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SUBSURFACE GEOLOGY OF RED WILLOW AND HITCHCOCK COUNTIES, NEBRASKA

by

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INTRODUCTION

Purpose

The purpose of this thesis is to determine the subsurface structure, stratigraphy, and geologic history of Red Willow and Hitchcock Counties, Nebraska, and to relate these geological factors to the accumulation of petroleum. Information compiled in this thesis will provide, for geologists working in the two counties and the surrounding area, a working knowledge of the geology thereof. The thesis could also provide a basis for outlining drilling locations which could lead to the discovery of new petroleum reserves.

Location

Red Willow and Hitchcock are east-west adjoining counties in southwestern Nebraska adjacent to the Kansas-Nebraska border. Hitchcock and Red Willow are, respectively, the second and third counties east of the Nebraska-Colorado border, the western boundary of Hitchcock being 36 miles east from that border. Red Willow County is bounded on the north by Frontier County, on the east by Furnas County, and on the south by Decatur County, Kansas. Hitchcock County is bounded on the north by Hayes County, on the west by Dundy County, and on the south by Rawlins County, Kansas (Fig. 1).

Red Willow and Hitchcock Counties and the immediate surrounding area is generally referred to, by the petroleum

industry, as the Kaneb area.

Size and Shape

Red Willow and Hitchcock Counties each have a north-south dimension of 24 miles and an east-west dimension of 30 miles. The area covered by each county is approximately 720 square miles.

Physiography

Red Willow and Hitchcock Counties are located in what is commonly known by Nebraska State geographers as the "Nebraska Plain", a subdivision of the "Great Plains" physiographic province. The equivalent of the "Nebraska Plain", immediately to the south, in Kansas, is referred to as the "High Plains" by Kansas geographers.

An estimated 80 percent of the Red Willow-Hitchcock area is uplands and the remainder is valley lowlands. Topographically, the area consists of four relatively level uplands or tablelands with dissected fringes, separated by the valleys of the Republican River, Frenchman River, Red Willow Creek and Beaver Creek. The largest of these nearly uneroded tablelands extends across the entire southern half of the two counties, from the Republican River valley south to the Beaver Creek valley near the Kansas-Nebraska border. The triangular area in northwestern Hitchcock County, between the Republican and Frenchman River valleys comprises a second tableland area. The area north of the Repub-

lican and Frenchman River valleys, from north-central Hitchcock County to the eastern edge of Red Willow County, is divided into nearly equal halves by Red Willow Creek and comprises the remaining two tableland areas. The general surface of these tablelands appears nearly flat but in detail it is marked throughout by very low, gentle swells. These tablelands consist of large, level remnants of extensive Pleistocene loess deposits underlain by locally cemented Tertiary sands and gravels of the Pliocene Ogallala Undifferentiated. These tablelands have not yet been completely dissected by drainage channels but drainage has been established over the greater part of their surface. Neither deep ravines have been cut nor has a sharply rolling or hilly topography been produced. The controversial depressions, generally referred to as "deflation basins", are as numerous on these tablelands as they are elsewhere in the Great Plains and have been attributed by laymen and geologists to various causes such as the wallowing of buffalo, solution-subsidence, wind scour, differential eolian deposition, differential compaction, and silt infiltration. The most striking feature of the landscape is the sudden change from the nearly level or very gently undulating tableland to the eroded valley slopes of the drainage channels. The descent from the level upland to the valleys of the smaller streams is frequently a sheer precipice with little or no sloping approach whereas the descent to the valleys of the principal streams is, as a rule, of a rounded sloping type. The major valleys, for the most part, are level and covered with Pleistocene

alluvium derived from the Pleistocene loess and the Tertiary sand and gravel of the upland area.

The Republican River, the principal stream draining the area, drops about 500 feet while traversing the two counties, resulting in a gradient of over 8 feet per mile. It enters Hitchcock County from the west and flows all the way across the two counties, leaving Red Willow County on its eastern border. The Frenchman River enters Hitchcock County in the north central part, flows southeastward, enters the Republican River 4 miles west of the Red Willow-Hitchcock County line, and drains the northern one-third of Hitchcock County. Red Willow Creek enters Red Willow County in the northwestern corner, drains that area, and flows into the Republican River near the center of the county. Beaver Creek cuts across the southeast corner of Red Willow County from west to east and drains that area.

Red Willow County has an average elevation of about 2,600 feet above sea level with a low of 2,250 feet in the east to a high of 2,880 feet in the west. The total relief of the county is 630 feet but the maximum relief in any one square mile does not exceed 250 feet.[1]

Hitchcock County has an average elevation of about 2,850 feet above sea level with a low of 2,530 feet in the east to a high of 3,200 feet in the west. The total relief of the county is 670 feet but the maximum relief in any one square mile does

1. Topographic Map of Red Willow County, Nebraska, U.S. Coast and Geodetic Survey.

not exceed 250 feet.[1]

Procedure

In this two-county area, the stratigraphy and lithology of the sedimentary rocks was determined by reviewing the literature, by examination of electric logs, and by examining the samples of 3 locations in Red Willow County and one location in Hitchcock County. The descriptions of the producing horizons were made from cores, core logs, cuttings, and electric logs, all of which are on file with the Nebraska Geological Survey, located on the campus of the University of Nebraska, Lincoln, Nebraska.

Subsurface structural contour maps were prepared on the base of the Kansas City Group (Plates V and VI). This horizon was chosen because of its stratigraphic position, structural importance, and economic significance. Also, the base of the Kansas City could be pinpointed on the electric log with more ease and greater accuracy than the top of the Kansas City or the top of the Lansing and therefore provides more accurate structural control. All sea level data on the base of the Kansas City were taken from electric logs. With the exception of one hole in the Barger Field, all locations were assumed to have correct elevation data and were taken into account on the structural maps. Within a producing area, a limited number of control points were used and the locations not used remain without elevation data. Wildcat locations without data either did not penetrate the Lansing-Kansas City or the

1. Topographic Map of Hitchcock County, Nebraska, U.S. Coast and Geodetic Survey.

location was in the process of being drilled at the time of mapping and therefore the information was unavailable. These comprise only 1 percent of the total locations drilled in the two counties.

A microfossil analysis was made from the previously mentioned 4 locations of the Shawnee, Lansing-Kansas City, and the Marmaton-Cherokee Groups. The analysis was made from the cuttings instead of the cores because of the difficulty in separating the limestone-embedded fossils from their matrix in the core and also because of the limited amount of core available. In the 3 groups analyzed, the various drillers, as a rule, collected samples at five-foot intervals. The individual samples of a complete group were quartered in a sample tray and collected in a container. From this container, half of the collection was transferred to a metal pie plate where it was slowly boiled in a 10 percent solution of sodium hydroxide for one hour or longer. A 10 percent solution of sodium hexametaphosphate was also tried and was found to produce the same results as sodium hydroxide but at a greater monetary cost. Finding the fossils undamaged, the second half of the sample was given the same treatment. This process satisfactorily deflocculated all but the red shales which were subjected to the method of alternate freezing and sudden thawing. This freezing and thawing method adequately dispersed the remaining shales. The samples were then dried and sieved, leaving only limestone and the fossils. As was observed before the deflocculation treatment, the shales contained few, if any, fossils. White

household vinegar 4½ percent acidity, was tried on a very small portion of one of the remaining samples but was found to dissolve the walls of the fusulinids more rapidly than the limestone cement or the calcite filling the cavities of the fusulinids so further treatment with the vinegar was discontinued. Over 50 percent of the fossils found had already been freed from their limestone cement by the action of the drill bit and most of them had been damaged to various degrees. To determine their constancy throughout the two-county area, all identifiable fossils in each of the 3 groups were then classified, counted, and their percentages calculated (Tables 1, 2, 3, 4, 5, 6, 7, and 8). In the case of a broken specimen, a fragment representing more than half a fossil was counted as a whole fossil for statistical purposes. Representative fossils from each species found were photographed (Plates I, II, III, and IV).

Previous Literature

One of the first geologic publications to include any part of the two-county area was "The Geological Section of Nebraska" by Reed and Condra in 1959. This publication is Nebraska Geological Survey Bulletin No. 14A. In 1961, the Rocky Mountain Association of Geologists published a brief one or two page report of each field in southwestern Nebraska. W. S. Larson in 1962 published an article on the Ackman Field in the November issue of Bulletin of the American Association of Petroleum Geologists. "Lithostratigraphy and Correlation of the Mississippian System in

Nebraska", by M. P. Carlson, Nebraska Geological Survey Bulletin No. 21, was published in 1963. A few other publications have appeared in World Oil and The Oil and Gas Journal since 1958 but they are very generalized and uninformative, possibly due to the lack of information at that time.

STRATIGRAPHY

Cenozoic Era

Quaternary System

Pleistocene Undifferentiated. Approximately 50 feet of eolian loess caps the upland areas and rests unconformably on the Ogallala. From 20 to 70 feet of Pleistocene alluvium covers the valleys of the Republican River, Red Willow Creek, Beaver Creek, and Frenchman River and lies unconformably on rocks of the Cretaceous Age. This alluvium consists of silt from the Pleistocene loess and sand, gravel, silt, and some clay from the Ogallala Group.

Tertiary System

Ogallala Undifferentiated. The Ogallala sediments are composed of gravel, sand, silt, and some clay, locally and sporadically cemented with calcium carbonate and, in a few isolated spots, cemented by silica. The color of this continental deposit is very light gray or ash-gray. The thickness ranges from 50 to 150 feet depending largely on the amount of deposition, and somewhat on the amount of post-Pliocene erosion and the topography of the truncated Cretaceous rocks upon which they rest unconformably. The Ogallala deposits are of Pliocene Age and are the only representatives of the Tertiary System in Red Willow and Hitchcock Counties. They underlie the Pleistocene loess throughout the two counties and crop out in the walls of the major valleys. Local

terms for the Ogallala include "glass rock", "magnesia rock", the erroneous term of "granite", and the most descriptive and widely used term, "mortar bed rock".

Mesozoic Era

Cretaceous System

Montana Group

Lance Formation. This formation is missing beneath the two-county area.

Fox Hills Sandstone Formation. This formation is missing beneath the two-county area.

Pierre Shale Formation. This formation is composed of gray shale with some chalky zones mostly in the upper portion. It contains pyrite and a few Inoceramus shell fragments. The Pierre Shale is present in the subsurface throughout Hitchcock County and is absent only in the northeast corner of Red Willow County where truncation over the Cambridge Arch has removed it in an area equal to approximately two townships. The thickness of the Pierre ranges from 0 feet in the northeast corner of Red Willow County to 700 feet in western Hitchcock County.

Colorado Group

Niobrara Chalk Formation. This formation consists of two distinct members, the Smoky Hill Chalk and the Fort Hays Limestone. The Smoky Hill is a shaly chalk with relatively abundant fragments of

Inoceramus shells. The cuttings are difficult to distinguish from the Pierre. The Smoky Hill, however, contains considerably more Inoceramus fragments and effervesces much more vigorously than the Pierre. The effervescense in the Pierre is largely due to the calcareous microfossils whereas the effervescense in the Smoky Hill is due to its calcium carbonate content. Thickness of the Smoky Hill is approximately 375 feet and the color of its cuttings is light gray. Underlying the Smoky Hill is the Fort Hays Limestone. It is a 50 to 60 foot section of chalky limestone at the base of the Niobrara and the cuttings are white.

Carlile Shale Formation. The total thickness of the Carlile is about 230 feet. The Codell Sandstone, in the upper part of this formation, may be as much as 20 feet thick and is a silty, fine-grained, gray sandstone that can easily be overlooked in the cuttings. Below the Codell is approximately 100 feet of gray, non-calcareous Blue Hill Shale beneath which is another approximately 100 feet of slightly calcareous Fairport Shale. The Fairport is slightly lighter in color than the Blue Hill. There are a few Inoceramus fragments in the lower half of the Carlile while the upper half seems to contain none.

Greenhorn Limestone Formation. This formation consists of nearly white limestones and gray calcareous shales in alternating layers. Most of the limestone strata appear in the upper portion while the lower rocks are predominately shale. In the samples, the shale cuttings far outnumber the limestone cuttings throughout the section. Inoceramus shell fragments are rather abundant

throughout the entire section. The thickness of the formation varies from 30 to 50 feet.

Graneros Shale Formation. This formation consists of dark gray shale with thin calcareous layers in the upper portion and some sand and sandy shale in the basal portion. This formation changes facially in the Nebraska Panhandle, northeastern Colorado, and southeastern Wyoming where the upper portion is referred to as the Belle Fourche Shale and the lower portion is referred to as the Mowry Shale. Some geologists include the Newcastle (Muddy) Sandstone and the Skull Creek Shale of the Dakota section in the Graneros Formation. In this report, the Newcastle and Skull Creek are not included in the Graneros. In the Hartville Uplift area of Wyoming, the complete section of Carlile, Greenhorn, and Graneros is often referred to as the Benton Shale. In the two-county area, the Graneros Shale, from the bottom of the Greenhorn to the top of the Dakota, ranges from 70 to 100 feet in thickness.

Dakota Group

The Dakota was named by Meek and Hayden in 1862 from Dakota County, Nebraska. Since that time, a number of geologists and geological survey groups have separated the Dakota into various formations and members so as to provide a workable classification for the particular locality in which they were working. The upper portion of the section is often referred to as the Dakota Sandstone, a usage conflicting with the name of the group. The following are stratigraphic classifications used by some mid-continent

state geological surveys and by E. F. Miller.

The Nebraska Geological Survey

Dakota Group
- Omadi (Dakota) Sandstone Formation
- Fuson Shale Formation
- Lakota Sandstone Formation

The Kansas Geological Survey

Dakota Formation
- Janssen Clay Member
- Terra Cotta Clay Member

The Wyoming Geological Survey

Dakota Group
- Newcastle Sand Formation
- Skull Creek Shale Formation
- Fall River (Dakota) Sandstone Formation
- Fuson Shale Formation
- Lakota Sandstone Formation

The South Dakota Geological Survey

Dakota Group
- Dakota Sandstone Formation
- Fuson Shale Formation
- Lakota Sandstone Formation

E. F. Miller (1929) Conference Kansas Geological Society Field Trip

Dakota Group
- Omadi Formation
  - Newcastle Sand
  - Skull Creek Shale
  - Fall River Sandstone
- Fuson Shale
- Lakota Sandstone

Dakota Undifferentiated. For purposes of this report, the Dakota will not be differentiated. In Red Willow and Hitchcock Counties the Dakota consists of interbedded and lenticular sands, shales,

and sandstones. The shales are gray and the sandstones are brown or red. Quartzitic lenses and pyrite-cemented fine sands are found locally. Siderite pellets are common throughout the section and, frequently, little other than shale and siderite pellets are encountered in Dakota samples, the fine sands having been washed through the shale shaker because of the samplers lack of knowledge of proper sampling techniques. None of the aforementioned divisions of the Dakota are discernable either from the samples or the electric logs. After spot checking logs west of Hitchcock County to the Wyoming border, it becomes quite apparent that the Newcastle Sand and the Skull Creek Shale are absent beneath Red Willow and Hitchcock Counties. Oil and gas are produced from the Dakota in eastern Wyoming, northeastern Colorado, and the southern Nebraska Panhandle but no shows of either oil or gas have been reported from this horizon in Red Willow and Hitchcock Counties. The total thickness of the Dakota in these two counties varies from 540 to 650 feet.

A major unconformity marks the base of the Cretaceous rocks in the mid-continent area. In southwestern Nebraska, the Dakota sediments rest upon the Morrison Formation of the Jurassic System whereas in the eastern part of the state they rest upon rocks of the Permian and Pennsylvanian Systems.

Jurassic System

Morrison Formation. This formation consists of green, gray, and red shales interbedded with lenticular sandstone and a little

limestone. The shales are predominantly green and are the distinguishing characteristic of the Morrison. The thickness of the formation ranges from 100 to 150 feet.

An unconformity occurs here at the base of the Morrison and rocks of the Sundance, Entrada, Twin Creek, and Nugget Formations are absent in the area covered by this report. All deposits of the Triassic System are missing, either by truncation or non-deposition. Consequently, the Morrison rests unconformably on rocks of the Permian System.

Paleozoic Era

Permian System

The difficulties pertaining to the correlation of the Permian in the mid-continent region are likewise present in the Cambridge Arch area. For a discussion of these difficulties and an attempted correlation of Permian divisions and classifications, see Condra and Reed, 1959. The following classification best fits the situation in Red Willow and Hitchcock Counties and has been modified from various classifications of State Geological Surveys, from the United States Geological Survey's proposed national Permian sections, from various individuals, and from a special Permian committee of the American Association of Petroleum geologists.

Cimarron Series

Kiger Group. The major hiatus occurring between the Jurassic

Morrison and the underlying Permian beds has caused the absence of this group as well as the aforementioned Triassic sediments.

Salt Fork Group. The absence of the equivalents to the Dog Creek and Blaine Formations of the upper portion of this group is also attributable to the hiatus occurring between the Morrison and the underlying Permian beds. A 120-foot section of the Flowerpot Shale Formation is present in western Hitchcock County while in eastern Red Willow County it disappears almost completely. The red to maroon shales that comprise this formation are readily recognized in the samples and on the electric log. Underlying the Flowerpot is a sequence of rocks equivalent to the Cedar Hills, Salt Plain, and Harper Formations. This interval consists of 200 to 300 feet of alternating fine sandstones, siltstones, and shales, all of which are predominantly red in color. Some of the sandstone, however, is gray with a tinge of red.

Sumner Group. Underlying the Salt Fork Group is the Stone Corral Anhydrite which is persistent beneath all of Red Willow, Hitchcock, and adjoining counties. This white anhydrite serves as an important stratigraphic marker-bed and is consistently 30 feet thick over most of southwestern Nebraska. Both in the samples and on the electric log it is the most obvious of all the strata penetrated. Below the Stone Corral are 220 to 360 feet of interbedded fine sandstones, siltstones, and shales belonging to the Ninnescah Formation. The shales and siltstones are red to maroon and the sandstones are mostly red, a few of them being gray with a red tinge.

Wolfcamp or Big Blue Series

Chase Group. This group contains the first carbonates of the Permian in this area although the group is still predominately composed of red clastics. The Chase Group consists largely of red and gray shales interbedded with fine, red, lenticular sandstones and some limestone. The limestone is off-white and slightly dolomitic near its base. The thickness of the Chase ranges from 120 to 300 feet.

Council Grove Group. Alternating layers of shale, sandstone, and limestone comprise this section. In the upper half of the group the shales predominate while the lower portion is composed of approximately one-half shales and one-half limestones and sandstones, these limestones and sandstones being present in equal proportions. The shales are red and gray, the sandstones red, and the limestones are off-white. The total thickness of the group is 240 to 310 feet.

Admire Group. This group consists of approximately 100 feet of red and gray shales interbedded with off-white limestones. The lower part of the Admire Group is missing because of an unconformity occurring between the base of the Admire Group and the underlying Pennsylvanian rocks.

Pennsylvanian System

Virgil Series

Wabaunsee Group. None of the formations or strata of this group,

present in the outcrop area of eastern Kansas and Nebraska, are identifiable as such in the subsurface of Red Willow and Hitchcock Counties. In this two-county area the group consists of equal portions of thin, interbedded limestones and red and gray shales. Fusulinids make their first appearance in the cuttings of this section. Thickness of the group is approximately 80 feet throughout the two-county area.

Shawnee Group. This group consists of off-white limestones intercalated with red and gray shales. The microfossils contained in the cuttings of this group consist of fusulinids, which are largely of the genus Triticites, crinoid columnals, immature brachiopods of the genera Ambocoelia and Composita, the bryozoan Rhombopora, and the ostracod Bairdia. The percentages of these fossils in the Shawnee Group are extremely variable but the fusulinids usually predominate. The upper 100 feet of the Shawnee Group is extremely difficult to correlate with outcrops in eastern Kansas and Nebraska. The basal 30 feet of this group consists of limestone, is readily discernable on the electric log, and is correlated with the Oread Formation. Oil is produced from the Oread in a number of wells in the Ackman, Sleepy Hollow, and Reiher Fields. The limestone has good reservoir characteristics in some spots within the upper 10 feet of closure in these three fields. Where the Oread is productive, it is composed of reworked fossiliferous material approaching a coquina in some wells. Unfortunately, this coquina-like development is confined to the upper 10 feet of the Oread and has a fairly high water content. Core analyses by Core

Laboratories, Inc., of one well in the Ackman Field and another in the Reiher Field, show as much as 500 millidarcys horizontal and vertical permeability, up to 30 percent porosity, from 25 to 45 percent residual oil saturation, and 40 to 70 percent water saturation. The Oread quickly loses its good reservoir characteristics at lower structural positions within these fields. Its reservoir development seems to be the result of a fossil-detritus build-up under depositional conditions related to micro-topographic features on the sea floor (M. P. Carlson, Nebraska Geological Survey, oral communication).

Douglas Group. The 35 feet of red and gray calcareous shales that separate the Oread from the underlying Lansing-Kansas City rocks is correlated with the Douglas Group.

Missouri Series

Pedee Group. No rocks beneath Red Willow and Hitchcock Counties have been assigned to this group. Pedee sediments in this area may have been reduced to a feather-edge deposit in which case they would be impossible to distinguish from the Douglas Group on the electric logs. Also, the Pedee Group may have been removed during the development of the unconformity present at this interval in the outcrop area of eastern Nebraska. No unconformity, however, is detectable at this point from the logs and samples of the two-county area.

Lansing-Kansas City Group. This group contains the principal oil-producing zones in Red Willow and Hitchcock Counties. The 200 to

300 foot interval can be divided into 6 limestones with intervening red, gray, and some green shales. The limestones are off-white and have been designated A, B, C, D, E, and F in descending order. Nearly every well in the two-county area produces from at least one of these 6 horizons.

The A zone, although exhibiting some vug porosity, has been a disappointment from a reservoir standpoint. For the most part it is dense and lithographic and productive in only a few wells. The thickness of this uppermost zone is approximately 20 feet. The porosity of the A zone is usually less than 8 percent and it has no appreciable permeability.

About 30 feet of red shale and sandy red shale separates the A zone from the B zone. Production is reported from the sandy interval in the Cahoj Field just across the border, south, in Rawlins County, Kansas, where the sandy shale grades into a sandstone. This sandy interval, however, is unproductive in Red Willow and Hitchcock Counties.

The B zone is an important producer in about half of the wells in the two-county area. This zone derives its reservoir capabilities from the development of vugs between what appear to be pieces of reworked limestone. The porosity is 11 to 15 percent and the permeability is less than 5 millidarcys. The oil saturation of the zone is about 20 percent and the water saturation 50 percent. This B zone is approximately 15 feet thick.

Separating the B zone from the C zone are 20 feet of red and green shale incorporating a persistent 3-foot stringer of nonpro-

ductive limestone. Oil shows have been encountered in the limestone stringer but it has no permeability.

The most important producing horizon is the C zone. It is productive in an estimated 90 percent of the wells in Red Willow and Hitchcock Counties. The zone obtains its reservoir qualities from the development of secondary porosity attributed to vertical fractures. The amount of fracturing in the C zone is much greater than in the B zone and, unlike the B zone, the C zone does not appear to have been reworked, at least not nearly to the same extent. The porosity of the C zone is 11 to 16 percent. Its permeability ranges from less than 5 millidarcys in the Ackman Field and 25 millidarcys in the Sleepy Hollow Field to over 200 millidarcys in the Reiher Field. The residual oil saturation of the zone is 15 to 25 percent, while the water saturation varies from 25 to 50 percent. The thickness of the C zone is approximately 20 feet.

About 35 feet of red, gray, and green calcareous shales underlie the C zone and separate it from the D zone.

The 15-foot D zone is productive in only a few wells in the two-county area because of its lack of good reservoir qualities. There is some oil staining associated with a small amount of vug porosity but the interconnection of the vugs is poor, resulting in low permeability. Porosity is usually less than 10 percent and the permeability ordinarily is less than 3 millidarcys. In the Reiher Field, the porosity exceeds 20 percent, permeabilities of 75 millidarcys have been recorded, the residual oil saturation is

20 to 25 percent, and the water saturation is approximately 50 percent.

There are 30 feet of red, gray, and green shales separating the D zone from the underlying E zone. This horizon has a persistent 2-foot stringer of limestone 10 feet from the top. The limestone stringer is productive only in the Reiher Field where the porosity is 15 percent and the permeability is 70 millidarcys.

The E zone is a fine crystalline limestone with some vug porosity. Only a few wells in the Silver Creek and Ackman Fields produce from this zone. The only core data available is from a Reiher well where the zone is nonproductive because the permeability is less than 2 millidarcys. Where the zone is productive it undoubtedly has much better reservoir characteristics. The thickness of the E zone is 15 feet.

About 25 feet of red and gray shales separate the E zone from the underlying F zone.

The F zone is the lowest limestone of the Lansing-Kansas City Group. Its reservoir qualities are very poor, having permeabilities of 1 millidarcy or less. In the few wells that do produce from this horizon the permeability may reach 5 millidarcys.

Underlying the F zone and forming the base of the Kansas City are from 10 to 30 feet of red sandy shale.

The fossils found in the cuttings of the entire Lansing-Kansas City section include fusulinids, crinoid columnals, brachiopods, bryozoans, ostracodes, and gastropods. The fossil assemblage of this section is much more consistent than that of the Shawnee

Group (Tables 2, 3, 4, 5, 6, 7, and 8)

The A.P.I. gravity of the Lansing-Kansas City oil in the two-county area varies from 29° to 31°.

Des Moines Series

The unconformity between the Missouri Series and the Des Moines Series, present in the outcrop area of these rocks, has been recognized in the subsurface throughout most of the state of Nebraska, including Red Willow and Hitchcock Counties.

Marmaton and Cherokee Groups. The boundary between these two groups has not been determined with any degree of accuracy in the Kaneb area, so they are discussed as one unit. The section consists principally of red shales which are intercalated with limestones in the upper half and sandstones in the lower half. Fusulinids, bryozoans, crinoid columnals, brachiopods, ostracodes, and gastropods comprise the fossil assemblage found in the cuttings of this unit. Fusulinella meeki is an index marker for the middle of the Cherokee Shale wherever this group crops out in Iowa, Missouri, Kansas, Oklahoma, and Arkansas. It is one of the most easily recognized of all fusulinids, being identified by the familiar honeycomb pattern displayed immediately beneath the outer surface. In the Kaneb area, Fusulinella meeki appear in the subsurface near the base of the Marmaton-Cherokee section and no thin sections are necessary for their identification as the outer surface usually has been removed by nature. The combined thickness of the Marmaton-Cherokee Groups ranges from 60 feet in east-

ern Red Willow County to 330 feet in western Hitchcock County.

Atoka and Morrow Series

Rocks of the Atoka and Morrow Series are absent beneath the entire state of Nebraska either by truncation or nondeposition. Basal sand. This zone consists entirely of medium to fine quartz sand-grains that are frosted, pitted, and well rounded. The sand is situated between the Cherokee and the Precambrian surface and varies in thickness from 0 to 30 feet.

Reservoir characteristics of the Basal sand are extremely good. The average porosity is 22 percent and the average permeability is 3,000 millidarcys. One core reveals as much as 35 percent porosity and 13,000 millidarcys permeability. The A.P.I. gravity of the oil derived from the sand is 31°.

Pre-Pennsylvanian

A major unconformity occurs between the Pennsylvanian and the Mississippian. Consequently, all pre-Pennsylvanian deposits have been truncated at the crest of the Cambridge Arch in the eastern two-thirds of Red Willow County and the Pennsylvanian Cherokee rests upon Precambrian granite. Progressing westward to the Hitchcock-Dundy county line, successively younger rocks underlie the Cherokee (Fig. 2). Beneath the Cherokee in southwest Hitchcock County is a narrow interval of dolomitic limestones assigned to the Mississippian System. These rocks have been assigned to subdivisions of the Mississippian by Carlson (1963)

but, for purposes of this report, are considered as one unit. Below this section is about 100 feet of Cambro-Ordovician Arbuckle which, in this area, consists of interbedded limestones, dolomitic limestones, and some shale. Underlying the Arbuckle and resting on Precambrian granite is the Lamotte or Reagan Sandstone of the Cambrian System. This sandstone is composed of a medium-grained sand that is readily identifiable from the samples and is easily recognized on the electric log. The Reagan varies in thickness from 50 to 100 feet beneath Hitchcock County and pinches out in western Red Willow County. In the two-county area there is no production from the pre-Pennsylvanian rocks.

GEOLOGIC HISTORY

The geologic history and structure in Red Willow and Hitchcock Counties is associated with the Cambridge Arch. The axis of this arch trends north-south through Cambridge, Nebraska, and derives its name from that town. Cambridge is located in Furnas County, 19 miles north of the Kansas-Nebraska border and 3 miles east of the Red Willow-Furnas county line.

Marmaton and Cherokee equivalents are present throughout Red Willow and Hitchcock Counties and over the crest of the Cambridge Arch in the southern tier of Nebraska counties. In eastern and central Red Willow County, near the apex of the arch, the Cherokee unconformably overlies the Precambrian surface. This is because early Pennsylvanian, or possibly late Mississippian, erosion removed beds of Mississippian, Devonian, Silurian, Ordovician, and Cambrian Ages, all of which are present farther east in the Central Nebraska Basin (Reed, 1954). West of the Cambridge Arch, in Hitchcock County, lower Mississippian, Cambro-Ordovician Arbuckle, and Cambrian Reagan beds are present between the Cherokee and the Precambrian. Other groups of pre-Pennsylvanian Age and Pennsylvanian Atokan and Morrowan are absent, probably because of nondeposition (Fig. 2).

The Cambridge Arch underwent several important periods of diastrophic movement during its geologic history. Probably the most significant movement is the early Pennsylvanian folding, as is evidenced by the truncation causing the previously described unconformity. According to E. C. Reed (oral communication) and the

knowledge obtained in the compilation of information and data for this report, the following is a history of the events which have taken place during the development of the Cambridge Arch.

Precambrian

There is no gneiss, schist, slate, or marble in the subsurface of Red Willow and Hitchcock Counties and there are no Precambrian sediments. The Precambrian granite, however, is mantled by a few feet of "granite wash", usually no more than 10 feet thick.

Paleozoic Era

Invasion by the Cambrian seas resulted in the deposition of the Reagan Sand over the entire area that later became the Cambridge Arch. Following the deposition of the Reagan, were the Cambro-Ordovician Arbuckle deposits in late Cambrian and early Ordovician time. At the close of Arbuckle time, the Siouxana Arch, to the north in what is now central Nebraska, was broadly and very gently upfolded. At this time a very wide area, including Red Willow and Hitchcock Counties, suffered the removal of a thin veneer of Arbuckle sediments over the higher portions of the east-west trending Siouxana uplift. A minor subsidence followed this uplift and the invading upper-Ordovician and Silurian seas, from the Central Nebraska Basin to the east, deposited progressively thinner sediments westward and northwestward toward the crest of the Siouxana Arch. Rejuvenation of the Siouxana uplift at the close of Silurian time resulted in the truncation of the thin

Silurian deposits. The overlap by the succeeding Devonian sediments thinned markedly from the Central Nebraska Basin westward to the present Cambridge Arch area. At the close of Devonian time, some uplift, folding, and erosion occurred with subsequent invasion of Mississippian seas from the east and southeast. This resulted in the overlap of Mississippian sediments westward, overriding the southern part of the arch area and extending well into present Colorado. At the close of Mississippian and early Pennsylvanian time, the Cambridge Arch made its first appearance. Diastrophic upwarping and the accompanying erosion removed all pre-Pennsylvanian sediments from the crest of the arch in eastern Red Willow and western Furnas Counties where the late Pennsylvanian Cherokee rests unconformably on Precambrian granite. This major uplift resulted in the truncation of pre-Pennsylvanian sediments on the flanks of the arch. Therefore, the Cherokee rests on successively younger beds with increasing distance from the crest of the arch to the extreme western edge of Hitchcock County and beyond, where the Cherokee unconformably overlies rocks of Mississippian Age. Subsequent subsidence and the following invasion by Pennsylvanian seas from the east and southeast, resulted in the deposition of thin layers of upper Pennsylvanian beds over the arch. That contemporaneous uplift of the arch (or subsidence of the Central Nebraska Basin and Denver-Julesburg Basin) occurred at the time of deposition is indicated by the thickening of upper Pennsylvanian sediments to the east and to the west of the arch. Some evidence of rejuvenation of the Siouxana Arch in early

Permian time has been detected by the Nebraska Geological Survey but to date is inconclusive (oral communication with Reed and others). Generally, however, subsurface studies indicate no great interruption in sedimentation between the Pennsylvanian and Permian periods. Permian strata were deposited in approximately the same thickness over the arch as in the adjoining present-day basins to the east and west.

Mesozoic Era

General uplift of the mid-continent area at the close of Permian time left the Kaneb area devoid of any Triassic and lower Jurassic sediments, the Jurassic Morrison being the only representative of the two periods. The last active movement of the Siouxana Arch is attributed to this post-Permian uplift. Invasion of Cretaceous seas from the west with some contemporaneous uplift along the Cambridge-Chadron Arch followed and thousands of feet of Cretaceous sediments were deposited over the arch as well as in the areas to the east and west. That this contemporaneous uplift of the arch occurred during Cretaceous deposition is evidenced by the thinning of Cretaceous sediments over the arch. In late Cretaceous time, the Denver-Julesburg Basin to the west was strongly downfolded and thousands of feet of Pierre Shale were deposited in the western part of the basin with lesser amounts over the arch. The subsidence of this basin helped to accentuate the prominence of the Cambridge Arch.

Cenozoic Era

In early Tertiary, or possibly very late Cretaceous time, the Cambridge Arch was strongly upfolded. This upfolding was followed by extensive erosion which removed the Pierre Shale from the crest of the arch, exposing Niobrara Chalk at the surface. Pierre Shale remained exposed at the surface to the west of the arch almost all the way to the Front Range and the Laramie Range as well as to the east of the arch, a third of the distance into the Central Nebraska Basin. The resulting peneplained, truncated surface received a deposit of a hundred feet or more of continental type Tertiary sediments. These deposits have been assigned to the Pliocene Epoch and are currently referred to as Ogallala Undifferentiated by the Nebraska Geological Survey. Some eastward to southeastward regional tilting occurred in post-Tertiary time followed by the deposition of a hundred to two hundred feet of Pleistocene loess. In summation, most of the present subsurface structure in the Kaneb area was generated by post-Cretaceous movement.

This concludes the geologic history of the Cambridge Arch and the Kaneb area as compiled from data gathered in the compilation of this report and from information received from E. C. Reed and other members of the Nebraska Geological Survey through oral communications.

STRUCTURE

Regional Structure

Red Willow and Hitchcock Counties are situated on the west flank of the Cambridge Arch, the most prominent structural feature in southwestern Nebraska. Although the Cambridge Arch in this area does not attain the structural prominence found along the arch in central and northern Nebraska, it is still the paramount structural feature associated with the accumulation of petroleum in the Kaneb area.

The regional dip on the base of the Kansas City in Red Willow County is about 18 to 20 feet per mile while in Hitchcock County the regional dip on the same horizon levels out to about 5 feet per mile.

Local Structure

The north-south trending monoclinal feature in western Red Willow County has not been named, to date, but will be referred to as the McCook Monocline for purposes of this report (Plate V). At the present time, no production is derived from or associated with the McCook Monocline. The structure does justify additional drilling, especially in the northern part of the county where faulting may exist.

As contoured on the base of the Kansas City, the Ackman Field shows a maximum closure of 35 feet while the Sleepy Hollow and all other fields in the two-county area show lesser amounts of closure

(Plates V and VI). Development drilling has shown sharp reverse dip along the east sides of both the Sleepy Hollow and Ackman Fields. Based on well-log correlations, no evidence of faulting has been detected along the east sides of these two fields. It is quite possible, however, that faulting may exist and that this anomalous steep dip is a reflection of such faulting. The structure of these fields is associated with movement along the Cambridge arch and can be compared to an anticlinorium-type feature.

Origin of Local Structures

Localized structural features, such as Ackman and Sleepy Hollow, may be the result of draping over Precambrian knobs (Larson, 1962). It seems more logical, however, to assume that these small structures were being formed concurrently with the larger deformational adjustments relating to the Cambridge Arch.

An isopach map (M. P. Carlson, unpublished) of the interval, from the top of the Permian Stone Corral to the top of the Pennsylvanian Lansing-Kansas City, shows a rather abrupt increase in thickness of the interval along the east sides of both the Ackman and Sleepy Hollow Fields. This phenomenon may be interpreted as indicating a continued basement adjustment during Permian sedimentation, along zones of weakness on the east flanks of these localized structures. From a regional isepach standpoint, these isolated interruptions of the regional thickening rate of this Permian interval from the northwest to the southeast offer evidence of structure. As an increase in the thickness of the isopach

interval on both sides of an elevated feature would be anticipated where draping occurs, it would seem that the draping origin could be ruled out. In addition, the increased number of fractures within the Lansing-Kansas City Limestones over these localized structures, as compared with the number of fractures found in these limestones off structure, seems to refute the application of a draping concept.

RELATIONSHIP OF STRUCTURE AND STRATIGRAPHY TO PETROLEUM ACCUMULATION

Oread-Lansing-Kansas City Interval

The alternating shales and limestones of the Oread-Lansing-Kansas City interval in southwestern Nebraska indicate depositional conditions of recurrent transgressing and receding shallow seas.

It is believed by some (Larson, 1962, and others) that fossil detrital build-ups occurred over micro-topographic features (3 to 10 feet of relief) on the Pennsylvanian sea floor and that such micro-topographic highs would have been attractive to carbonate-secreting organisms which were seeking more light, warmer waters, and near-surface plankton food supply. Thus, organic build-ups over these features would very likely have occurred.

A number of facts seem to refute this idea: (1), the fossil content is predominantly composed of fusulinids which are not known to be localized on micro-topographic highs or in reef-type deposits; (2), the fossil content is just as abundant off-structure as on-structure; and (3), some structurally well located tests have encountered a tight, impermeable, unproductive Oread-Lansing-Kansas City section.

Judging from the cores, most of the permeability in the Oread-Lansing-Kansas City is due to fractures and vugs but some permeability is contributed by fossil detritus. The vugs are due to water infiltration and the fractures are probably associated

with the tectonic movements along the Cambridge Arch. It appears that the optimum depositional and post-depositional conditions of proper environment, source material, tectonics, structure, fracturing, and water infiltration are harmoniously combined in the fields producing from the Oread-Lansing-Kansas City limestones.

Because of the lithologic nature of the limestones and the thinness of the intervening shales, it is concluded that the oil accumulations within the Oread-Lansing-Kansas City are indigenous to these beds in the two-county area.

Basal Sand

This sand body is usually referred to as basal sand or Sleepy Hollow sand and occurs at a stratigraphic position which could allow it to be called either Cambrian Reagan or basal Pennsylvanian. Wherever the sand is encountered it is always located between the Pennsylvanian Cherokee and the Precambrian surface. The sand consists entirely of medium to fine sand grains which are frosted, pitted, and well rounded. The only occurrence of the basal sand, other than in the Sleepy Hollow Field and a few Silver Creek wells, is in a wildcat location (C-SE-NE, Sec. 25, T4N, R28W) drilled 5 miles northwest of the Sleepy Hollow Field. Here the sand is unproductive and differs slightly from that of the Sleepy Hollow and Silver Creek in that the grains are slightly more angular, finer, and a small portion of them are cemented by pyrite. The grains are, however, frosted and pitted and the sand is stratigraphically equivalent to that of the Sleepy Hollow and Silver

Creek by electric log correlation. There is no faunal evidence within the sand in the Sleepy Hollow and Silver Creek wells but the sand from the wildcat location mentioned above is fossiliferous, containing fusulinids, crinoid columnals, and brachiopod shell fragments, some of which are slightly pyritized and many of which have pyrite crystals attached to them. Because of the partially pyritized fossils in the wildcat location, and the reworked appearance of the sand wherever it is encountered, it seems logical to correlate the sand as basal Pennsylvanian rather than Cambrian Reagan. It is unlikely that Reagan Sand would have survived the late Mississippian diastrophism in these isolated spots so near the crest of the Cambridge Arch. It seems probable, however, that the exposed area of the Reagan present on the west flank of the arch was the source for the basal sand. In other words, the basal sand, wherever it occurs, appears to be reworked Reagan and seems to have been reworked in early Pennsylvanian time. Also, it is probably correct to assume that the sand body was deposited as an off-shore bar or in a micro-topographic low.

HISTORY OF THE PETROLEUM INDUSTRY IN THE KANEB AREA

In July of 1956, M. J. Lebsack brought in Barger No. 1 in the northwest corner of Red Willow County for an initial production of 240 BOPD from the Lansing-Kansas City Limestones. As offsets were developed, the pool became known as the Barger Field. This was the first production along the west flank of the Cambridge Arch in southwestern Nebraska and helped to direct the interest of operators to that area. In 1957, fifteen tests were drilled in Dundy, Hayes, Red Willow and Furnas Counties. Only two of the tests proved to be productive, the Jones No. 1 in Dundy County was completed for 20 BOPD from the Lansing-Kansas City Group and the Poore No. 1 in Red Willow County produced 60 BOPD from the same horizon. The Poore Field, to date, remains a one-well field. In 1958, Skelly Oil Company's Lewis No. 1 became the discovery well of the Reiher Field in Hitchcock County. This well had an initial production of 143 BOPD from the Lansing-Kansas City. At that time, none of these fields offered much encouragement, either in regard to ultimate recovery or for future exploration. The Cahoj Field, just across the Kansas-Nebraska border in Rawlins County, Kansas, was discovered early in 1959. This field produced from multiple zones in the Lansing-Kansas City Group as well as from the Oread Limestone. The discovery of the Ackman Field late in 1959, along with the Cahoj Field, offered the first real incentive in the Kaneb area and encouraged exploration to the extent that the Kaneb area became known as one of the "hottest"

drilling spots in the United States by the end of 1960. The Sleepy Hollow Field, discovered in 1960, ranks economically as the most important field in the entire Kaneb area. Other fields that were discovered as a result of successful exploration at Cahoj, Ackman, and Sleepy Hollow, include Silver Creek, Midway, Zenith, Reiher, Culbertson, Driftwood, and a few more fields as yet unnamed. Most of the oil produced in these fields comes from the Lansing-Kansas City. The Sleepy Hollow Field also produces from the basal sand as well as from the Lansing-Kansas City. Silver Creek Field, which has some basal sand production, is productive primarily from several zones in the Lansing-Kansas City. The Reiher Field has prolific production from the Oread as well as the Lansing-Kansas City.

DEVELOPMENT AND COMPLETION PRACTICES

The Nebraska Conservation and Survey Division requires 40-acre spacing of all wells producing from the same horizon below a depth of 2,500 feet. Since the wells in southwestern Nebraska range from 3,500 to 5,000 feet, they are all drilled on 40-acre locations.

From 150 to 400 feet of 7 inch, 8 5/8 inch or 9 5/8 inch surface casing is set through the Ogallala and 4½ inch or 5½ inch casing is set to the bottom and perforated. Normally, 2 inch or 2⅛ inch tubing is used in the production string. For Oread-Lansing-Kansas City Limestone production the wells are usually acidized, sometimes with as much as 3,000 gallons. On wells with a potential production from both the basal sand and the limestones, two types of dual completion are in practice, one using two strings of casing, the other using 7 inch casing and parallel tubing. Some of the locations in the Sleepy Hollow Field have twin wells, the Lansing-Kansas City well being off-set 50 to 150 feet from the basal sand well. The reason for drilling twin wells is not known by the author. A suggested explanation is that in the event of a breakdown in one well the remaining well could continue production from the second horizon but this seems somewhat illogical because of the economic factors involved in drilling a second well. In all but one or two of these twin-well locations, the basal sand well preceeded the Lansing-Kansas City well. It can be assumed that, in the early stages of the development of the Sleepy Hollow Field, production from the Lansing-Kansas City had probably been over-

looked after encountering the prolific basal sand. After production from the Lansing-Kansas City was realized, the 4½ inch or 5½ inch casing in the initial wells was too small for dual completion and therefore twin wells had to be drilled.

Electrical and induction logs are the ones most commonly used in the Kaneb area. These logs are made from total depth to surface casing. Sometimes a micro log or caliper gamma-ray sonic log is made from total depth to the top of the Pennsylvanian. Gamma-ray neutron logs are made by some operators after running the completion string.

FUTURE POSSIBILITIES OF THE KANEB AREA

The future of petroleum in the Kaneb area looks excellent. Further subsurface mapping on the base of the Kansas City and other horizons could reveal, on the west flank of the Cambridge Arch, more structures such as Sleepy Hollow, Ackman, and Silver Creek. Such additional structures would most likely be found to the north of the present fields, probably in Frontier County. The Pennsylvanian Cherokee Shale overlies Mississippian, Cambro-Ordovician Arbuckle, and Cambrian Reagan beds, and Precambrian granite in that order from the west (Fig. 2). Mapping the surface of this angular unconformity at the base of the Cherokee Shale could disclose some excellent traps in the Reagan to the north of Red Willow County where the Cambridge Arch becomes more prominent. Whether or not these traps contain hydrocarbons would have to be verified by an exploration drilling program. The granite wash which overlies so much of the Precambrian granite in this two-county area has good reservoir characteristics and could contain petroleum where there is entrapment.

Additional drilling in the northern portion of the McCook Monocline is certainly justifiable. Whatever reserves might be found at the northern end of this structure would be small in areal extent but the probable longevity of the wells and the prolificness with which they might produce could well off-set the cost of an exploration drilling program

Drilling in Hitchcock County has been very sparse and in

most areas insufficient for good structural control. With a drilling program such as the one that covered Red Willow County, Hitchcock County may prove to have comparable reserves.

Secondary recovery by water flooding is anticipated by producers operating in the Sleepy Hollow Field. Producers operating in other fields in the Kaneb area will probably incorporate a similar recovery method as the need for such a program rises.

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APPENDIX

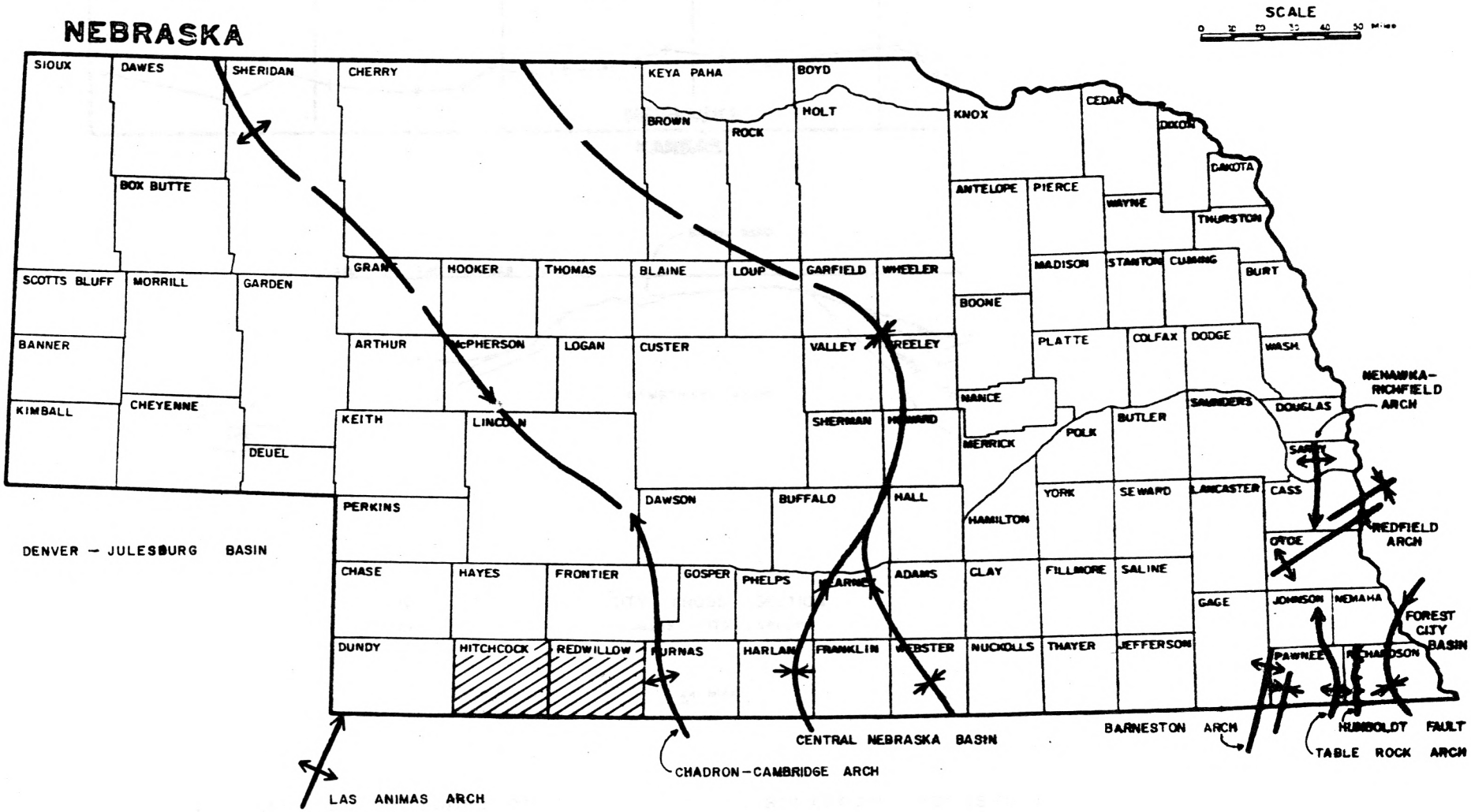


Fig. 1. Major geologic structures in Nebraska.

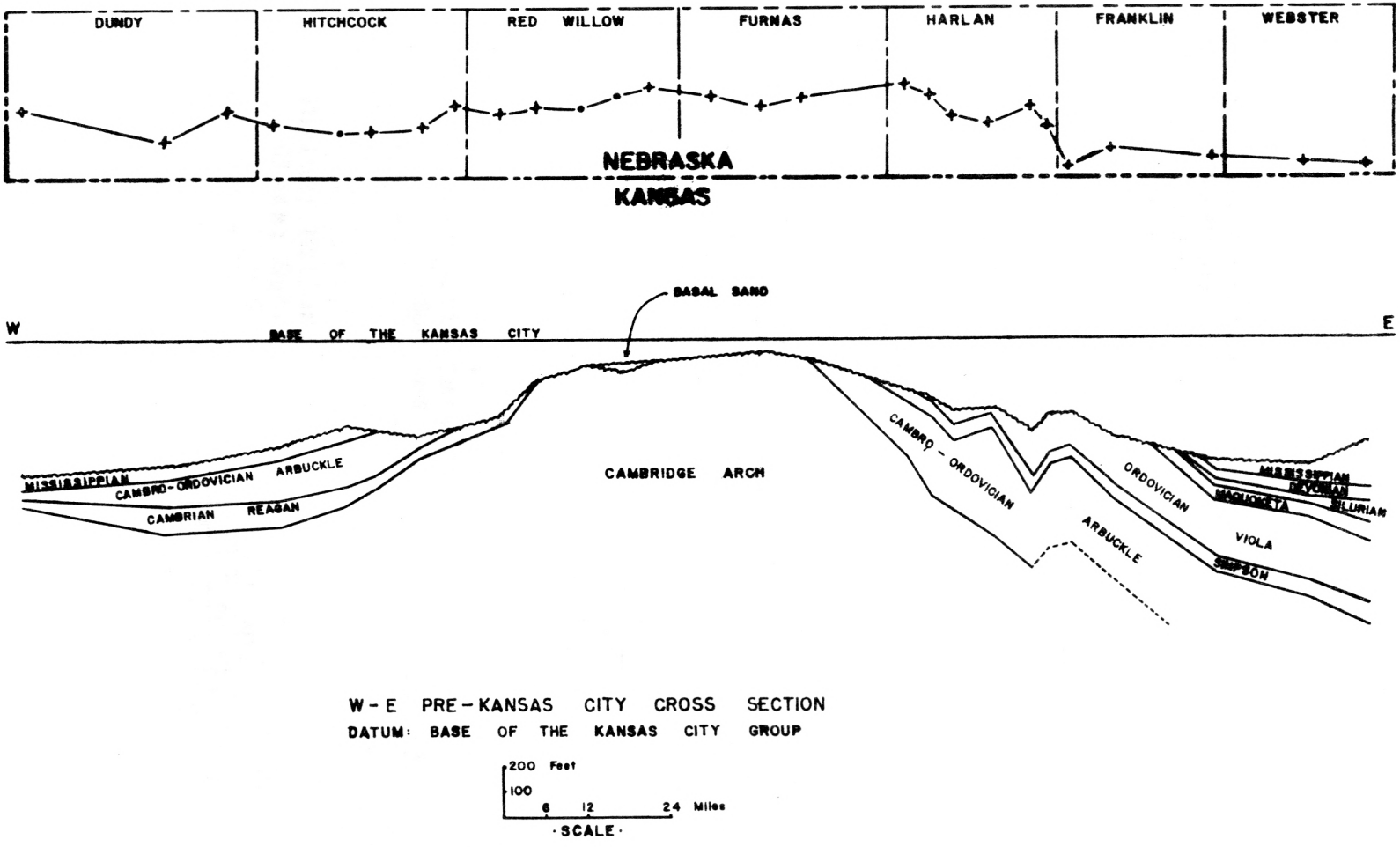


Fig. 2. West-east regional cross section in southern Nebraska showing stratigraphic relationships at the beginning of Kansas City deposition.

Table 1

TAXONOMY OF THE FOSSILS STUDIED

Phylum: Protozoa
Class: Sarcodina
Order: Foraminiferida
Family: Fusulinidae
Species: *Triticites* sp.
Fusulinella meeki
Fusulinella haworthi

Phylum: Bryozoa
Class: Gymnolaemata
Order: Cryptostomata
Species: *Rhombopora lepidodendroides*
Rhabdomeson sp.

Phylum: Echinodermata
Subphylum: Pelmatozoa
Class: Crinoidea

Phylum: Arthropoda
Subphylum: Crustacea
Class: Ostracoda
Species: *Bairdia* sp.
Ellipsella ampla
Jonesina craterigera

Phylum: Brachiopoda
Class: Inarticulata
Species: *Ambocoelia expansa*
Class: Articulata
Species: *Composita subtilita*
Composita sp.
Chonetina sp.

Phylum: Mollusca
Class: Gastropoda
Species: *Worthenia* sp.
Leptoptygma sp.
Gyrodes abyssina
Straparolus sp.
Euomphalus sp.
Amphiscapha sp.
Serpulospira sp.
Bucanopsis modesta
Class: Cephalopoda

Table 2

FOSSIL COUNT AND PERCENTAGES

Red Willow County

C - NW - SW
Sec. 27 - 3N - 27W

SHAWNEE GROUP	Number	Percent
Brachiopods (3 exfoliated *Composita*)	3	15.0
Cephalopods (?)	2	10.0
Crinoid columnals	1	5.0
Fusulinids	12	60.0
Gastropods (1 *Straparolus*)	1	5.0
Ostracodes (1 *Bairdia*)	1	5.0
	20	

LANSING-KANSAS CITY GROUP		
Brachiopods (3 *Ambocoelia*) (1 exfoliated *Composita*) (1 *Composita subtilita*)	5	4.6
Bryozoans (1 *Rhabdomeson*)	1	0.9
Cephalopods (?)	2	1.9
Crinoid columnals	22	20.4
Fusulinids	64	59.2
Gastropods (2 *Leptoptygma*)	2	1.9
Ostracodes (4 *Bairdia*) (1 male & 1 female *Ellipsella*)	6	5.6
Unidentified fragments	6	5.6
	108	

MARMATON-CHEROKEE GROUP (Not penetrated)

Table 3

FOSSIL COUNT AND PERCENTAGES

Red Willow County

SW - SW - SE
Sec. 11 - 2N - 28W

SHAWNEE GROUP	Number	Percent
Brachiopods	1	20.0
Bryozoans (1 Rhombopora)	1	20.0
Fusulinids	2	40.0
Ostracodes (1 Bairdia)	1	20.0
	5	

LANSING-KANSAS CITY GROUP		
Brachiopods (5 Ambocoelia)	5	8.8
Bryozoans (2 Rhombopora)	2	3.5
Cephalopods (?)	2	3.5
Crinoid columnals	9	15.8
Fusulinids	31	54.4
Gastropods (1 Leptotyrma)	1	1.8
Unidentified fragments	7	12.3
	57	

MARMATON-CHEROKEE GROUP (Not penetrated)

Table 4

FOSSIL COUNT AND PERCENTAGES

Red Willow County — C - SE - NW Sec. 17 - 4N - 29W

SHAWNEE GROUP	Number	Percent
Bryozoans (1 *Rhombopora*)	1	5.6
Cephalopods (?)	1	5.6
Crinoid columnals	12	66.6
Fusulinids	1	5.6
Ostracodes (1 *Bairdia*)	1	5.6
Unidentified fragments	2	11.1
	18	

LANSING-KANSAS CITY GROUP		
Brachiopods (1 *Ambocoelia*)	1	0.4
Bryozoans (5 *Rhombopora*)	5	2.1
Cephalopods (?)	3	1.3
Crinoid columnals	53	22.5
Fusulinids	157	66.5
Gastropods (1 *Worthenia* ?)	2	0.8
Ostracodes (5 *Bairdia* (3 male & 1 female *Ellipsella*)	9	3.8
Unidentified fragments	6	2.5
	236	

MARMATON-CHEROKEE GROUP		
Brachiopods (2 *Ambocoelia*)	2	1.2
Bryozoans (5 *Rhombopora*)	5	3.1
Cephalopods (?)	3	1.9
Crinoid columnals	81	50.3
Fusulinids (14 *Fusulinella meeki*)	54	33.5
Ostracodes (7 *Bairdia* (2 male & 1 female *Ellipsella*)	10	6.2
Unidentified fragments	6	3.7
	161	

Table 5

FOSSIL COUNT AND PERCENTAGES

Hitchcock County

C - NE - NE
Sec. 36 - 1N - 32W

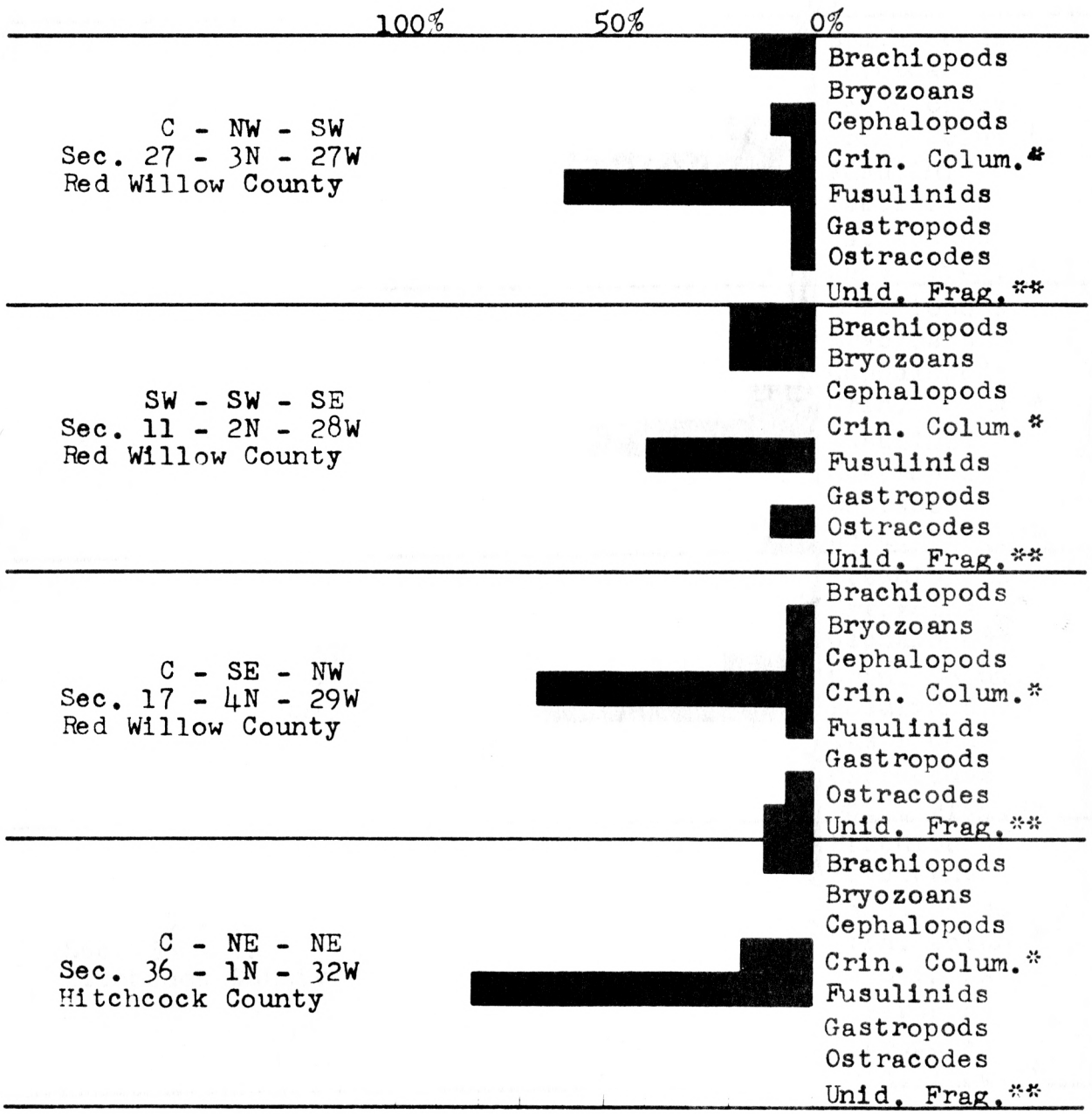
SHAWNEE GROUP	Number	Percent
Brachiopods (7 *Ambocoelia*)	7	11.1
Crinoid columnals	5	7.9
Fusulinids	51	81.0
	63	

LANSING-KANSAS CITY GROUP		
Brachiopods (6 *Ambocoelia*)	6	12.0
Bryozoans (2 *Rhombopora*)	2	4.0
Crinoid columnals	10	20.0
Fusulinids	23	46.0
Gastropods (1 *Bucanopsis*)(1 *Leptoptygma*)	2	4.0
Ostracodes (1 *Ellipsella*)(1 *Jonesina*)	2	4.0
Unidentified fragments	5	10.0
	50	

MARMATON-CHEROKEE GROUP		
Brachiopods (12 *Ambocoelia*)(2 *Chonetina*)	14	23.3
Bryozoans (5 *Rhombopora*)	5	8.3
Crinoid columnals	9	15.0
Fusulinids (4 *Fusulinella meeki*)	23	38.3
Gastropods	1	1.7
Ostracodes (1 *Bairdia*)(1 female *Ellipsella*)	2	3.3
Unidentified fragments	6	10.0
	60	

Table 6

PERCENTAGE GRAPH OF SHAWNEE GROUP FOSSILS

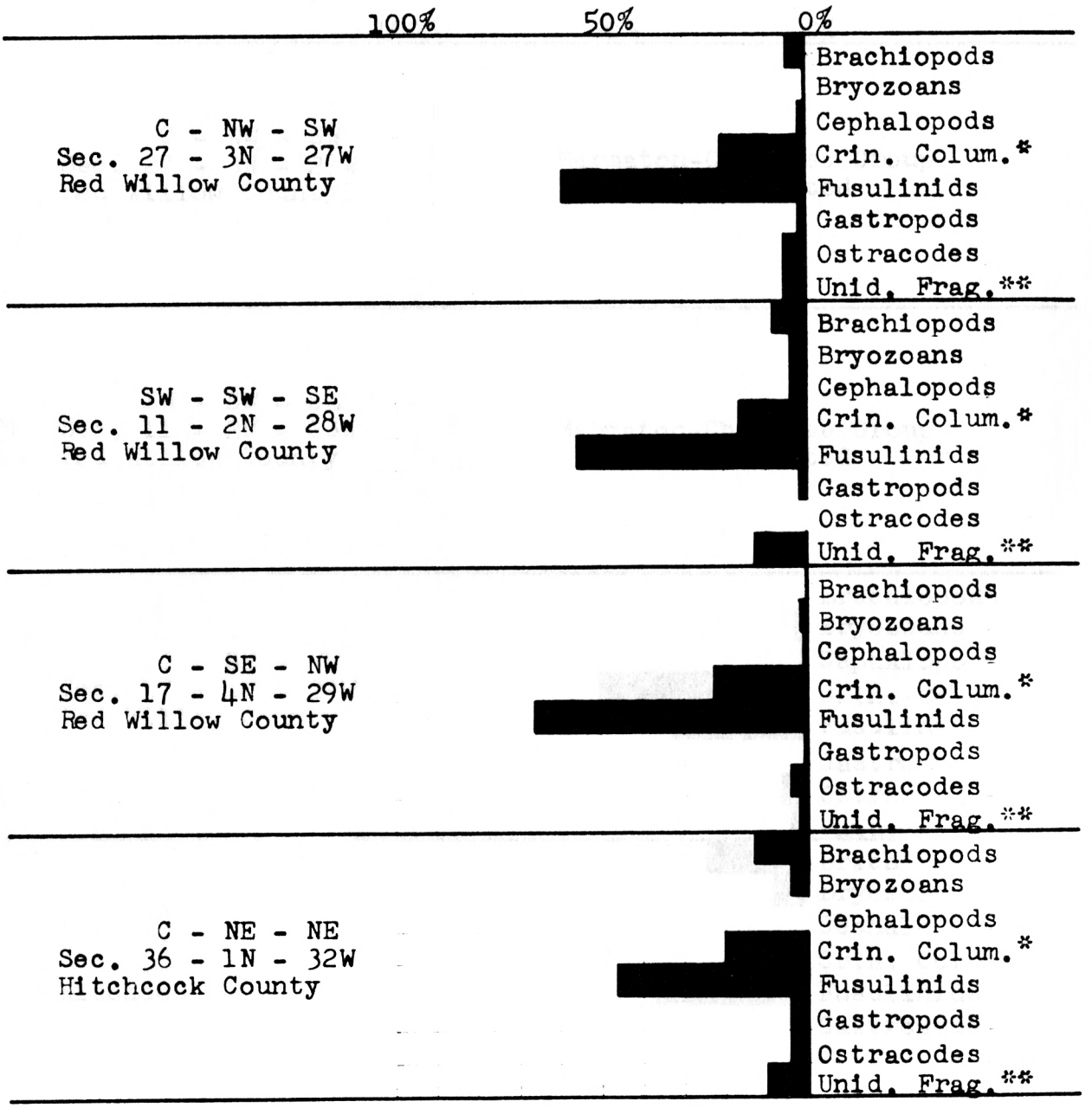


* Crinoid Columnals

** Unidentified Fragments

Table 7

PERCENTAGE GRAPH OF LANSING-KANSAS CITY GROUP FOSSILS

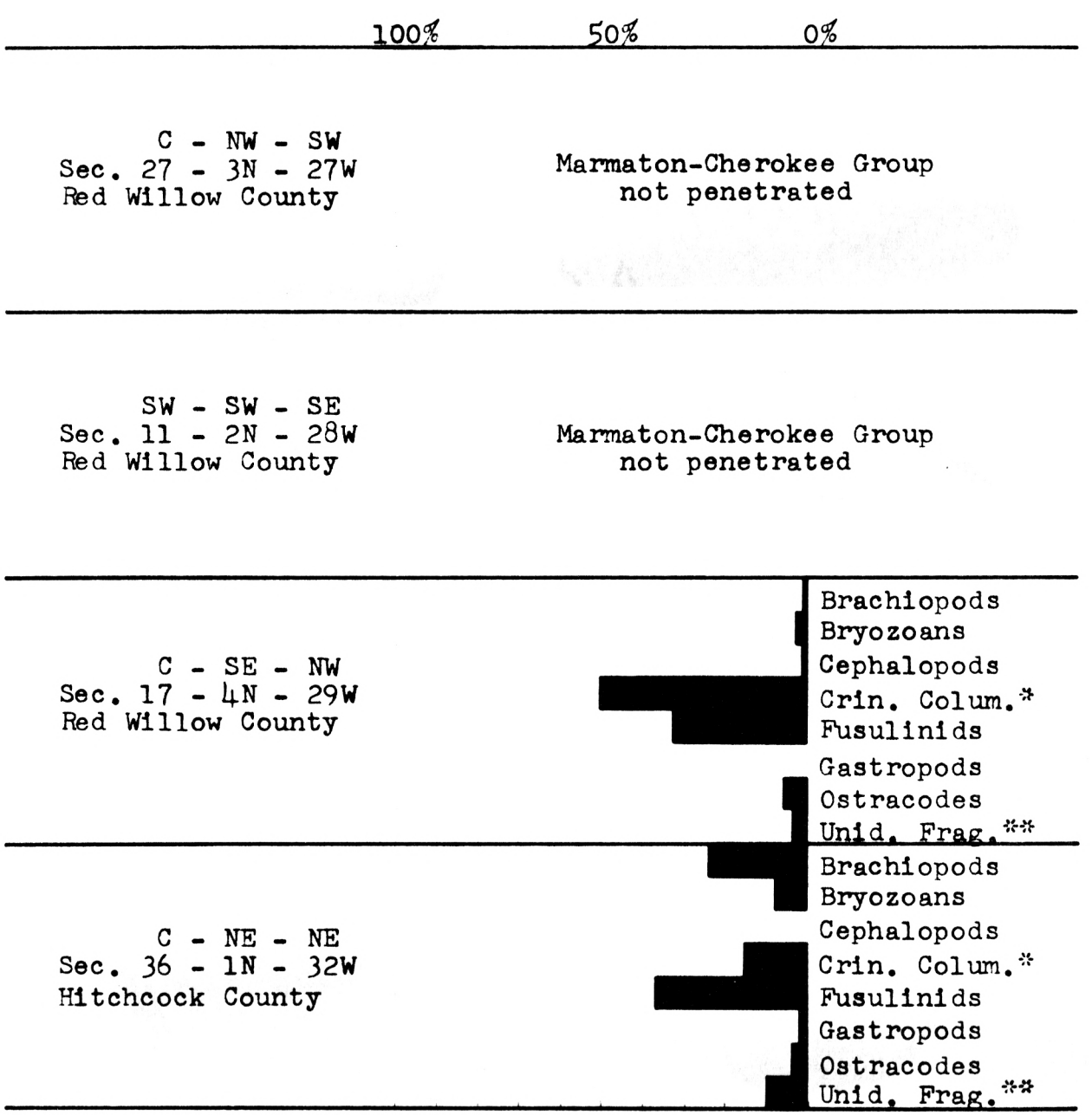


* Crinoid Columnals

** Unidentified Fragments

Table 8

PERCENTAGE GRAPH OF MARMATON-CHEROKEE GROUP FOSSILS

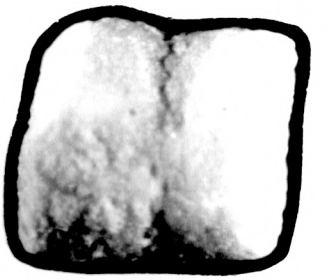


* Crinoid Columnals

** Unidentified Fragments

SHAWNEE GROUP FOSSILS PLATE I

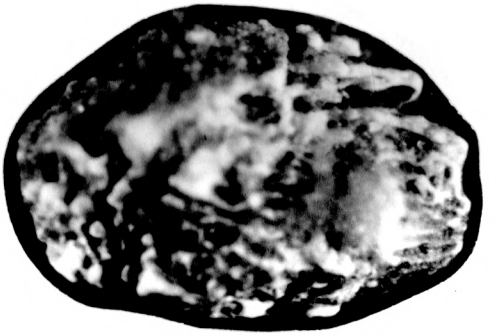
Triticites (X31)



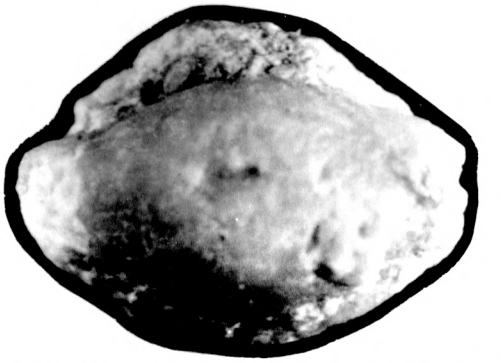
Crinoid (X27)

Rhombopora (X17)

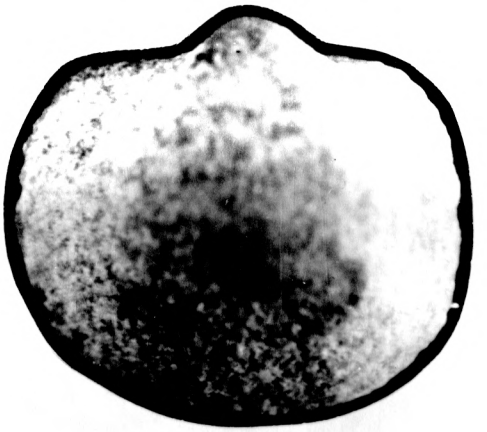
Cephalopod (X30)



Triticites
(oil stained, X34)



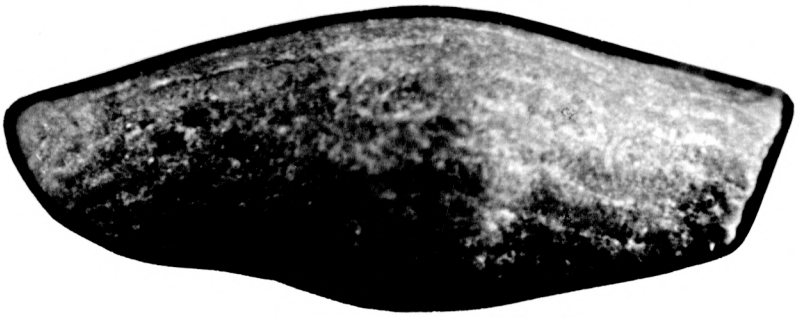
Fusulinella haworthi (X30)



Ambocoelia
(pedicle view, X30)

Ambocoelia
(pedicle view, X31)

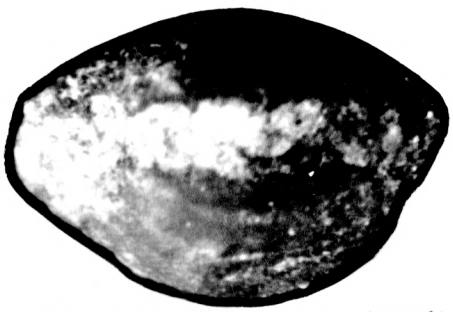
LANSING-KANSAS CITY GROUP FOSSILS PLATE II



Triticites (X41)

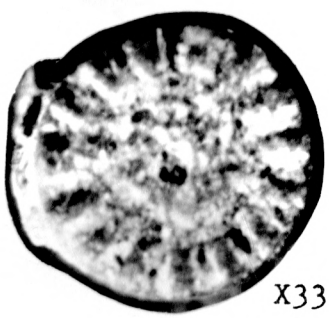
Triticites
(oil stained, X31)

Ambocoelia
(pedicle view, X9)

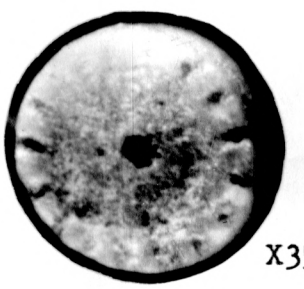


Fusulinella haworthi (X35)

Ambocoelia
(brachial view, X7)



X33



X35

X9

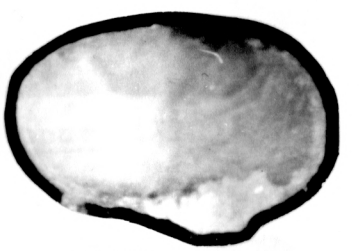
Crinoids

LANSING-KANSAS CITY GROUP FOSSILS PLATE III

Bairdia
(right valve, X42)

Bairdia
(left valve, X42)

Bairdia
(dorsal view, X42)

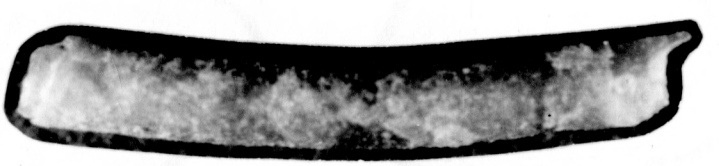


Ellipsella
(right valve, X42)

Rhombopora
(X10)

Worthenia ? (X37)

Composita
(exfoliated, X10)



Cephalopod (X30)

MARMATON-CHEROKEE GROUP FOSSILS PLATE IV

Bairdia
(right valve, X27)

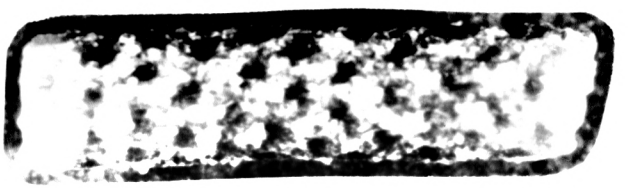
X13

X27

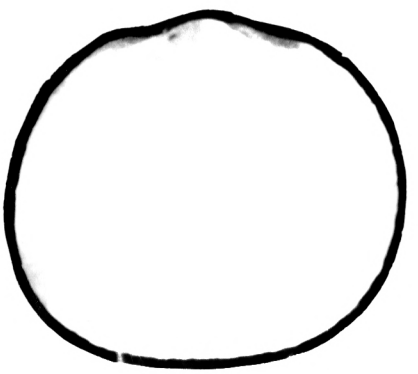
Crinoids

X7

Ellipsella
(right valve, X40)



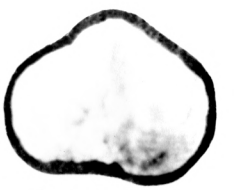
Rhombopora (X100)



Amboccelia
(pedicle view, X28)

Amboccelia
(pedicle view, X10)

Chonetina
(pedicle view, X9)



Chonetina
(pedicle view, X9)

Fusulinella meeki (X52)

Fusulinella meeki (X44)

PLATE V. Subsurface structural map of Red Willow County.

PLATE V

RED WILLOW COUNTY, NEBRASKA

R 30 W | R 29 W | R 28 W | R 27 W | R 26 W

T 4 N | T 3 N | T 2 N | T 1 N

BARGER FIELD

INDIANOLA

BARTLEY

SLEEPY HOLLOW FIELD

McCOOK

ACKMAN FIELD

SILVER CREEK FIELD

POORE FIELD

DANBURY

MIDWAY FIELD

LEGEND

- Location
- Oil Well
- Abandoned Oil Well
- Dry Hole
- Water Disposal Well

STRUCTURAL CONTOUR MAP
ON THE BASE OF THE KANSAS CITY GROUP

Scale: 1 inch = 1 mile

Contour Interval: 10 Feet

Datum: Sea Level

JAN. 7, 1964

N

Ed Sander

PLATE VI. Subsurface structural map of Hitchcock County.

PLATE VI

HITCHCOCK COUNTY, NEBRASKA

R 35 W | R 34 W | R 33 W | R 32 W | R 31 W

T 4 N | T 3 N | T 2 N | T 1 N

PALISADE

STRATTON

TRENTON

HUDSON FIELD

DRIFTWOOD FIELD

CULBERTSON

CULBERTSON FIELD

REIHER FIELD

STRUCTURAL CONTOUR MAP
ON THE BASE OF THE KANSAS CITY GROUP

LEGEND

- Location
- Oil Well
- Abandoned Oil Well
- Dry Hole
- Water Disposal Well

Scale: 1 inch = 1 mile

Contour Interval: 10 Feet

Datum: Sea Level

JAN. 7, 1964

N

Ed Sander

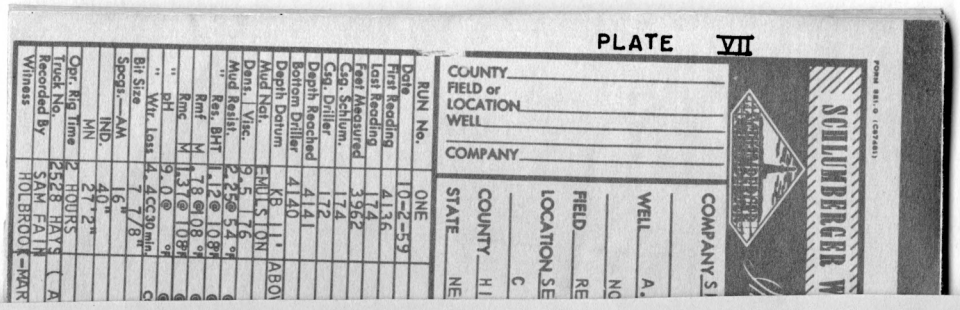


PLATE VII

SCHLUMBERGER W

COMPANY S.

WELL A.

NO

FIELD RE

LOCATION SE

C

COUNTY HI

STATE NE

COUNTY
FIELD or
LOCATION
WELL
COMPANY

RUN No.	ONE
Date	10-2-59
First Reading	4136
Last Reading	174
Feet Measured	3962
Csg. Schlum.	174
Csg. Driller	172
Depth Reached	4141
Bottom Driller	4140
Depth Datum	KB 11' ABO
Mud Nat.	EMULSION
Dens. Visc.	9.5 46
Mud Resist.	2.25@ 54 °F
" Res. BHT	1.12@ 108°F
Rmf M	78@108°F
Rmc M	1.37@ 108°F
" pH	9.0@ °F
" Wtr. Loss	4.4CC/30 min
Bit Size	7 7/8
Spsg.—AM	
IND.	16"
	40"
	27"2"
MN	
Opr. Rig Time	2 HOURS
Truck No.	2528 HAYS (A
Recorded by	SAM FAIN
Witness	HOLBROOK-MAR

FORM 681-0 (CS7465)

PLATE VII. Electric well log.

The following well log is presented in 9 sections for ease of delivery.

Section 1

FORM 521. G (CS7481)

SCHLUMBERGER WELL SURVEYING CORPORATION

HOUSTON, TEXAS

Induction-Electrical Log

COMPANY SKELLY OIL CO.

WELL A.O. NEWPORT NO. 2

FIELD REIHER

LOCATION SEC. 28-1N-32W C SW NE

COUNTY HITCHCOCK

STATE NEBRASKA

Other Surveys: SGR/ML

Location of Well

Elevation: D.F., K.B. 2832 or G.L. 2821

FILING No. 35,036

COUNTY / FIELD or LOCATION / WELL / COMPANY

FOLD HERE

RUN No.	ONE					WLB
Date	10-2-59					
First Reading	4136					
Last Reading	174					
Feet Measured	3962					
Csg. Schlum.	174					
Csg. Driller	172					
Depth Reached	4141					
Bottom Driller	4140					
Depth Datum	KB 11' ABOVE GL					
Mud Nat.	EMULSION					
Dens. / Visc.	9.5 / 76					
Mud Resist.	2.25@54 °F	@ °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	1.12@109°F	@ °F	@ °F	@ °F	@ °F	@ °F
Rmf M	1.79@108 °F	@ °F	@ °F	@ °F	@ °F	@ °F
Rmc M	1.37@109°F	@ °F	@ °F	@ °F	@ °F	@ °F
" pH	9.0@ °F	@ °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	4.4 CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"					
Spcgs.—AM	16'					
IND.	40"					
MN	2'2"					
Opr. Rig Time	2 HOURS					
Truck No.	2528 HAYS (ATWOOD)					
Recorded By	SAM FAIN					
Witness	HOLBROOK-MARTZ					

REMARKS. C.D. USED S.O. 17211

Corridge No. 251
Panel No. 213
Sonde No. 232

CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m

INDUCTION 0 500 1000 1500

RESISTIVITY -ohms. m²/m

16" NORMAL 0 50 500

INDUCTION 0 50 500

DEPTHS

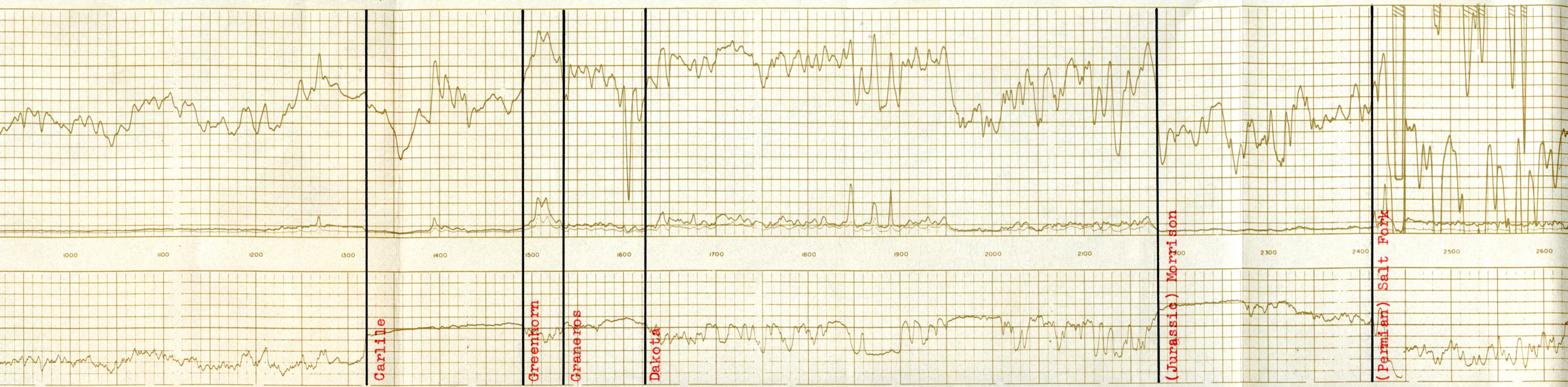
SPONTANEOUS POTENTIAL millivolts

0300 0400 0500 0600 0700 0800 0900 1000 1100 1200

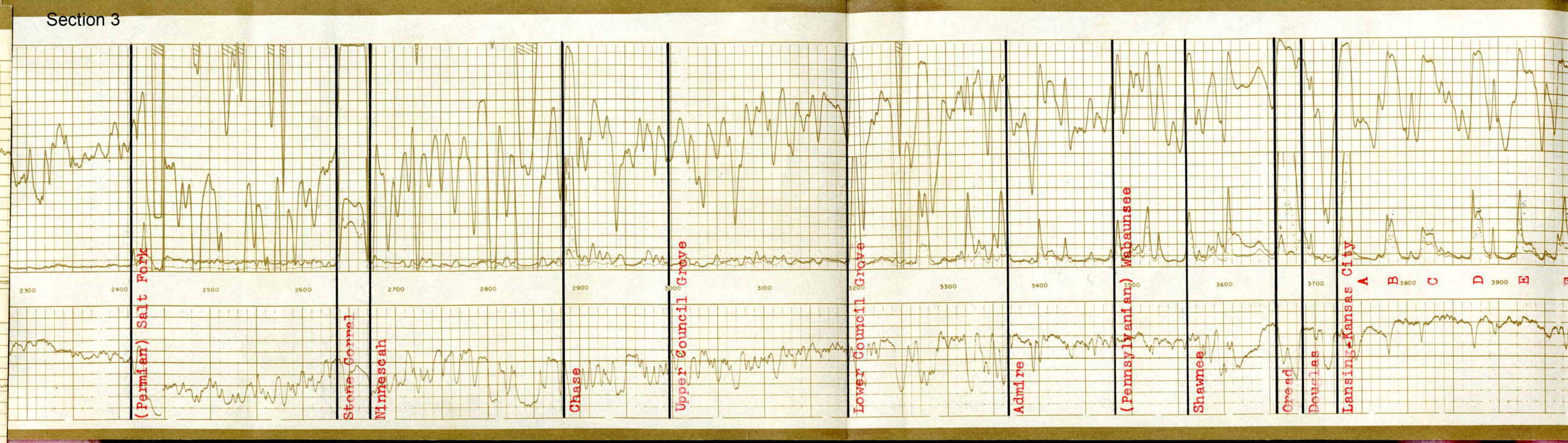
(Cretaceous) Pierre

Niobrara

Section 2


1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Carlile
Greenhorn
Graneros
Dakota
(Jurassic) Morrison
(Permian) Salt Fork

Section 3


2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
(Permian) Salt Fork
Stone Corral
Ninnescah
Chase
Upper Council Grove
Lower Council Grove
Admire
(Pennsylvanian) Wabaunsee
Shawnee
Oread
Douglas
Lansing-Kansas City
A
B
C
D
E

Lansing-Kansas City

A
B
3800
C
D
3900
E
F
4000

BKC

Marmaton

4100

16" NORMAL
0 50
0 500
INDUCTION
0 50
0 500

RESISTIVITY
-ohms. m²/m

INDUCTION
1000 500 0
1500 1000

15

SPONTANEOUS-POTENTIAL
millivolts

DEPTHS

CONDUCTIVITY
millimhos/m = 1000 / ohms. m²/m

COMPANY SKELLY OIL CO.
WELL A.O. NEWPORT NO. 2
FIELD REITHER
COUNTY HITCHCOCK STATE NEBRASKA

SWSC FR 4136
SWSC TD 4141
DRLR TD 4140
Elev:
KB 2832
DF
GL 2821

DETAIL LOG
5" = 100'

SPONTANEOUS-POTENTIAL
millivolts

DEPTHS

CONDUCTIVITY
millimhos/m = 1000 / ohms. m²/m

INDUCTION
1000 500 0
1500 1000

15

RESISTIVITY
-ohms. m²/m

16" NORMAL
0 50
0 500
INDUCTION
0 50
0 500

3300

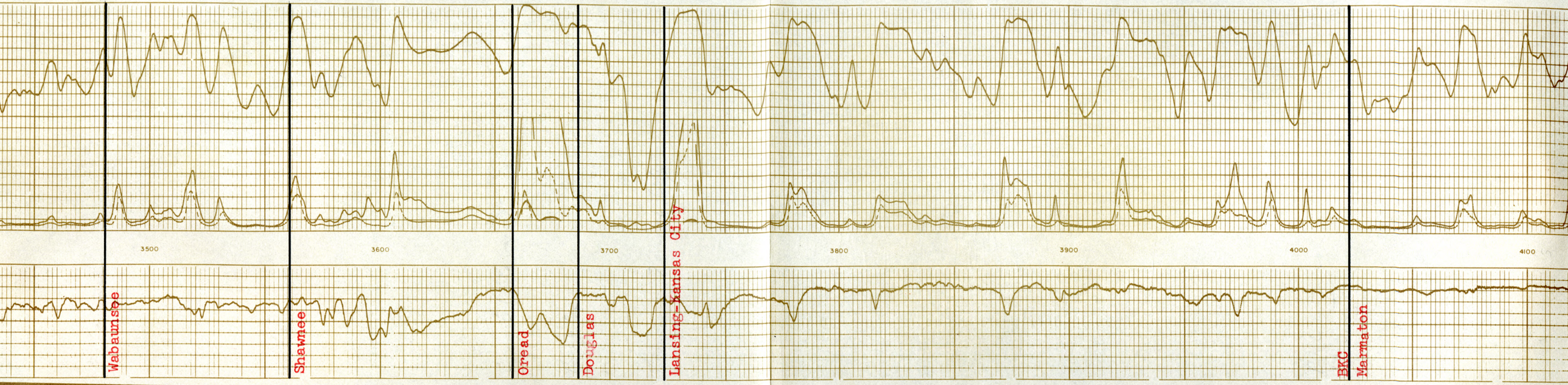
Admire

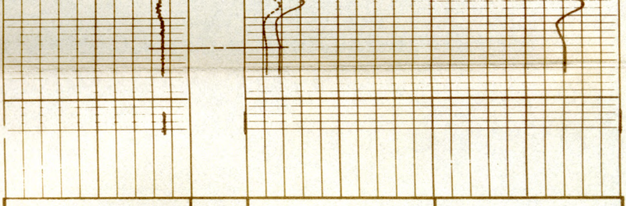
3400

Wabaunsee

3500

Section 5


3500
3600
3700
3800
3900
4000
4100
Wabaunsee
Shawnee
Oread
Douglas
Lansing-Kansas City
BKC
Marmaton



16" NORMAL
0 — 50
0 — 500

INDUCTION
0 — 50
0 — 500

RESISTIVITY
-ohms. m²/m

INDUCTION
1000 — 500 — 1500 — 1000

SPONTANEOUS-POTENTIAL
millivolts

DEPTHS

CONDUCTIVITY
millimhos/m = 1000 / ohms. m²/m

COMPANY SKELLY OIL CO.
WELL A.O. NEWPORT NO. 2
FIELD REIHER
COUNTY HITCHCOCK STATE NEBRASKA

SWSC FR 4136
SWSC TD 4141
DRLR TD 4140
Elev:
KB 2832
DF
GL 2821

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3678 to 3682	.07		23,000 Sw CHART USED D-2		
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3670 to 3676	.07		23,000 Sw CHART USED D-2		
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3659 to 3654	.07		23,000 Sw CHART USED D-2		
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3709 to 3718	.055		18,000 Sw CHART USED D-2		100 %
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3743 to 3750	.055		18,000 Sw CHART USED		
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3777 to 3780	.055		21,000 Sw CHART USED		
REMARKS TOO THIN FOR Rt DETERMINATION					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3870 to 3874	.055		21,000 Sw CHART USED D-2		
REMARKS					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3921 to 3924	.055		21,000 Sw CHART USED		
REMARKS TOO THIN FOR Rt DETERMINATION					

INTERVAL	Rw	m	ROS or Vm	POROSITY	WATER SATURATION
3971 to 3975	.055		21,000 Sw CHART USED D-2		
REMARKS					

This interpretation represents our best judgment. Nevertheless, since all interpretations are opinions based solely on inferences from electrical or other measurements, we cannot and do not guarantee the accuracy or correctness of any interpretation and shall not be liable or responsible for any loss, cost damages, or expenses that may be incurred or sustained resulting from this or any other interpretation."

SCHLUMBERGER WELL SURVEYING CORPORATION

SCHLUMBERGER

Quantitative Interpretation

SWSC ONLY

1300

RECIPROCATOR
500 MMHO
50 OHM

BEFORE SURVEY

6

5

BEFORE SURVEY

6 5 4 3 2 1

4100

AFTER SURVEY

6 5 4 3 2 1

SONDE ON WOODEN HORSE
NOT PERFORMED DUE TO FOUL WEATHER.
SHF

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

SCHLUMBERGER

MICROLOGGING®

COUNTY HITCHCOCK
FIELD or LOCATION REIHER SEC. 28-IN-32W
WELL A.O. NEWPORT NO. 2
COMPANY SKELLY OIL CO.

COMPANY SKELLY OIL CO.

WELL A.O. NEWPORT NO. 2

FIELD REIHER

LOCATION SEC. 28-IN-32W SW NE

COUNTY HITCHCOCK

STATE NEBRASKA

Other Surveys
I-ES SGR

Location of Well

Elevation: D.F.:
K.B.: 2832
or G.L.: 2821

Log Depths Measured From KB 11 Ft. above GL 35036 KB

RUN No.	ONE			
Date	10-3-59			
First Reading	4140			
Last Reading	3300			
Feet Measured	840			
Depth Reached	4141			
Bottom Driller	4140			
Mud Nat.	EMULSION			
Dens. Visc.	9.5 76			
Mud Resist.	2.25 @ 54 F	@ F	@ F	@ F
" Res. BHT	1.12 @ 108 F	@ F	@ F	@ F
" pH	9.0 @ F	@ F	@ F	@ F
" Wtr. Loss	4.4 CC 30 min	CC 30 min		CC 30 min
" Rmf M	.78 @ 108 F	@ F	@ F	@ F
" Rmc M	1.37 @ 108 F	@ F	@ F	@ F
Mud Log: Rm	1.25			
Depth	3540			
Bit Size	7 7/8"			
Sonde Type	PMS-A			
Pad Type	H			
Opr. Rig Time	1-HOUR			
Truck No.	2528-HAYS (ATWOOD)			
Recorded By	SAM FAIN			
Witness	HALBROOK-MARTZ			

FOLD HERE

REMARKS

RESISTIVITY ohms. m²/m

0 Micro Inverse 1" x 1" 20 40

0 Micro Normal 2" 20 40

DEPTHS

MICROCALIPER

6 7 8 9 10 11 12 13 14 15½

Hole Diameter in Inches

BIT SIZE

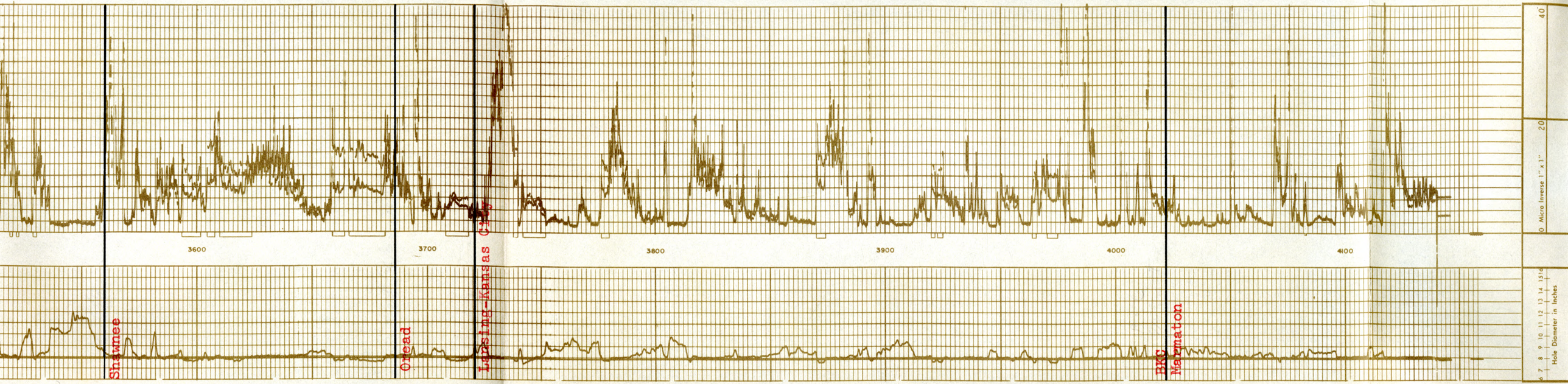
CALIPER

3300 3400 3500

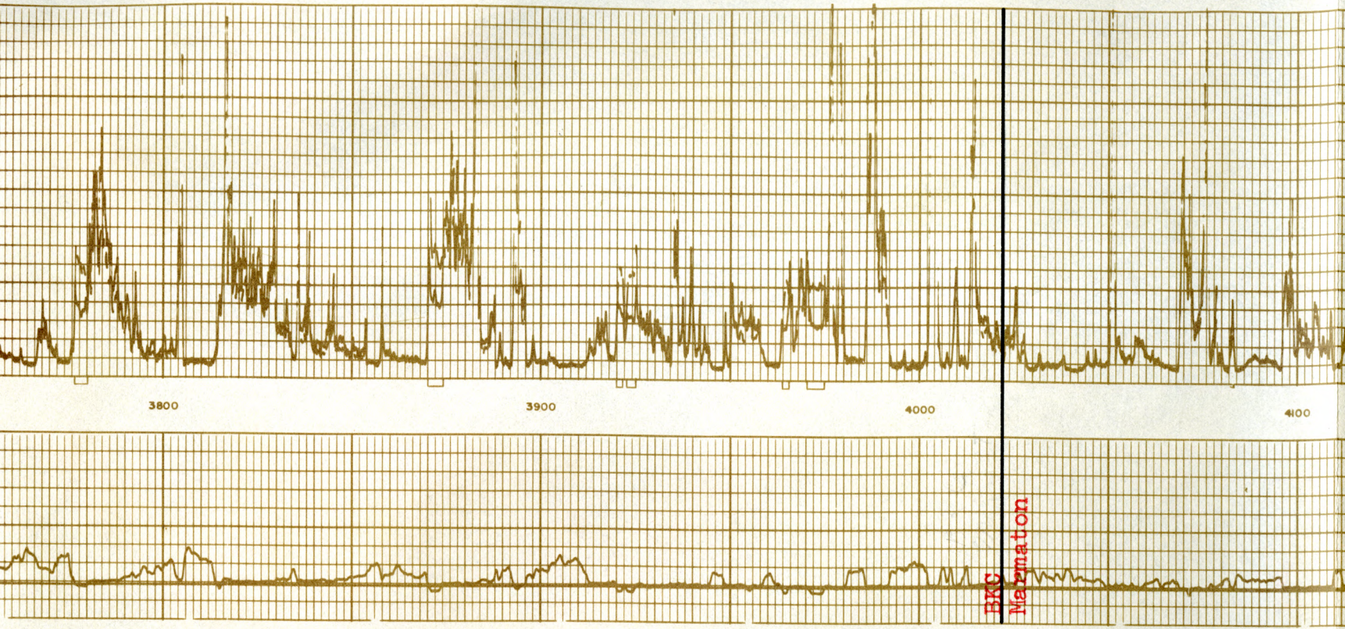
Adaire

Wabaunsee

Section 8


3600
3700
3800
3900
4000
4100
Shawnee
Oread
Lansing-Kansas City
BKC
Marmaton
0 Micro Inverse 1" x 1"
20
40
6 7 8 9 10 11 12 13 14 15 1/4
Hole Diameter in Inches

Section 9



0 Micro Inverse 1" x 1" 20
0 Micro Normal 2" 20
40
40
RESISTIVITY
ohms. m^2/m
DEPTHS
MICROCALIPER
6 7 8 9 10 11 12 13 14 15 16
Hole Diameter in Inches

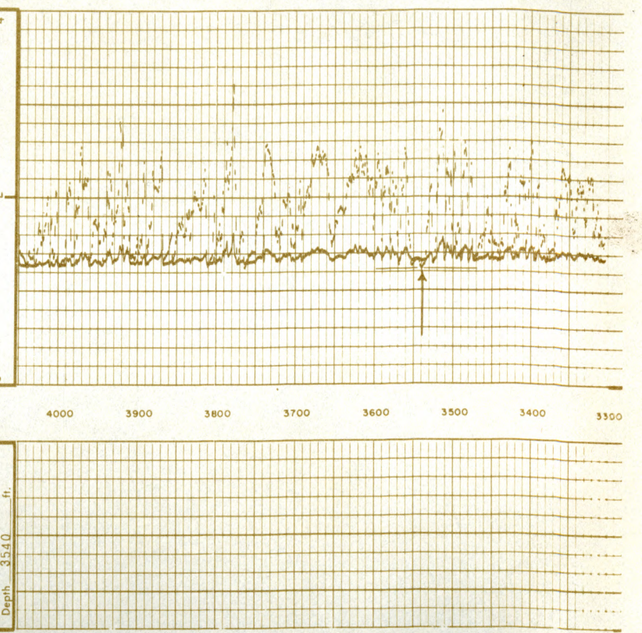
COMPANY SKELLY OIL CO.
WELL A.O. NEWPORT NO. 2
FIELD RELHER
COUNTY HITCHCOCK STATE NEBRASKA

Rm 1.12 @ 108 °F
Rmf .76 @ 108 °F
Rmc 1.37 @ 108 °F
BHT 108 °F

SWSC FR 4140
SWSC TD 4141
DRLR TD 4140
Elev.: KB 2832
DF
GL 2821

SURVEY WITH SONDE COLLAPSED

Apparent Rm 1.25 Ω m² m
Depth 3540 ft.



SUBSURFACE GEOLOGY OF RED WILLOW AND HITCHCOCK COUNTIES, NEBRASKA

by

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ABSTRACT

The purpose of this thesis is to determine the subsurface structure, stratigraphy, and geologic history of Red Willow and Hitchcock Counties, Nebraska, to relate these geological factors to the accumulation of petroleum in this section of the Kaneb area, and to provide a basis for outlining future drilling locations. Data on the development and completion practices in this two-county area are also included so as to provide a guide for production companies unfamiliar with the procedures in this region.

In the Red Willow and Hitchcock County area, the stratigraphy and lithology of the sedimentary rocks encountered was determined by reviewing the literature and by examining the electric logs, cuttings, core logs and cores. Subsurface structural contour maps were prepared on the base of the Lansing-Kansas City Group. A typical electric log from this area was marked at lithologic changes and is included in the thesis. From a limited number of locations, a microfossil identification and count was made from cuttings of the Shawnee, Lansing-Kansas City, and Marmaton-Cherokee Groups. Photographs were made of the various species of microfossils found and are also included in the thesis.

Drilling in Hitchcock County has been insufficient for working out proper structural control in that county. Additional drilling in the northwestern part of Red Willow County could prove a small but excellent field on the McCook Monocline. Subsurface structural mapping of the counties to the north of the

area studied could reveal more structures on the west flank of the Cambridge Arch similar to the Sleepy Hollow Field in Red Willow County. Secondary recovery projects should substantially increase the initial recovery of nearly all fields in this two-county area. In the area studied, the combined findings of the subsurface data and the structural maps prepared indicate that there are some possible undiscovered petroleum traps in both counties and in surrounding areas.