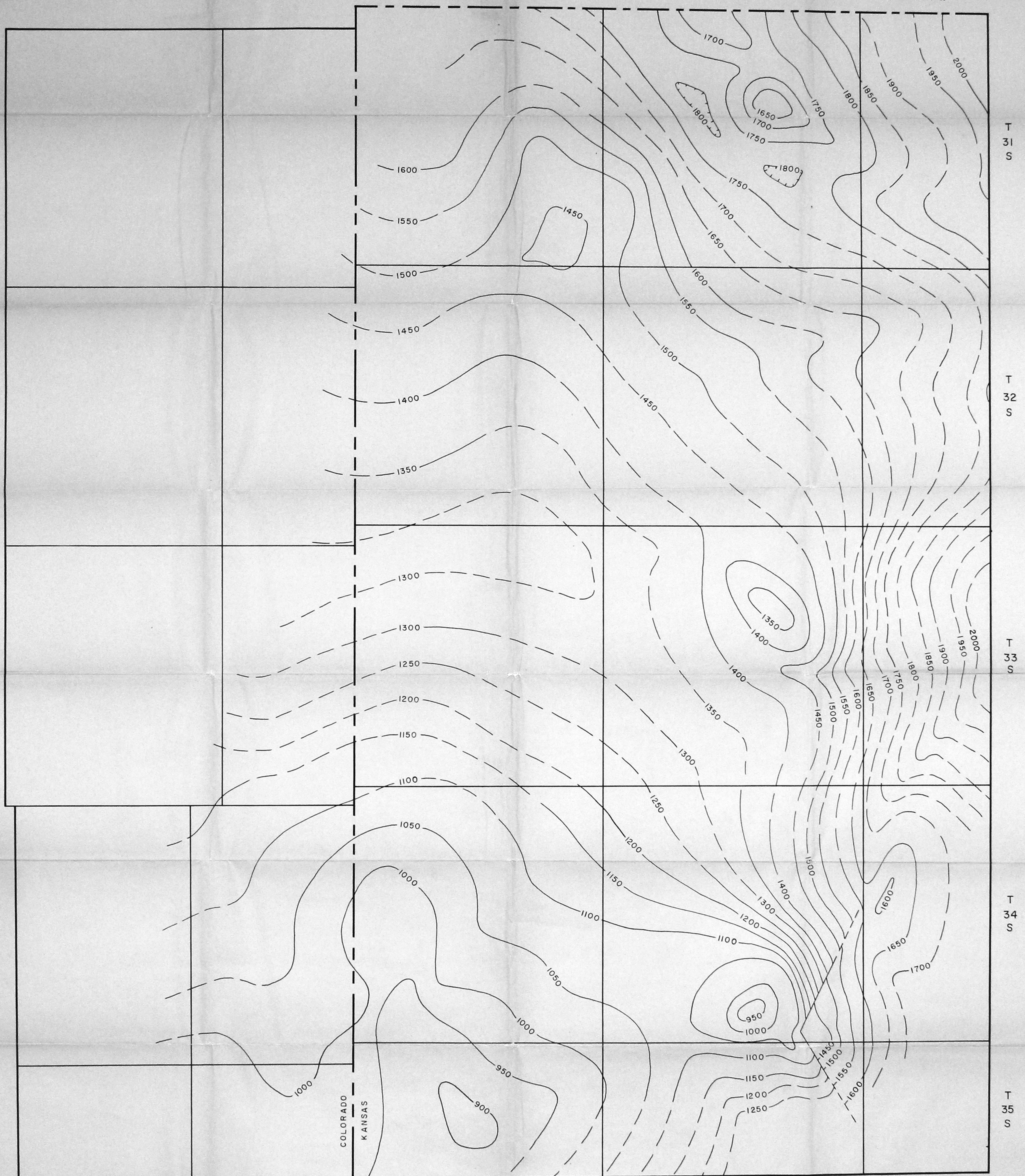
R 42 W

R 41 W

R 43 W

R 42 W

R 41 W



STRUCTURAL CONTOUR MAP ON THE TOP OF THE KEYS SAND

GREENWOOD FIELD AREA

MORTON COUNTY, KANSAS - BACA COUNTY, COLORADO

0 1 2 3 4 miles

SCALE

ALL ELEVATIONS BELOW SEA LEVEL

PAUL M. STRUNK 1958

STATE LINE

COUNTY LINE

TOWNSHIP LINE

DATUM PLANE: SEA LEVEL

CONTOUR INTERVAL: 50 feet

R 42 W

R 41 W

R 43 W

R 42 W

R 41 W



ISOPACH MAP OF THE KEYS SAND
GREENWOOD FIELD AREA
IN MORTON COUNTY, KANSAS & BACA COUNTY,
COLORADO

STATE LINE
COUNTY LINE
TOWNSHIP LINE

CONTOUR INTERVAL: 20 feet

0 1 2 3 4 miles
SCALE



PAUL M. STRUNK 1958

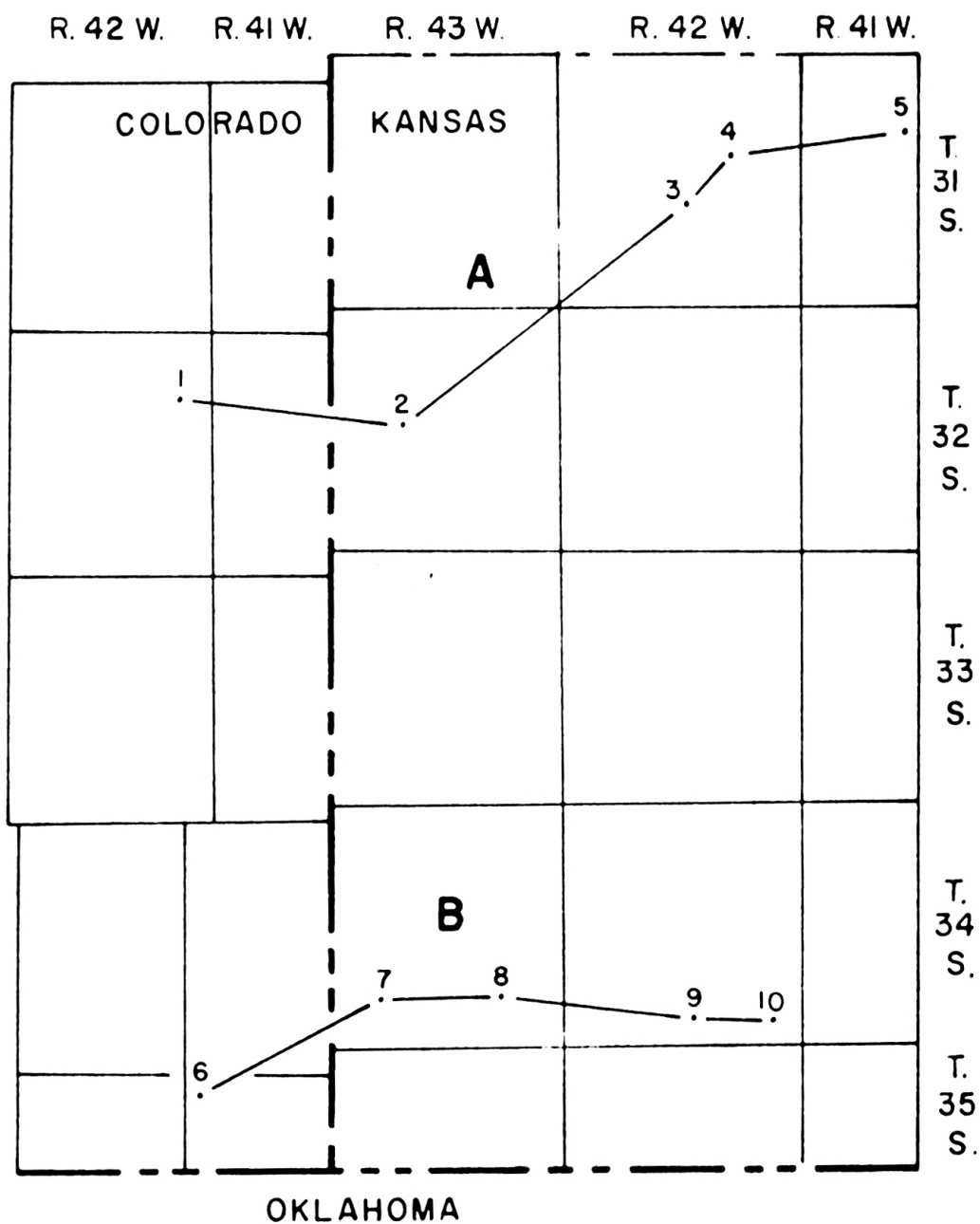
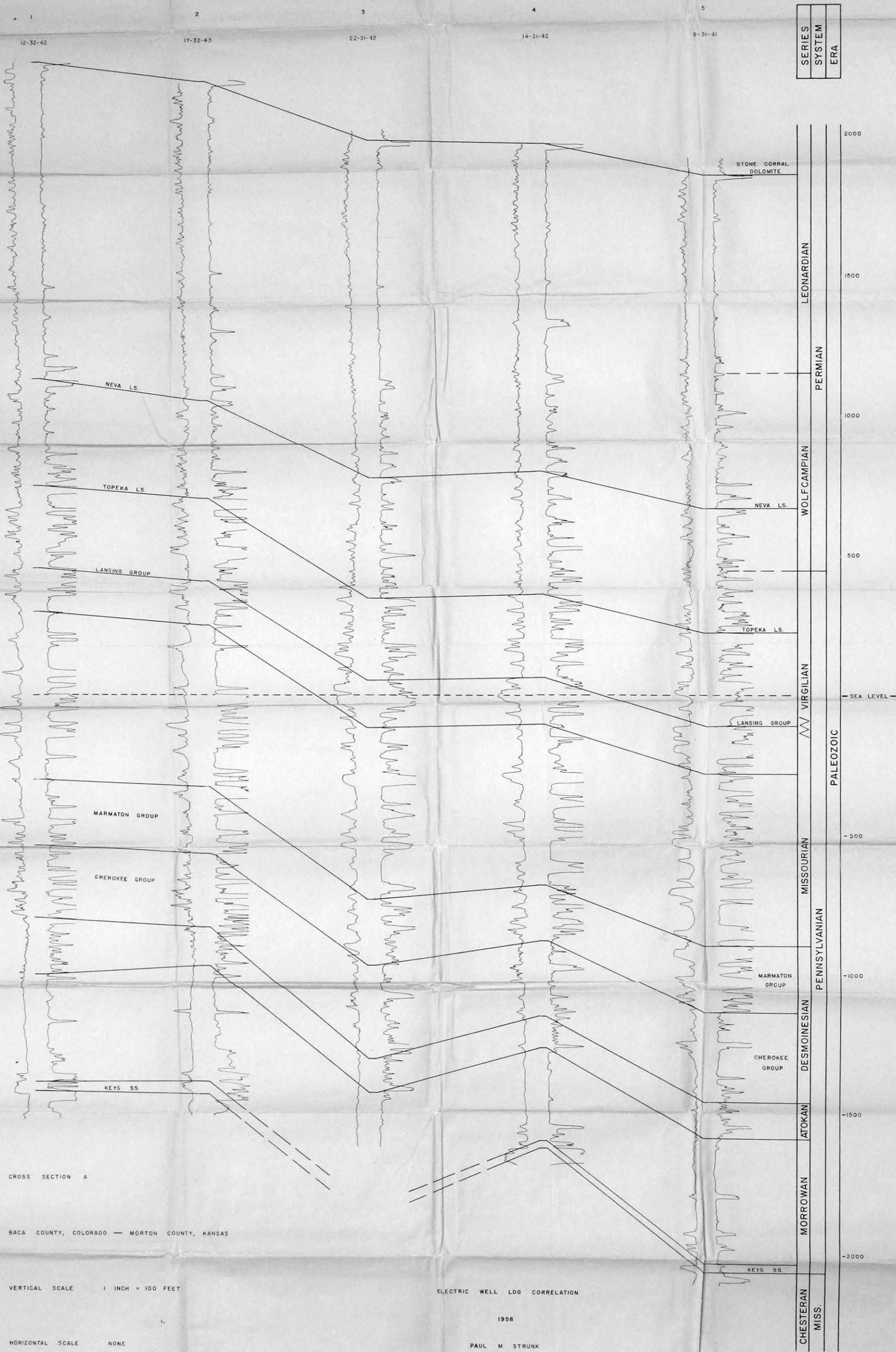


Fig. 12. Map of the Greenwood field area showing the location of wells used to construct cross sections A and B.

FIGURES 13 AND 14
(in accompanying plate box)

CROSS SECTION A



CROSS SECTION B

6 7 8 9 10
6-35-41 29-34-43 26-34-43 34-34-42 36-34-42

SERIES
SYSTEM
ERA



CROSS SECTION B

BACA COUNTY, COLORADO — MORTON COUNTY, KANSAS

VERTICAL SCALE 1 INCH = 100 FEET

HORIZONTAL SCALE NONE

ELECTRIC WELL LOG CORRELATION

1958

PAUL M. STRUNK

THE SUBSURFACE GEOLOGY OF THE GREENWOOD FIELD AREA LOCATED IN
MORTON COUNTY, KANSAS AND BACA COUNTY, COLORADO

by

PAUL MILTON STRUNK

B. S., Kansas State College
of Agriculture and Applied Science, 1956

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

1958

This study was to determine the relationship of stratigraphy, structure and petroleum accumulation in the Greenwood field area located in southwestern Kansas and southeastern Colorado. This area occupies the western part of Morton County, Kansas and the eastern part of Baca County, Colorado.

Electric well logs, Herndon maps and scout tickets were used to prepare structural contour maps, isopach maps and cross sections of the area. These maps and cross sections depict the relationship of petroleum accumulation to structure and stratigraphy.

Structurally, the Greenwood field area is located on the western flank of the Hugoton embayment. It is the lower portion of a northeast-southwest structural trend that reaches its maximum relief at Keys dome to the southwest. The Sierra Grande uplift and the Las Animas arch lie to the west and northwest. Rock units present in the area range from pre-Cambrian to Quaternary with Silurian and Devonian rocks being absent.

Gas production in the Greenwood gas field comes from the Wabaunsee, Shawnee and Lansing-Kansas groups. Structural contour maps prepared on the Topeka limestone and the Lansing group indicate that a stratigraphic trap is responsible for the accumulation of gas in this field. Rocks of Morrowan age are responsible for the only deep production of oil and gas in the area. A structural contour map on the Keys sand (basal Morrow) shows that structural highs and some possible faulting are responsible for most of the accumulation of oil and gas in Morrowan strata.

The future potential of oil and gas in the Greenwood field area is good. There is still room for expansion of the already

proven Wabaunsee, Shawnee and Lansing-Kansas City production.

The Morrow is untested in much of the area and possible structural highs in the untested areas could provide future production. The potential of middle and lower Mississippian, Ordovician and Cambro-Ordovician strata cannot be estimated until more deep wells have been drilled.