# A FACIES STUDY OF THE DES MOINES SERIES IN THE FOREST CITY BASIN

by

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# INTRODUCTION

## Location

The Forest City Basin is geographically in the Central United States, and lies within the boundaries of four states, Kansas, Missouri, Iowa, and Nebraska. The oval shaped basin contains an area of approximately 40,000 square miles (Plate I).

Geomorphically the Forest City Basin is situated in the Central Lowlands province. Dendritic drainage is eastward and relief is moderate; however, near the junction of streams and rivers the relief may become relatively steep. Westward regional dip locally is interrupted by minor structural features.

Geologically the Forest City Basin is bounded by the Salina Basin to the west, the Cherokee Basin to the south, and the Illinois Basin to the northeast. The Nemaha Uplift separates the Forest City Basin from the Salina Basin; and to the south the Cherokee Basin is separated from the Forest City Basin by the subsurface Bourbon Arch. Eastward the Ozark Uplift and the Lincoln fold separate the Forest City Basin from the Illinois Basin. The Sioux Uplift and the Wisconsin Dome form the northern boundary of the Forest City Basin (Plate I).

## Present Investigation

The present investigation was undertaken to study the relationship of structure to oil accumulation, and to analyze the relationship between specific facies values and associated oil accumulations in Cherokee and Marmaton rocks of Des Moines age.

## EXPLANATION OF PLATE I

Location of the Forest City Basin and adjacent tectonic framework.

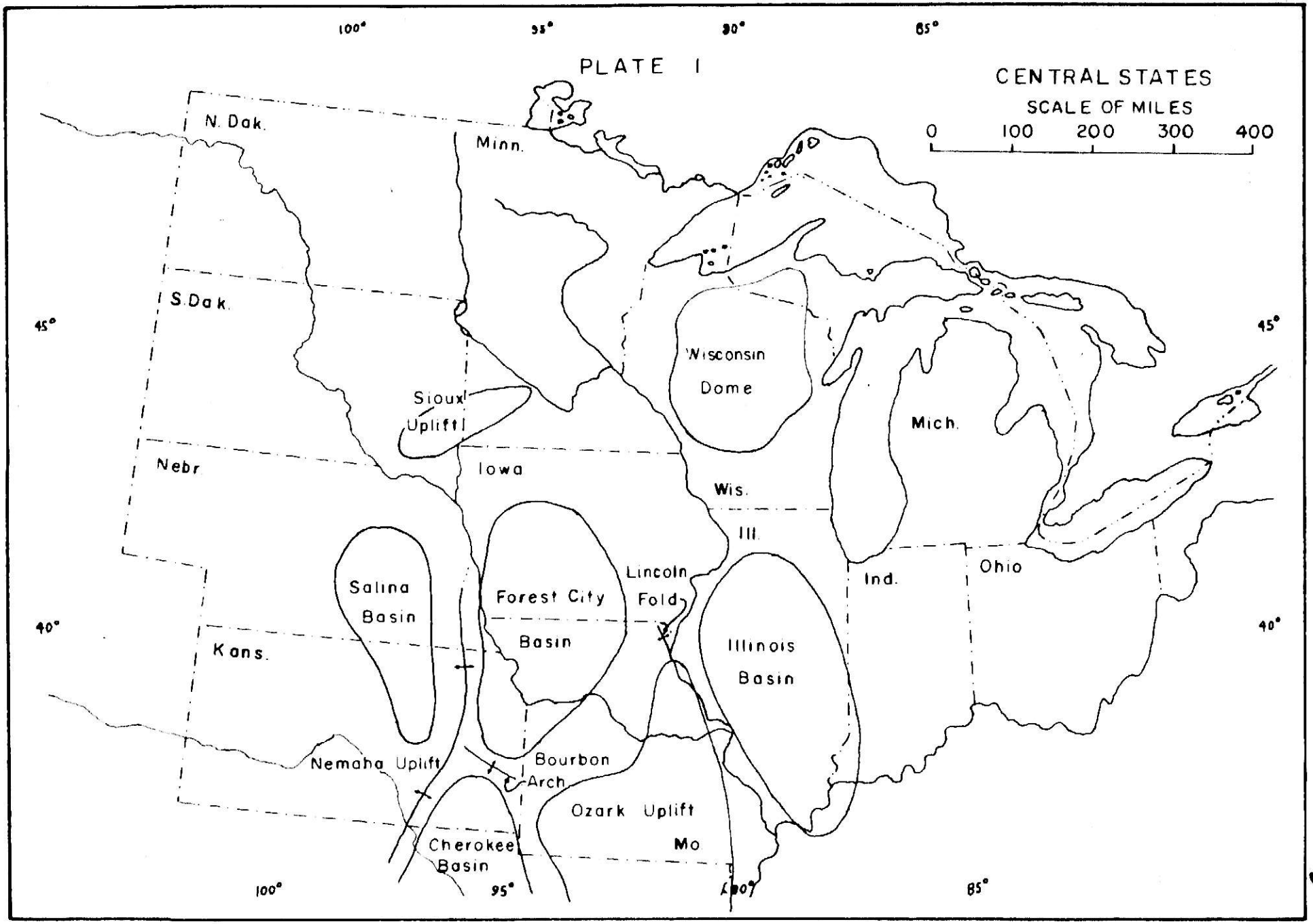


PLATE I
CENTRAL STATES
SCALE OF MILES
0 100 200 300 400
100°
95°
90°
85°
45°
40°
N. Dak.
Minn.
S. Dak.
Nebr.
Iowa
Wis.
Ill.
Mich.
Ind.
Ohio
Kans.
Mo.
Wisconsin Dome
Sioux Uplift
Salina Basin
Forest City Basin
Lincoln Fold
Illinois Basin
Nemaha Uplift
Bourbon Arch
Ozark Uplift
Cherokee Basin

The investigation also was to provide additional information concerning facies variation, source, and the direction of transportation of sediments which comprise the Des Moines Series of the middle Pennsylvanian period. Geologic data was summarized by the preparation and interpretation of facies and isopach maps, and also from previous investigations. Approximately 250 drillers' logs and sample logs were used as a source of subsurface data in the construction of the facies and isopach maps.

The areal boundaries for the investigation were arbitrarily set at the erosional outcrops in eastern Kansas, northwestern Missouri, and southwestern Iowa. In the subsurface in western Iowa, pre-Cretaceous erosion removed portions of the Marmaton and Cherokee groups; therefore, the south edge of the unconformity between the Des Moines and Cretaceous rocks was chosen as the northern areal boundary. The Bourbon Arch at the southern margin of the Forest City Basin, and the Nemaha Uplift of Kansas and Nebraska served as the southern and western boundaries for the investigation.

The basal stratigraphic boundary for the Cherokee group was placed at the contact of this group and the underlying Mississippian limestones. The basal sandstones or chert-bearing beds which overlie the Mississippian limestones were considered Cherokee in age; however, the basal sandstones or chert-bearing beds, which were reported as containing considerable amounts of limestone fragments in sample logs and drillers' logs, were considered Mississippian in age. This method of interpretation was used to differentiate between material which was transported and

that which probably formed in place. Thus material which was transported would contain only minor amounts of limestone fragments. The upper stratigraphic boundary for the Cherokee group is the base of the Fort Scott limestone of the overlying Marmaton group (Plate II).

The upper stratigraphic boundary for the Marmaton group is the Hepler sandstone lying at the base of the overlying Pleasanton group. In areas where the Hepler sandstone is not present, the top of the Lenapah Limestone served as the upper boundary. This introduced a stratigraphic interval variation of approximately 20 feet; however, this was considered to be a minor factor on a semi-regional basis. The base of the Fort Scott limestone served as the basal stratigraphic boundary for the Marmaton group (Plate II). Previous investigations were relied upon for the mineralogical composition of sandstones in the Des Moines Series because few well samples and well cores were analyzed by the writer. Sandstones of Des Moines age have been classified as to type on the basis of the most prevalent composition; therefore, sandstones which are classified as being composed mainly of one composition may locally contain a different composition.

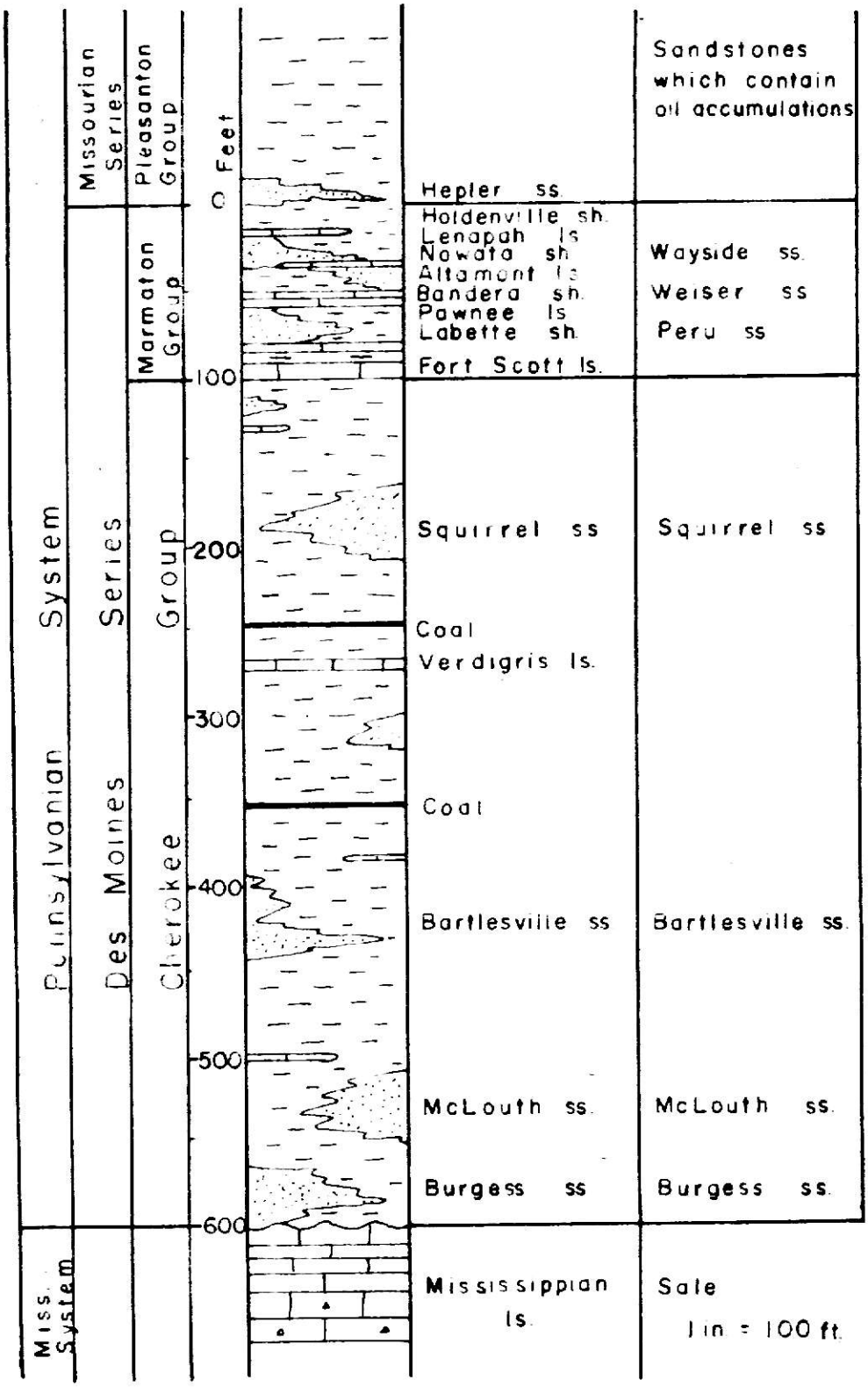
## Previous Investigations

Many geologic investigations have been made on various geological aspects of the Forest City Basin and the Des Moines Series. Some of the major studies include the work of Broadhead (1873-4) who described Cherokee rocks in western Missouri; and

## EXPLANATION OF PLATE II

Generalized subsurface geologic column showing the more important stratigraphic units in the Des Moines Series of the middle Pennsylvanian period, and the more important sandstones that are petroleum reservoir rocks.

# PLATE II




By M L Maderak, 1960

later reports on Cherokee or early Des Moines rocks include those of Ohern (1910), Greene and Pond (1926), Pierce and Courtier (1937), Searight and others (1953), and Howe (1956).

Extensive investigations have also been conducted on Marmaton rocks; probably some of the more important investigations include those of Moore (1936), Cline (1941), Jewett (1945), and Moore and others (1951).

John W. Ockerman (1935) analyzed the subsurface rocks in northeastern Kansas, and Osborn (1938) compared the stratigraphy of the Forest City Basin to that of the Illinois Basin. McQueen and Greene (1938) described the stratigraphy of the Forest City Basin, and Lee (1943) discussed the stratigraphy and structural development of the basin. Lee (1956) further discussed the stratigraphy and structural development of the Salina Basin and related its geologic development with that of the Forest City Basin. Numerous investigations have also been made by the State Geological Surveys in Iowa and Nebraska in conjunction with other reports.

## STRATIGRAPHY OF THE DES MOINES SERIES

The Des Moines Series of Kansas, Missouri, Iowa, and Nebraska is subdivided into the upper Marmaton group and the lower Cherokee group (Plate II).

### Cherokee Group

The Cherokee group has been investigated in detail by Searight and others (1953), and Howe (1956). Cherokee outcrops

extend in a broad belt eastward from Oklahoma through Cherokee County, Kansas, around the flanks of the Ozark Uplift, northward through northeastern Missouri into southeastern Iowa (Lee, 1943). In most areas in Iowa, the Cherokee rocks are covered by younger sediments or sedimentary rocks. In the subsurface, the Cherokee group is composed predominantly of shale, many sandstones, and minor amounts of limestones (Plate II). Coal is present as a local component. The Cherokee group is that interval of sedimentary rocks which lie between the older Mississippian rocks and the younger Marmaton rocks (Howe, 1956). However, near the Nemaha Uplift, the Cherokee rocks may lie on older rocks.

The shales in the Cherokee group are micaceous, silty, sandy, and almost any combination is possible. The sandstones are mainly micaceous; however, chert sandstones and quartzose sandstones are common. Sandstones of Cherokee age have been classified as to type on the basis of the most prevalent composition; therefore, units which are classified quartzose may locally contain sub-graywacke type sandstones. The porosity of the sandstones vary with the composition; usually the micaceous sandstones have the lowest porosity. The Cherokee group is, therefore, composed predominantly of shale with many sandstones and minor amounts of limestones and coals.

Because of the lithologic variance between subsurface rocks and outcropping rocks, a generalized subsurface nomenclature has been used to discuss the stratigraphy of the Cherokee group rather than the detailed nomenclature which is accepted for outcropping rocks by the various State Geological Surveys. This

subsurface nomenclature is accepted in Kansas and adjoining states, and the names of this nomenclature occur in the United States Geological Bulletin 896, Lexicon of Geologic Names of the United States (Wilmarth, 1938), and the Kansas State Geological Bulletin 104, Oil and Gas in Eastern Kansas (Jewett, 1954). This nomenclature is also accepted by the petroleum industry in Kansas (Plate II).

The basal unit of the Cherokee group in the Forest City Basin is a dark unnamed shale (Lee, 1943). This shale is present in the deeper parts of the basin in Brown and Doniphan Counties, Kansas, and adjoining marginal areas. This unit represents the earliest deposit in the Cherokee group, and the dark shale lies in contact with the Mississippian limestones. The thickness of the unnamed shale varies from 0 to 20 feet (Fig. 1, Plate II).

The Burgess sandstone lies above the unnamed dark shale; however, because of the limited areal extent of the dark shale, the Burgess sandstone overlaps the dark shale and lies in contact with the Mississippian limestones. The Burgess sandstone is composed of quartz, and chert fragments derived from exposed Mississippian rocks which were not covered by the deposition of the dark shale (Lee, 1943). This sandstone varies from 0 to approximately 150 feet thick; however, the average thickness is about 25 feet.

The McLouth sandstone is an extensive sedimentary unit which occurs in Jefferson and Leavenworth Counties, Kansas, and parts of northwestern Missouri, and which appears to have been

deposited as sheet or blanket bodies which may locally "wedge out". The McLouth sandstone is stratigraphically above the Burgess sandstone, and is separated from the Burgess by a dark shale. This dark shale overlaps the older Burgess sandstone and most of the Mississippian rocks. Lee and Payne (1944) have reported the McLouth sandstone to be separated from the Mississippian rocks by a dark shale; however, in many areas, topographic highs created both by erosion and structural deformation in the underlying Mississippian limestones, prevented the deposition of the dark shale. Therefore, the McLouth sandstone may lie in contact with the Mississippian limestones, or in contact with the dark shale. The McLouth sandstone is approximately 30 feet thick, however its thickness ranges from 0 to over 100 feet. The mineralogical composition of the McLouth sandstone is similar to that of the Burgess sandstone (Lee and Payne, 1944).

The Bartlesville sandstone is younger than the McLouth sandstone, and the Bartlesville is separated from the McLouth by a shale unit (Plate II). The Bartlesville sandstone occurs in southern Iowa and northwestern Missouri, and locally it is present in northeastern Kansas. In the Missouri and Iowa portions of the Forest City Basin the sandstone appears to be the result of channel fillings which grade into fan or deltaic deposits. In Kansas the sandstone appears as local blanket or sheet deposits. The channel deposits may be as thick as 70 feet, and the sheet or blanket sandstones average about 15 feet thick. The Bartlesville sandstone has a sub-graywacke composition (Greene, 1945, Siever, 1957).

The Squirrel sandstone occupies the upper portion of the Cherokee group, and has been observed in well samples in all parts of the basin. Along the eastern margin of the basin the sandstone occurs as channel fillings which grades laterally into sheet and lense shaped deposits. The sandstone is usually approximately 30 feet thick and has a composition similar to the Bartlesville sandstone.

Limestones have been observed in outcrops, however few units have been reported in the subsurface because they were missed or just not reported during drilling, or because they were not present. Probably the only persistent unit of any areal extent is the Verdigris limestone.

The Verdigris occurs in the upper part of the Cherokee group below the Squirrel sandstone (Plate II). The limestone is approximately 10 feet thick and appears to be present in all parts of the basin except near the Nemaha Uplift. In outcrops the Verdigris is a highly fossiliferous dark to gray rock consisting of three limestones approximately 1 to 2 feet thick separated by shale beds (Howe, 1956).

Thickness of the Cherokee group is variable. In Brown County, Kansas, it is approximately 900 feet thick, however, elsewhere it is much thinner. The average thickness of the Cherokee group is about 500 feet. It becomes thinner northward through Iowa, toward the Nemaha and Ozark Uplifts, and over the Bourbon Arch where it is about 250 feet thick (Fig. 1). The thickness of the Cherokee group is dependent upon many factors; however, topographic irregularities, resulting from erosion and

structural deformation of the underlying units, seems to have had the greatest effect in influencing the thickness.

## Marmaton Group

Outcropping rocks of the Marmaton group have been discussed by Jewett (1945). The group includes rocks from the top of the Cherokee group to the base of the Pleasanton group which is the oldest unit in the Missourian Series. The subsurface rocks consist of limestones of variable thicknesses separated by shales.

The Fort Scott limestone is the basal formation of the Marmaton group which is separated in the middle by a dark shale. This unit is a good subsurface stratigraphic marker because it is persistent over most of the basin. Locally near the Nemaha Uplift the Fort Scott limestone may grade into a sandstone. The average thickness of the limestone is about 30 feet; however, locally the thickness may vary considerably.

Above the Fort Scott limestone is the Labette shale which is gray in color in well samples and is approximately 30 feet thick. Locally the Labette shale may grade into the Peru sandstone. The Peru sandstone occurs as channel deposits of a subgraywacke composition containing many limestone fragments derived from the underlying rocks (Jewett, 1945).

The Labette shale is overlain by the Pawnee limestone which may contain shale partings about one foot thick. In general, the limestone is about 25 feet thick; but locally the thickness may vary from 0 to about 40 feet. The Pawnee is the upper limestone in the lower half of the Marmaton group (Plate II).

The upper half of the Marmaton group consists of three shales, Bandera, Nowata, and Holdenville, separated by two limestones, Alamont and Lenapah (Plate II). The shales may grade locally into channel or lense-shaped sandstone bodies. In areas where the Hepler sandstone, which is the basal rock unit of the Pleasanton group, was not deposited, the upper Holdenville shale of the Marmaton group cannot be distinguished from the shaly Pleasanton group. Therefore, the Holdenville shale may not be recorded on drillers' logs or sample logs. The average thickness of the individual shale units is about 15 feet.

The upper Lenapah limestone in many areas has been removed by local erosion shortly after its deposition, and many of the older limestones in the upper part of the Marmaton group may locally grade into shales; therefore, many local variations may exist in the upper half of the Marmaton group.

The Marmaton group varies in thickness from 0 to 200 feet, and the average thickness is about 100 feet. In general it increases in thickness toward the southern part of the basin. The Marmaton section is relatively thin over the Nemaha Uplift where Cherokee rocks failed to cover the crest, and locally in Pottawatomie and Nemaha Counties, Kansas, and Nemaha County, Nebraska, Marmaton rocks may be missing because of non-deposition or local erosion. Therefore, where Cherokee rocks are not present, Marmaton rocks lie in contact with pre-Cambrian rocks; and in areas where Marmaton rocks are missing, rocks of the overlying Pleasanton group lie in contact with rocks of pre-Cambrian age.

## FACIES AND ISOPACH MAPS

Facies as defined by Y. A. Zhemchuzinikov (1959) is a relative concept pertaining to the distinctions which correspond to a stratigraphic unit. Facies reflects the environment of the accumulation of sedimentary rocks or layers; therefore, facies is that which may be conceived or deduced from all indicated features of a sedimentary rock or layer by which one can come to a conclusion about the rock or layer and the physiogeographical, biochemical, and geochemical conditions of its origin.

A facies map shows geographically the overall variations of the lithologic characteristics of a stratigraphic unit (Krumbein and Sloss, 1956, p. 403).

After a stratigraphic unit has been chosen, numerous methods are available for contrasting areal lithologic variations. One of the more general methods used to delineate lithologic variations or facies changes is by the use of clastic ratios (Krumbein and Sloss, 1956, p. 404). Determination of the thicknesses of clastics and non-clastics in a stratigraphic unit makes possible a ratio expression in which:

$$\text{Clastic Ratio} = \frac{\text{thickness of clastics}}{\text{thickness of non-clastics}}$$

This information may be obtained from drillers' logs, sample logs, or electric logs. Examination of the ratio quickly indicates that a ratio of 1 pertains to a unit which is composed of 50 per cent clastics and 50 per cent non-clastics. Thus as the ratio increases the unit becomes more clastic, and as the ratio

approaches zero the unit becomes non-clastic.

If the stratigraphic unit under consideration is composed chiefly of clastics, a sand-shale ratio may be used to indicate the varying lithology (Krumbein and Sloss, 1956, p. 406). This ratio is an expression between coarse and fine clastics, and may be expressed by the following formula:

$$\text{Sand-Shale Ratio} = \frac{\text{conglomerate + sandstone}}{\text{siltstone + shale}}$$

A sedimentary rock interval which has a ratio of 1 will be composed of 50 per cent fine clastics and 50 per cent coarse clastics. When the ratio approaches infinity the unit in question increases in composition toward that of a coarse clastic, however when the ratio approaches zero the unit in question approaches the composition of a fine clastic.

In conjunction with facies maps, isopach maps may be constructed to show the varying thicknesses of a stratigraphic unit by use of contour lines (Krumbein and Sloss, 1956, p. 401). Such maps require two key stratigraphic units which are continuous over the area to be investigated, and can also be used as limits for the facies maps. The key units are at the top and bottom of the stratigraphic interval in question. When the upper key unit of a particular stratigraphic layer is used as a datum plane, the lower key unit reflects the shape of the topographic and structural surface during the time the upper key unit was being deposited. Thus isopach maps have the advantage of showing underlying structure and topographic expression at the time

the stratigraphic layer was being deposited, and also show the varying thicknesses areally. Therefore, most facies maps are drawn on an isopach base which provides the thicknesses of the stratigraphic unit and also shows the lithologic variations geographically (Krumbein, 1952). The use of such combinations, facies and isopach maps, results in the development of particular patterns which were dependent upon many environmental factors during the time of deposition (Plate III). Isopachous and facies lines which show ovate patterns, two circular parallel lines, tend to suggest development in an evaporite or intracratonic basin (Krumbein, 1952). Facies lines may loop over isopachous lines forming a curvilinear discordant pattern (Plate III). Such a pattern may arise when clastics are concentrated in a local subsiding area, such as a delta. Irregular spotty patterns occur near the edge of detrital sheet sands where accumulation was intermittent (Krumbein, 1952). In areas where the facies lines meet the zero isopach abruptly, a possibility exists that the original shore line does not correspond to the zero isopach; however, had the facies lines and the zero isopach been parallel, a possibility would exist that the zero isopach was a shore line boundary (Krumbein, 1958).

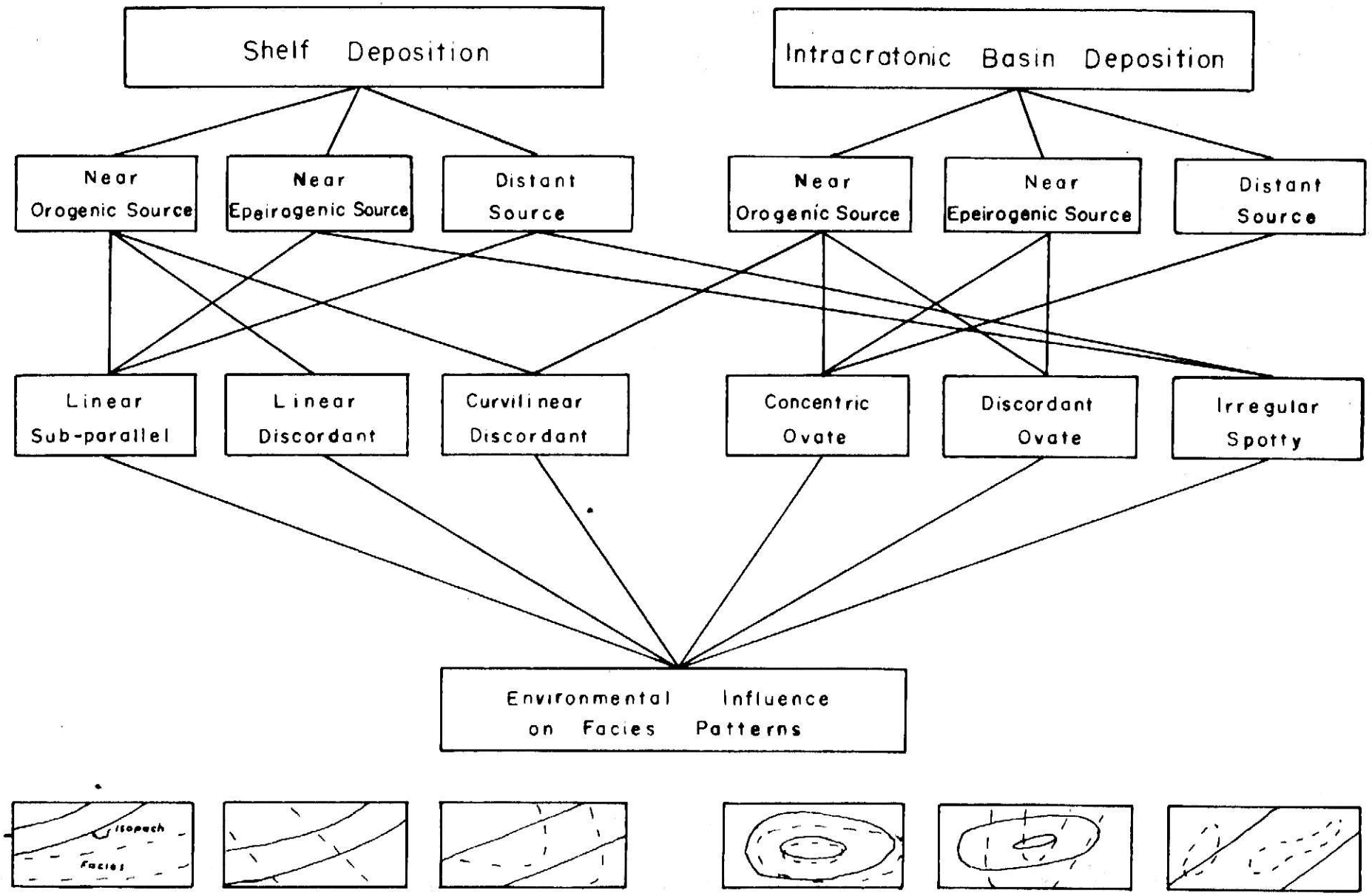
The use of facies-isopach maps, and known lithologic compositions provides an even greater indication of the tectonic conditions which were present at the depositional area. Quartzose sandstone typically occurs on shelf areas and indicates tectonic stability, and graywackes are indicators of strong negative conditions. The occurrence of sub-graywacke sandstones,

## EXPLANATION OF PLATE III

The plate shows the relation between facies lines and isopachous (solid) in terms of tectonics and source areas. The lower suggests the nature of environmental influence on patterns (Krumbein, 1952).

PLATE III

Controlling Conditions




From Krumbein, 1952

coarse silty shales, and nodular limestones suggest increasing contemporaneous tectonism (Krumbein, 1948).

## INTERPRETATION OF MAPS

### Cherokee Isopach Map

The Cherokee group represents an interval between the top of the Mississippian limestones, and the base of the Marmaton group. The thickness of this interval ranges from 0 to 900 feet (Fig. 2). Cherokee rocks did not cover the northern portion of the Nemaha Uplift, but along the flanks of the structure the Cherokee rocks are approximately 350 feet thick. The Cherokee section also thins over the Bourbon Arch where it has a minimum thickness of about 250 feet. The dendritic patterns delineated by the isopachous contour lines suggest that stream erosion played an important role in the deposition of sediments within the basin. The shape of the dendritic patterns are indicative of stream erosion; therefore, the thickest portions of the patterns tend to suggest the location and direction of the stream valleys. Drainage slopes within the basin were predominantly from the north and east, however, some drainage did result from the south and southeast because of the Bourbon Arch and the Ozark Uplift which is indicated by the shape and thicknesses of the dendritic patterns which extend northward and westward from the structures to the deeper parts of the basin (Fig. 2). The patterns produced by the isopachous lines in southwestern Iowa seem to suggest that several major trunk valleys pass through

Iowa into Brown County, Kansas. The exact position of the valleys is not known because only a limited number of well logs were available in Iowa; in general, the valleys cut across southwestern Iowa from the northwest and north to converge approximately in Page County, Iowa (Fig. 2). The presence of numerous stream valleys which converge toward the deeper part of the basin in Brown County, Kansas, and which are represented by the dendritic patterns of the isopachous lines, tend to suggest that deposition and uplift occurred contemporaneously. The inferred well developed valleys in the northern flank of the Bourbon Arch also tend to suggest that the arch was a barrier from the beginning which separated the Cherokee Basin from the Forest City Basin (Fig. 2). Only minor modifications of that structure by erosional processes would have taken place had the Bourbon Arch formed in the later part of Cherokee time, and the valleys in the northern flank of the Bourbon Arch would have been discontinuous with respect to other valleys in that portion of the basin. Differential subsidence followed by the deposition of sediments probably created the thickening of the Cherokee interval in Franklin, Osage, and Shawnee Counties, Kansas. It should be noted that stream valleys do not occur in the flanks of the Nemaha Uplift; therefore, it is highly probable the Nemaha Uplift was never of high relief, and the areal drainage from the topographic high parts of the structure was slight.

## Cherokee Facies Map

The Cherokee group in the Forest City Basin contains mostly

shale, many sandstones, and minor amounts of limestones and coal. As previously mentioned, the Cherokee group contains mostly clastics, and the relationship of the clastics is shown by the sand-shale ratio map (Fig. 2). The numerous different patterns and ratios which are displayed on the facies map indicate that unstable depositional conditions existed at the site of deposition. The sub-parallel trends formed by the facies and isopachous lines along the western margin of the basin indicate that the northern portion of the Nemaha Uplift was probably a western shoreline boundary during the deposition of the Cherokee group; however, the southern part of the Nemaha Uplift and the Bourbon Arch, where the facies and isopachous lines are not parallel, were only temporary boundaries (Fig. 2). The isopachous "zero" line along the eastern margin of the basin in northwestern Missouri was arbitrarily placed at the western edge of the erosional surface of the Cherokee group. The facies and isopachous lines are not parallel in that portion of the basin; therefore, the isopachous "zero" line in the Missouri portion of the Forest City Basin was not an eastern shoreline boundary for the Cherokee group (Fig. 2). The "zero" isopachous line in the Iowa portion of the Forest City Basin was arbitrarily placed along the southern edge of the unconformity which occurs between rocks of Cherokee and Cretaceous age. The facies and isopachous lines tend to be sub-parallel in the northern portion of the Forest City Basin; therefore, the northern shoreline boundary for the Cherokee group nearly coincides with the "zero" isopachous line (Fig. 2).

Most of the interior facies patterns are linear or

curvilinear discordant which tend to indicate a near, weak to moderately strong orogenic source from which accumulation of sediments was intermittent (Plate III). One would expect such patterns where the size and amount of material being transported into the basin was dependent upon tectonic activity reexposing old source areas or causing the reworking of previously deposited sediments. In general, the patterns indicate great flexibility in the amount of material being derived from the source, and many changing environmental conditions at the site of deposition. The Cherokee group in the northern half of the Forest City Basin contains more sandstones than its southern counterpart. Ratios between .5 - 1 contain 25 to 50 feet of sandstone per 100 feet of stratigraphic section. The northern portion of the Forest City Basin contains many areas that have ratios which are greater than, or as great as .5 - 1; however, few areas occur in the southern part of the basin which have a ratio as great as .5 - 1. The only major area with a ratio between .5 - 1 occurs in the southeastern portion of the basin which is adjacent to the Ozark Uplift (Fig. 2). Sandstones and conglomerates occur along the Nemaha Uplift; however, the areal distribution of the clastics is limited. Spotty patterns occur in Wyandotte and Miami Counties, Kansas, and Andrew County, Missouri, which are probably the result of sedimentary by-passing caused by fluctuations in current intensity and the amount of sediments being transported to the area of deposition. Thus during changing depositional conditions an exact concordance seldom exists between isopachous lines and facies lines; therefore, in most areas a facies lag

seems to have developed where thickening occurs over a broader area than the facies change. This is probably the result of unstable tectonic environmental conditions and rapid deposition.

## Marmaton Isopach Map

The sedimentary rock interval between the top of the Cherokee group and the base of the Pleasanton group is the Marmaton group. The thickness of this interval ranges from about 75 feet in southwestern Iowa to more than 200 feet in the southern portion of the basin. The Marmaton rocks along the crest of the northern portion of the Nemaha Uplift have a thickness of approximately 50 feet, and locally many areas exist in Pottawatomie and Nemaha Counties, Kansas, and Nemaha County, Nebraska, where Marmaton rocks did not cover the crest of that structure. The southern portion of the Nemaha Uplift, and the Bourbon Arch were buried structures during the end of Marmaton time; this is evident from the isopachous lines which project across the structures (Fig. 3). The general southward thickening of the Marmaton group indicates that the Cherokee Basin and Forest City Basin were connected to form a single area of deposition. Only in the northern part of the Forest City Basin is there any evidence of channel deposition which is indicated by a thickening of the dendritic patterns formed by the Marmaton isopachous lines. Fewer topographic features present in the underlying rocks probably caused the development of a more uniform thickness in the stratigraphic interval; however, in many areas differential compaction of the lower Cherokee group, and also

differential subsidence followed by deposition, caused local thickening in the Marmaton sedimentary rocks.

## Marmaton Facies Map

The Marmaton group is composed mostly of shales and limestones; therefore, a clastic ratio has been used to differentiate the lithology. This method does not distinguish between sandstone and shale, as sandstone and shale are both included in clastic sedimentary rocks; however, minor amounts of sandstone do occur in northwestern Missouri where the clastic ratios are greater than 2 (Fig. 3). The very minor sub-parallel trends formed by the facies and isopachous lines along the Nemaha Uplift tend to suggest that the Nemaha Uplift was probably a temporary shoreline boundary during the deposition of the Marmaton group. The "zero" iscpachous line was arbitrarily placed in the northern and eastern portions of the Forest City Basin at the southern and western edges of the unconformity which occurs in the sub-surface between rocks of Marmaton and Cretaceous age, and at outcrops of Marmaton age. The facies and isopachous lines are not parallel in the northern and eastern portions of the basin; therefore, the isopachous "zero" line was not a shoreline boundary during the deposition of the Marmaton group (Fig. 3).

Most of the interior patterns are linear or curvilinear discordant which tend to indicate a near, weak to moderately strong orogenic source of sediments. The general lack of sandstones in the Marmaton rocks tends to suggest that tectonic

movements were of a small magnitude during Marmaton time; therefore, the ratios vary in proportion to variations in the amount of limestones and shales present at any one area. Higher clastic ratios which indicate a relatively high proportion of clastics are concentrated in the southern portion of the basin which suggest that the Forest City Basin and the Cherokee Basin had merged to form a long arm of the Ouachita Basin of western Arkansas and eastern Oklahoma. A concentration of fine clastics, shales and siltstones, appear along the partially buried Nemaha Uplift which indicates that structure was a local source of sediments for the Marmaton group (Fig. 3). Limestones generally occur along areas where the stratigraphic section is thin; however, in many areas the deposition of clastic sediments overshadowed the deposition of limestones. Deposition of considerable amounts of limestones and shales indicate structural movements during Marmaton time were of less intensity as compared to Cherokee time.

## GEOLOGIC HISTORY

The area which the Forest City Basin now occupies was subjected to many structural conditions prior to the development of the basin. From late Cambrian time to the end of Arbuckle time the Ozark region of Missouri was subsiding and southeastern Nebraska and northeastern Kansas were rising (Lee, 1956).

After St. Peter time and prior to the deposition of the Mississippian limestones a broad area in southeastern Nebraska and northeastern Kansas, which had previously been a positive

area, began a long period of differential subsidence which resulted in the development of the North Kansas Basin. The Ozark region of Missouri was being uplifted during the development of the North Kansas Basin (Lee, 1956).

The Forest City Basin was the result of deformation which occurred following the deposition of the Mississippian limestones; however, before the invasion of the Pennsylvanian sea, the beveled surface was reelevated, deformed, and subjected to brief intermittent erosion (Lee, 1956). The Bourbon Arch and the Nemaha Uplift were being modified by erosional processes during the period of deformation. The dendritic patterns delineated by the isopachous contour lines suggest that stream erosion played an important role in the deposition of sediments within the basin (Fig. 2). The thickest areas within the dendritic patterns formed by the Cherokee isopachous lines indicate the relative position and direction of the stream valleys. The inferred, well developed, valleys in the northern flank of the Bourbon Arch which can be traced to the deeper portion of the Forest City Basin in Brown County, Kansas, tend to suggest that the arch was a barrier which temporarily separated the Cherokee Basin from the Forest City Basin (Fig. 2). One would expect the sediments present on the beveled Mississippian surface to be composed mostly of silts and clays prior to the reelevation of that surface because low relief is indicative of fine sediments. Thus upon reelevation of the Mississippian surface, the first material removed by erosional processes would be the finer clastics. The close or narrow spacing or the facies lines and the

increase of the sand-shale ratios toward the Nemaha Uplift suggests that little detrital material was being derived from that area (Fig. 2). This also indicates that the Nemaha Uplift was probably always of low relief formed by minor uplift that continued throughout Cherokee and Marmaton time. These uplifts, characterized by continued subsidence of the basin, and reelevation of the marginal areas, probably preserved the direction of transportation of sediments to the basin. Thus, the Bourbon Arch and the Nemaha Uplift were acting as topographic barriers that confined sedimentation and formed the boundaries for an inland sea.

The first unit of Cherokee age to be deposited in the Forest City Basin was a dark unnamed shale. The material for this shale consisted of fine clastics, clays and silts, which were derived from the newly formed Bourbon Arch, the Nemaha Uplift, and marginal areas to the north and east of the new basin. Increasing tectonism would increase the rate of erosion causing the deposition of the dark shale to be gradually overshadowed by the deposition of the Burgess sediments (Plate II). The sand-shale ratios of the Cherokee facies map (Fig. 2) increase toward the northern portion of the basin. This suggests that the source of detrital material for the sandstones in the Cherokee group was north of the Forest City Basin. The source areas were probably parts of the Canadian Shield, the Trans-Continental Arch, and previously deposited sediments adjacent to the source areas.

The Burgess and McLouth sandstones of the lower Cherokee group are composed of quartz and chert fragments, and are

classified as quartzose sandstones (Lee and Payne, 1944, Greene, 1945, Siever, 1957). Many concentrations of clean quartz sandstones are probably due to the reworking of previously deposited sediments. The detrital sediments within the Mississippian limestones nor the Nemaha Uplift area could not have been the major source of quartz. This is evident from the close or narrow spacing of the facies lines and the rate of increase of the sand-shale ratios toward the Nemaha Uplift; therefore, the source of quartz for the Burgess and McLouth sandstones was probably to the north of the basin. The higher per cent of sandstones that are present in the northern portion of the basin tends to support the influence of a northern source area (Facies map, Fig. 2).

Marine fossils have been identified in sedimentary rocks of McLouth age (Lee and Payne, 1944). In eastern Jefferson County, Kansas, the McLouth sandstone lies at a depth approximately 500 feet below the bottom of the Fort Scott limestone. The Fort Scott limestone has been used as a horizontal datum for the study of the structure underlying the Cherokee rocks. The lowest portion of the Bourbon Arch in the southern part of Lyon County, Kansas, lies approximately 375 feet below the Fort Scott datum; therefore, the first marine sediments were deposited at a level below the lowest portion of the Bourbon Arch. Approximately 125 feet of structural relief separated the Forest City and the Cherokee Basins during this period of marine invasion. This approximation does not consider the thickness of material that was probably removed from the crest of the Bourbon Arch

prior to the deposition of the McLouth sandstone, nor does it consider the amount of subsidence that may have taken place before the deposition of the McLouth sandstone. However, it is evident that a marine connection had to exist somewhere, probably between the Forest City Basin and the Illinois Basin. The exact position of the connection between the Forest City Basin and the Illinois Basin is not known because the present investigation was not carried to the limits of the Pennsylvanian outcrops. Correlation of sandstones between eastern Missouri and western Illinois have been made, however the problem of whether the lower Cherokee sandstones are marine or non-marine could not be determined (Siever, 1957). The Cherokee isopach map (Fig. 2) indicates a thickening of the sedimentary rocks in Putnam County, Missouri, and Wayne County, Iowa. The Cherokee facies map (Fig. 2) indicates an influx of sandy clastics, represented by the ratios from .5 - 1, from the northwestern Illinois area. Siever (1957) reports the eastern Missouri sandstones of early Cherokee age to be finer than those of western Illinois, and that the sandstones were probably deposited as sheet deposits that wedge out locally. Lense-shaped sandstone bodies are also common. The Cherokee facies map (Fig. 2) indicates a tongue of sandy clastics of considerable lateral extent, represented by the ratios from .5 - 1, becoming smaller in geographic distribution as the distance increases from the possible area of connection. This tongue of sandy clastics may represent deposition in a coastal plain alluvial environment where current activity between the two basins was moderately strong. The fact that

marine fossils have not been identified in the sandstones of early Cherokee age in the probable connection area may result from current intensity and abrasion during transportation which modified the fossil remains beyond recognition. The plant fossils that are present in the Cherokee sandstones were probably transported to the area of deposition by saltation and flotation, and thus would escape destruction. Diastrophic movements along the growing Appalachian area probably caused the level of the Illinois sea to fluctuate. Plants of many types probably grew in the connection area between the Forest City and Illinois Basins during times when the sea was low. The growth of plants may also have occurred when a static level between the basins developed that caused temporary deposition within the connection because of a decrease in current intensity. A decrease in sea level, or the temporary restriction in the connection brought non-marine conditions to the Forest City Basin. Such cyclic conditions existed through the entire Des Moines Epoch. It must be presumed that the Burgess sandstone and the overlying shale which occurs below the McLouth sandstone must have been deposited in a non-marine environment because marine fossils have not been identified in rocks older than McLouth age. A common source area is indicated by the fact that the Burgess and McLouth sandstones have the same composition. The marine water entered the Forest City Basin from the Illinois Basin through a connection north of the Lincoln fold during the deposition of the McLouth sandstone. The decreasing rate of erosion in the source areas brought about the deposition of silts and clays

which overshadowed the deposition of the McLouth sandstone.

The deposition of the silts and clays is represented by a shale unit which occurs above the McLouth sandstone and below the Bartlesville sandstone (Plate II). Increasing subsidence in the Forest City Basin and the Cherokee Basin followed by the deposition of the shale unit resulted in the burial of the Bourbon Arch, and caused the Forest City and Cherokee Basins to merge. Thus prior to the deposition of the Bartlesville sandstone, the joining of the two basins formed a long arm which was part of the larger Ouachita Basin of western Arkansas and eastern Oklahoma. The Illinois Basin had merged with the Forest City Basin during McLouth time.

Renewed uplift of the structural elements which border the Forest City Basin to the north caused an influx of different sediments. This phase of deposition has been designated as the Bartlesville sandstone. Whereas the Burgess and McLouth sandstones are of a quartzose variety, the Bartlesville and Squirrel sandstones, which occur stratigraphically above the McLouth sandstone, are mostly sub-graywackes. The Bartlesville and Squirrel sandstones contain mica flakes, feldspar grains, angular grains of quartz, and metamorphic quartzite, (Lee and Payne, 1944, Greene, 1945, Siever, 1957). The Cherokee facies map (Fig. 2) indicates that the greater concentrations of sandstones occur in the northern portion of the Forest City Basin; therefore, the major source areas were probably parts of the Canadian Shield and the Trans-Continental Arch. The change in composition from quartzose to sub-graywacke occurred after McLouth time

and before the deposition of the Bartlesville sandstone. The change in composition probably resulted from erosional processes uncovering a partially buried granitic area, and indicates an increase of tectonic activity in areas north of the Forest City Basin.

The Squirrel sandstone is separated from the Bartlesville sandstone by a shale unit. The deposition of the shale unit indicates tectonic activity had diminished from that of Bartlesville time. This shale unit is separated in the middle by the Verdigris limestone. The Verdigris limestone is present over most of the basin, and indicates that more stable conditions existed for a short time (Plate II).

The Squirrel sandstone represents the last renewal of tectonic activity during Cherokee time. This sandstone grades into a shale which separates the Squirrel sandstone from the Fort Scott limestone of the Marmaton group.

The Marmaton group overlies the Cherokee group without notable disconformity (Jewett, 1945). The vast number of limestones within the Marmaton group indicates that stable conditions existed intermittently during Marmaton time. In many areas the shales which separate successive limestone units grade into, or abruptly change to sandstones. Most sandstones occur as channel fillings which probably resulted from the reworking of previously deposited sediments (Jewett, 1945). Therefore, tectonic activity during the deposition of the Marmaton group was probably limited to subsidence within the basin and very minor structural movements at the major source areas north of

the Forest City Basin. An important unconformity separates Marmaton rocks from the overlying Pleasanton group.

Information has been presented which indicates that the major source areas were probably parts of the Canadian Shield and Trans-Continental Arch. The Nemaha Uplift was the source of minor amounts of sediments. It was probably more a source of fine clastics, shales and siltstones, and minor amounts of sandstones.

The close or narrow spacing and the increasing ratio values of the Cherokee facies lines (Fig. 2) indicate a rapid facies change; therefore, the amount of detrital material being derived from the Nemaha Uplift area was small. Another source of sediments was from the Ozark Uplift. The ratios from .5 - 1 of the Cherokee facies map (Fig. 2) indicate that considerable amounts of sandy clastics were deposited in the southeastern portion of the Forest City Basin and the northeastern portion of the Cherokee Basin. The encroaching Cherokee sea probably reworked this material and deposited it as off-shore bars which are typical of that area (Bass, 1936).

In the Des Moines Series of the Forest City Basin, lense, sheet, and channel sandstone deposits can be classified on the basis of shape. The lense and sheet deposits resulted from streams depositing their loads in a shallow brackish environment where wave action distributed the sands (Lee and Payne, 1944, Siever, 1957). However many sheet deposits may simply represent non-channel sandstone phases lying between areas in which channel sandstones were deposited. The channel sandstones of western

Missouri probably grade into sheet type bodies. In the Marmaton group many channel sandstones were derived from local sediments (Jewett, 1945). It is further evident that the sandstones can be either marine or non-marine in origin. In general the sandstones were deposited in a variety of shallow water, littoral, lagoonal, deltaic, and coastal plain alluvial environments (Lee and Payne, 1944, Jewett, 1945, Siever, 1957). Other evidence of changing environmental conditions is provided by the large number of sandstones, shales, limestones, and coals which have been identified in well samples, on well logs, and at the outcrops.

The positive areas during Des Moines time were probably the Trans-Continental Arch, parts of the Canadian Shield, the Nemaha Uplift, and the Ozark Uplift area. Tectonic activity during the deposition of the Des Moines Series was probably limited to intermittent subsidence of the Forest City Basin, rejuvenation of faulting and uplift of the source areas, and local growing structural elements existed within the basin, synclines and anticlines, which along with pre-existing structural and topographic elements probably influenced the thickness and the type of deposition. Thus at the end of the Des Moines Epoch, and prior to regional uplift, the Forest City, Cherokee, and Illinois Basins were part of one large embayment of the encroaching Pennsylvanian sea (Fig. 3).

## PETROLEUM PRODUCTION AND ITS RELATIONSHIP TO GEOLOGIC STRUCTURE AND SEDIMENTARY ROCK FACIES

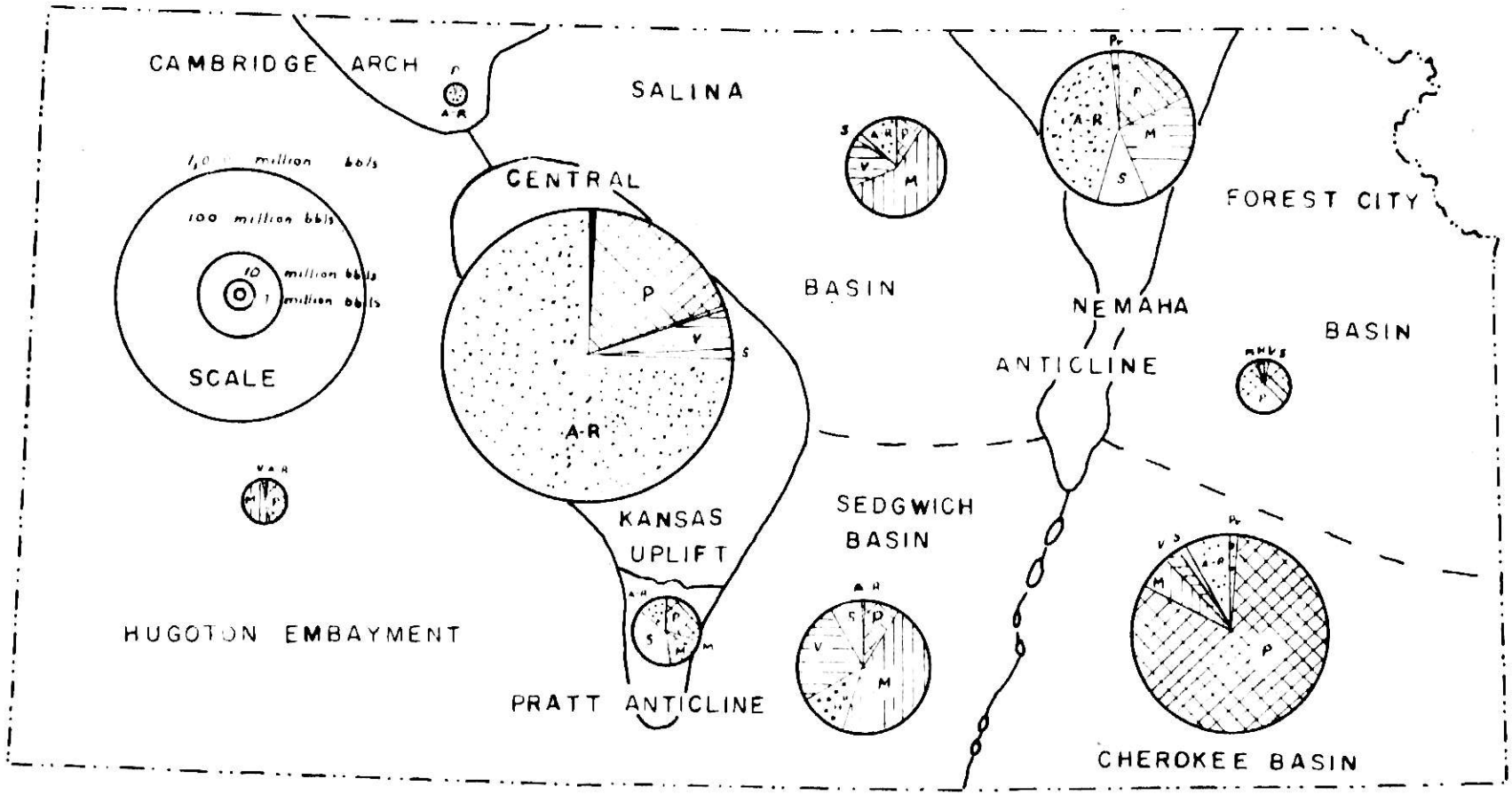
Petroleum production from sedimentary rocks in the Kansas

portion of the Forest City Basin is slight in comparison to other Kansas post-Mississippian structural provinces. Plate IV shows the percentage of cumulative oil production by producing zones for the various structural provinces in Kansas. The writer estimates that approximately 150,000 barrels of oil were produced during 1958 in Nebraska and Missouri. Commercial accumulations of oil were not discovered in Iowa during 1958, nor were commercial accumulations of oil discovered in sedimentary rocks of Des Moines age in the Nebraska portion of the Forest City Basin. Petroleum production during 1958 from rocks of Des Moines age in the Kansas portion of the basin amounted to approximately 2,310,000 barrels (Goebel, Hilpman, and Beene, 1959). The writer estimates approximately 15,000 barrels of oil was produced from rocks of Des Moines age in the Missouri portion of the Forest City Basin. The major oil accumulations that were present in the basin during 1958 occurred in rocks of Cherokee age. Within the Cherokee group the Burgess, McLouth, Bartlesville, and Squirrel sandstones are the main reservoir rocks. Minor accumulations of oil occur in rocks of Marmaton age, and the Marmaton group contains the Peru, Weiser, and Wayside sandstones. Production records by county are printed each year by the Oil and Gas Division of the Kansas Geological Survey. Plate V shows the location of oil fields which have production from rocks of Des Moines age. Statistics on oil production by county are given in Table 1.

## EXPLANATION OF PLATE IV

Map of Kansas showing percentage of cumulative oil production by producing zones for post-Mississippian structural provinces (Goebel, Hilpman, and Beene, 1959).

# PLATE IV



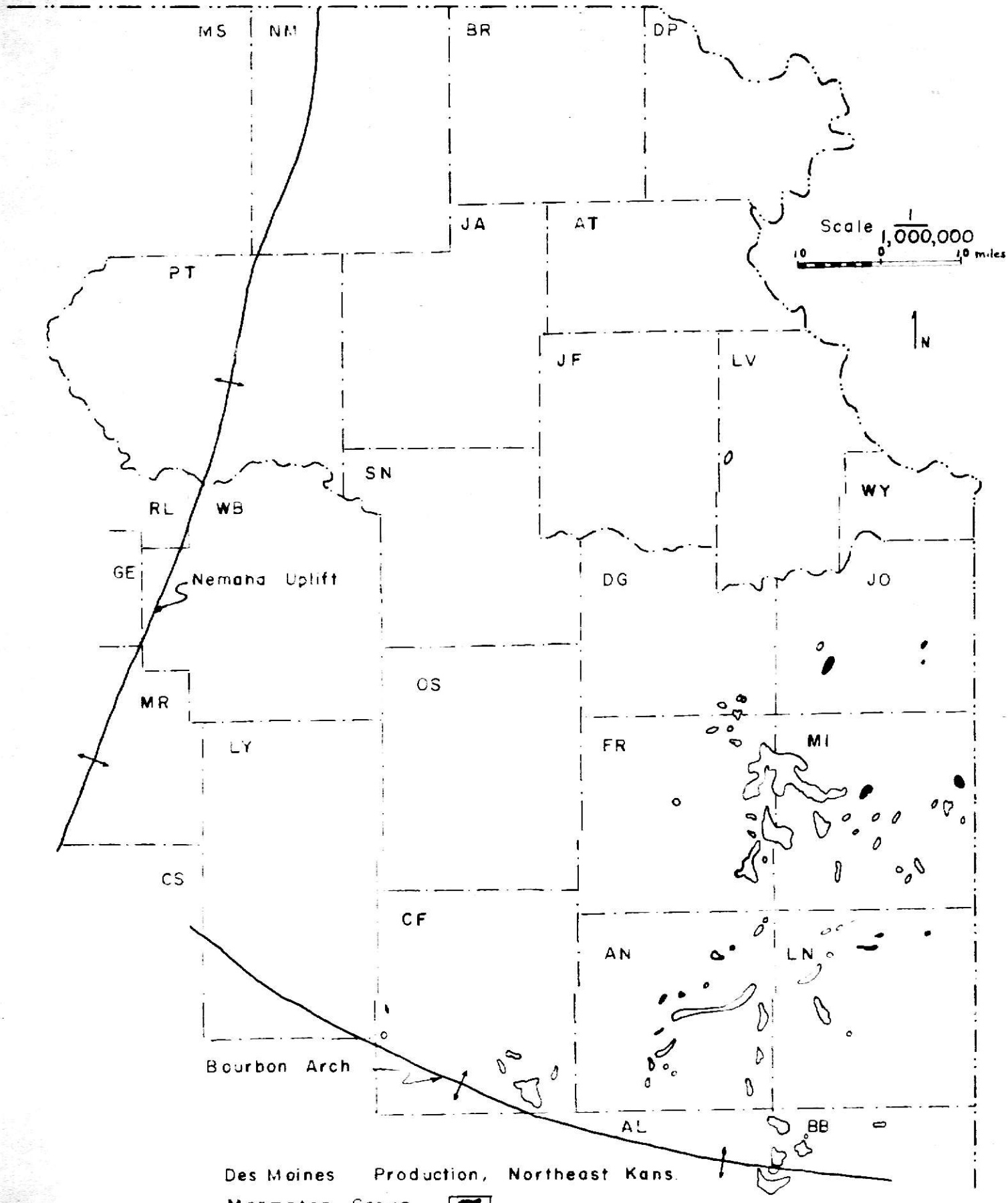

Pr-Permian P-Pennsylvanian M-Mississippian H-Hunton V-Viola S-Simpson A-R-Arbuckle-Reagan PC-Precambrian

From Goebel, Hilpman, Beene, 1959

## EXPLANATION OF PLATE V

The map shows the location of various fields that have oil production from Marmaton and Cherokee rocks.

# PLATE V




By M.L. Moderak, 1960

Table 1. Barrels of oil produced from rocks of Des Moines age during 1958 in the Forest City Basin.

| Oil production in bbls. by county | | | | |
|---|---|---|---|---|
| Above 500,000 | Above 100,000 | Above 50,000 | Above 10,000 | Less than 10,000 |
| Allen<br>Anderson | Franklin<br>Miami | Linn | Bourbon<br>Coffey | Douglas<br>Leavenworth<br>Johnson |

## Cherokee Production

Most reservoir rocks in the Cherokee group are channel and lense-shaped sandstone bodies which provide stratigraphic traps when surrounded by impermeable shale or limestone. Correlation of the producing areas (Plate V) with the Cherokee isopach map (Fig. 2) indicates that most accumulations are located in areas of topographic and structural highs as reflected by thinning in the Cherokee interval associated with the underlying Mississippian limestones. Many of the major topographic and structural highs are reflected in surface rocks, and are mappable locally (Jewett, 1954). Therefore, a majority of the Cherokee reservoir rocks have surface structural anomalies resulting from differential compaction of the shale units over structural and topographic highs which are present in the underlying Mississippian rocks. Structural control resulting from differential compaction is probably one of the major factors which influenced petroleum accumulation. Accumulation of oil in Cherokee rocks in

Franklin, Miami, and Leavenworth Counties, Kansas, is probably influenced by such buried structures. Topographic and structural highs exist in Cass, Clinton, and Worth Counties, Missouri, which have reported little, or have not, as of 1958, reported commercial accumulations of petroleum.

A good correlation between 1958 oil accumulations in Cherokee rocks and a particular facies value does not exist, however, most accumulations occur where the facies ratios are .5 - 1 or less (comparison of Cherokee facies map, Fig. 2, and Plate V). The Banker's field in Leavenworth County, Kansas, and parts of Franklin County, Kansas, have accumulations in Cherokee rocks that have ratios less than .125. One fourth of the area within the Forest City Basin contains rocks which have a ratio that is less than .125, and in which accumulation of oil has not, as of 1958, been discovered. The fact that little correlation exists between specific facies values and present accumulations of oil is probably the result of the number of well logs used in the investigation, and the variability of the sand-shale ratios within a restricted area. Also, the units selected within the Cherokee group represent different segments of the depositional framework. A facies study by county which would utilize a greater number of well logs might result in a better correlation between oil accumulations and a specific facies. This type of facies analysis might possibly be used as a basis for future exploration. Therefore, due to the semi-regional aspect of the investigation, and the changing characteristics of individual sandstone bodies, it is impossible to draw an accurate conclusion

between the relationship of 1958 oil accumulations and specific facies values. The only apparent correlation is between present accumulations and topographic and structural highs in the underlying Mississippian limestones as revealed by thinning in the Cherokee stratigraphic interval (Cherokee isopach map, Fig. 2).

## Marmaton Production

A relationship between the Marmaton isopach map (Fig. 3) and oil accumulations in Marmaton rocks during 1958 (Plate V) does not exist primarily because the structural and topographic features which influenced Cherokee accumulation were covered by the deposition of the Cherokee sediments. A correlation exists between present accumulations of oil in Miami County, Kansas, where some of the county's production is from Marmaton rocks, and a structural high which is delineated by thinning in the Cherokee stratigraphic interval (Fig. 2). This correlation is probably caused by differential compaction of the Cherokee shales over a structural or topographic high in the underlying Mississippian limestones which resulted in forming the structural control necessary to influence accumulation in the Marmaton rocks.

Petroleum accumulations in rocks of Marmaton age in Miami and Linn Counties, Kansas, lie between the ratios 2 - 4 (Marmaton facies map, Fig. 3). Approximately one fourth of the Marmaton rocks in the Forest City Basin are composed of this ratio; therefore, it is evident, as in Figure 2 of the Cherokee group, little possibility exists for using this facies investigation as

an exploration tool. One area in northeastern Miami County, Kansas, has an oil accumulation in a specific facies which has a clastic ratio greater than 8. Several areas exist along the Nemaha Uplift, and an area exists in southeastern Wabaunsee County, Kansas, which contain rocks having a clastic ratio that exceeds 8, and which during 1958 have not been reported as containing commercial accumulations of petroleum. The relationship of structure to oil accumulation has been discussed; therefore, it is evident that more intensive facies investigations are needed to analyze the relationship between a specific facies value and associated oil accumulation in order to permit facies evaluation of untested areas.

## CONCLUSION

The Forest City Basin was the result of deformation which occurred following the deposition of the Mississippian limestones. The Nemaha Uplift and the Bourbon Arch were formed during this period of deformation. The Bourbon Arch and the Nemaha Uplift were topographic barriers which confined sedimentation and formed the boundaries for an inland sea. The oldest deposit of Cherokee age that is present in the deeper portion of the basin is an unnamed dark shale. The first marine sediments to be deposited within the basin are of McLouth age, and evidence gained from the Cherokee facies map indicates that marine water probably entered the Forest City Basin by a connection north of the Lincoln fold from the Illinois Basin. Structural evidence gained from the interpretation of the Cherokee isopach map

indicates the first marine sediments were probably deposited at a level below the lowest portion of the Bourbon Arch. Therefore, the Bourbon Arch was a temporary barrier which separated the Forest City Basin from the Cherokee Basin. The Forest City and Cherokee Basins merged sometime before the deposition of the Bartlesville sandstone. The Burgess and McLouth sandstones have a quartzose composition, and the Bartlesville and Squirrel sandstones are of a sub-graywacke type. The major source of sediments was from the north, and the source area was probably parts of the Canadian Shield and the Trans-Continental Arch. The Nemaha Uplift was never of high relief, nor was it a major source of sediments; however, the Nemaha Uplift and the Ozark Uplift were minor sources of sediments for areas near the structures.

A correlation exists between Cherokee oil accumulations which were known during 1958, and structural and topographic highs in the underlying Mississippian limestones that are delineated by thinning in the Cherokee stratigraphic interval. Topographic and structural highs in the Mississippian limestones have been reflected by differential compaction of the Cherokee shales to the Marmaton rocks; thus differential compaction may have locally resulted in forming the structural control necessary to cause oil accumulation in Marmaton rocks. A relationship between a specific facies value and known oil accumulations of 1958 was not determined.

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# APPENDIX

# OVERSIZED MAP

## THE FOLLOWING MAP IS FILMED IN SECTIONS.

## THE FIRST IMAGE(S) IS OF THE LEGEND

## THE FOLLOWING IMAGES WILL BE TAKEN FROM LEFT TO RIGHT, TOP TO BOTTOM. SEE EXAMPLE BELOW;

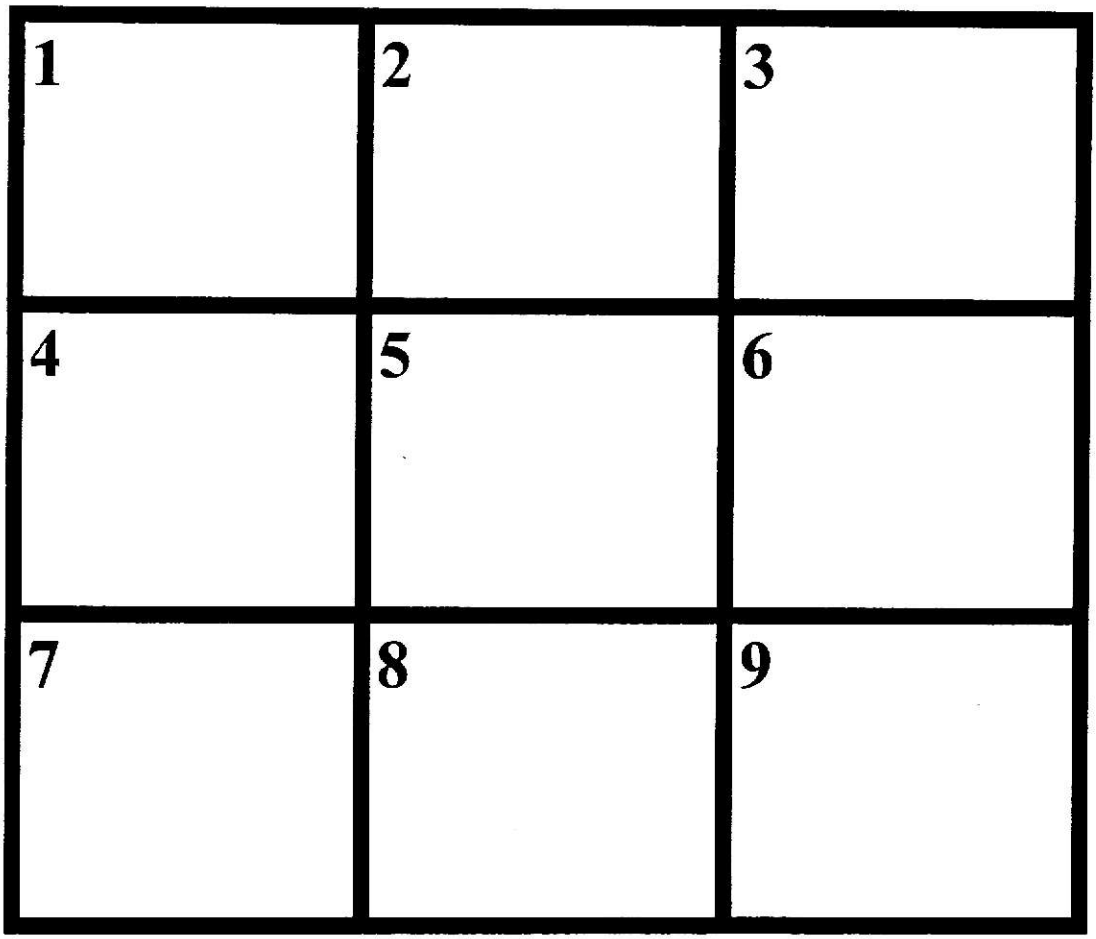


FIGURE 1

7½x10½
PEERLESS
CLASP
FEDERAL ENVELOPE CO.

Figure 1

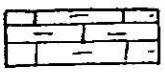
# FOREST CITY BASIN
## Des Moines Series

Lithology

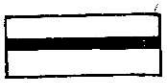
sandstone

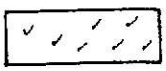
sandy-shale

shale


shaly-limestone

limestone

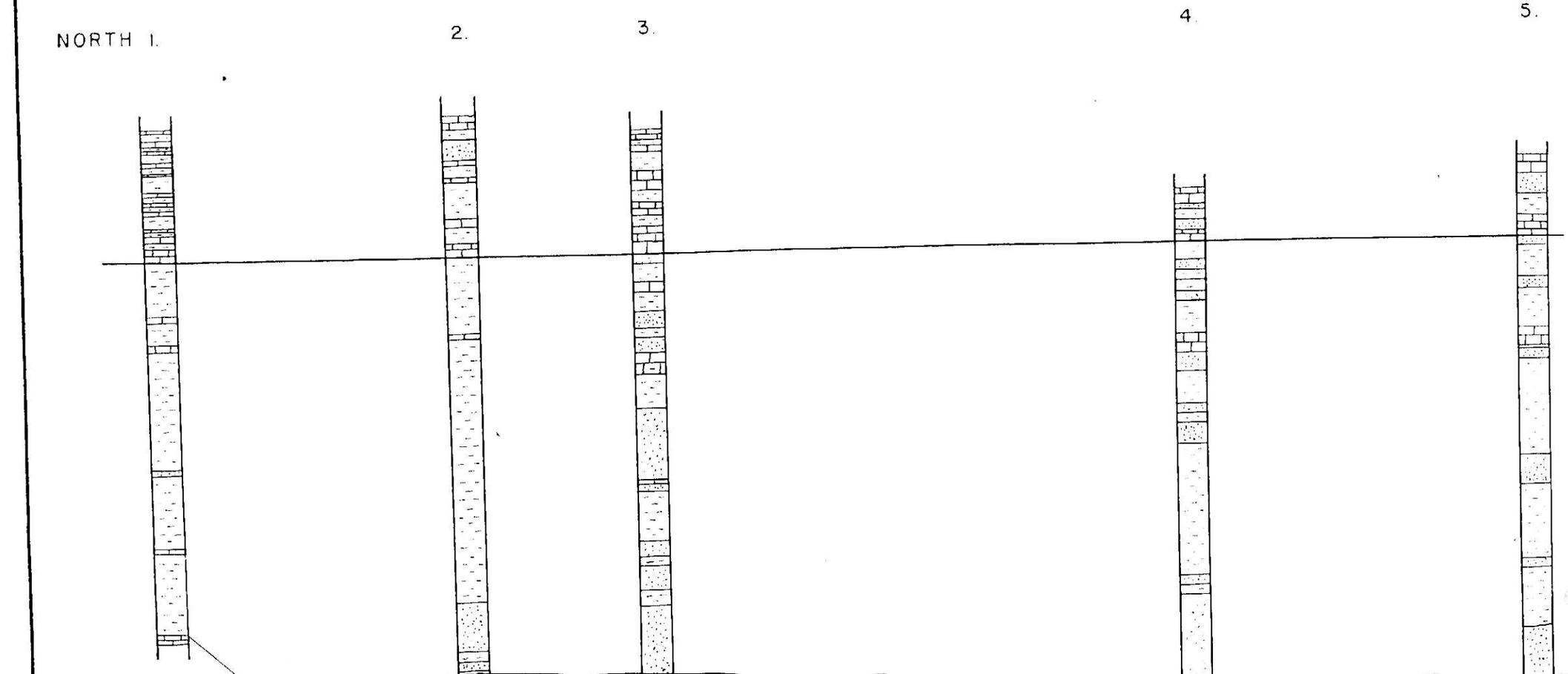

coal


granite

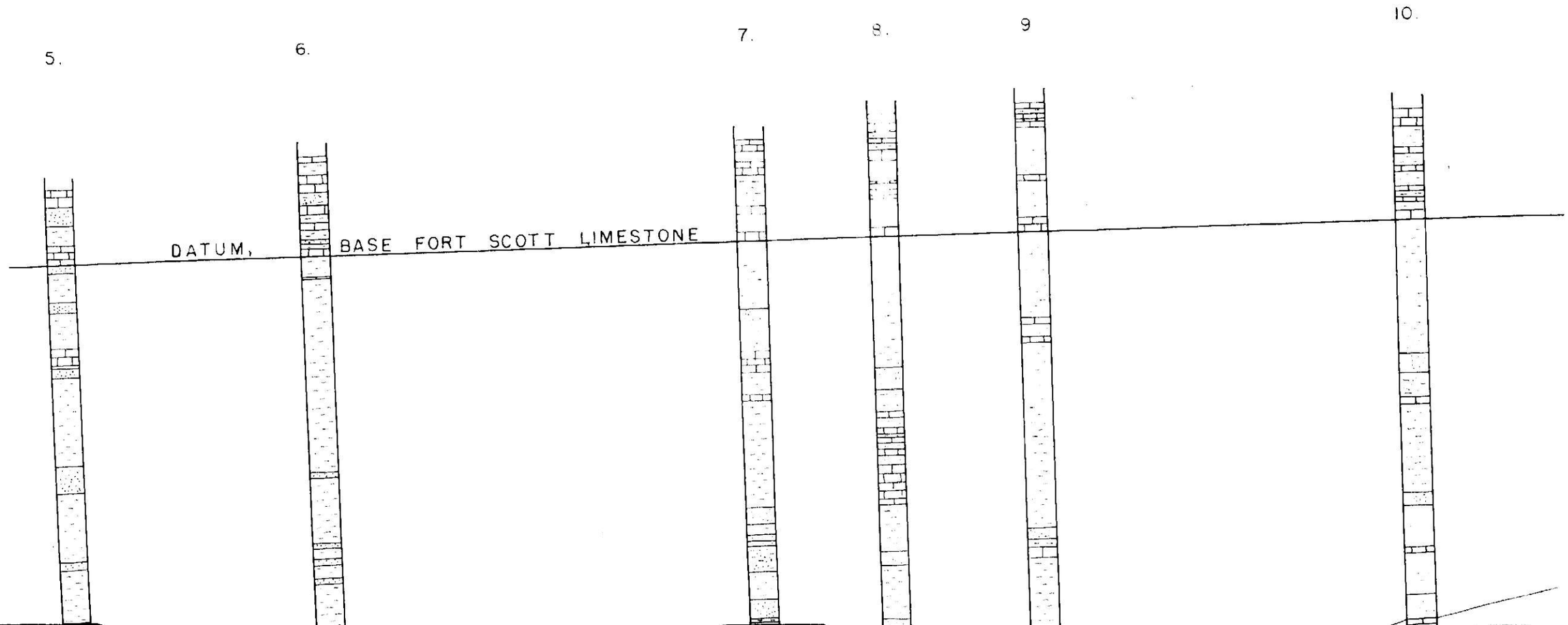
Drawn by

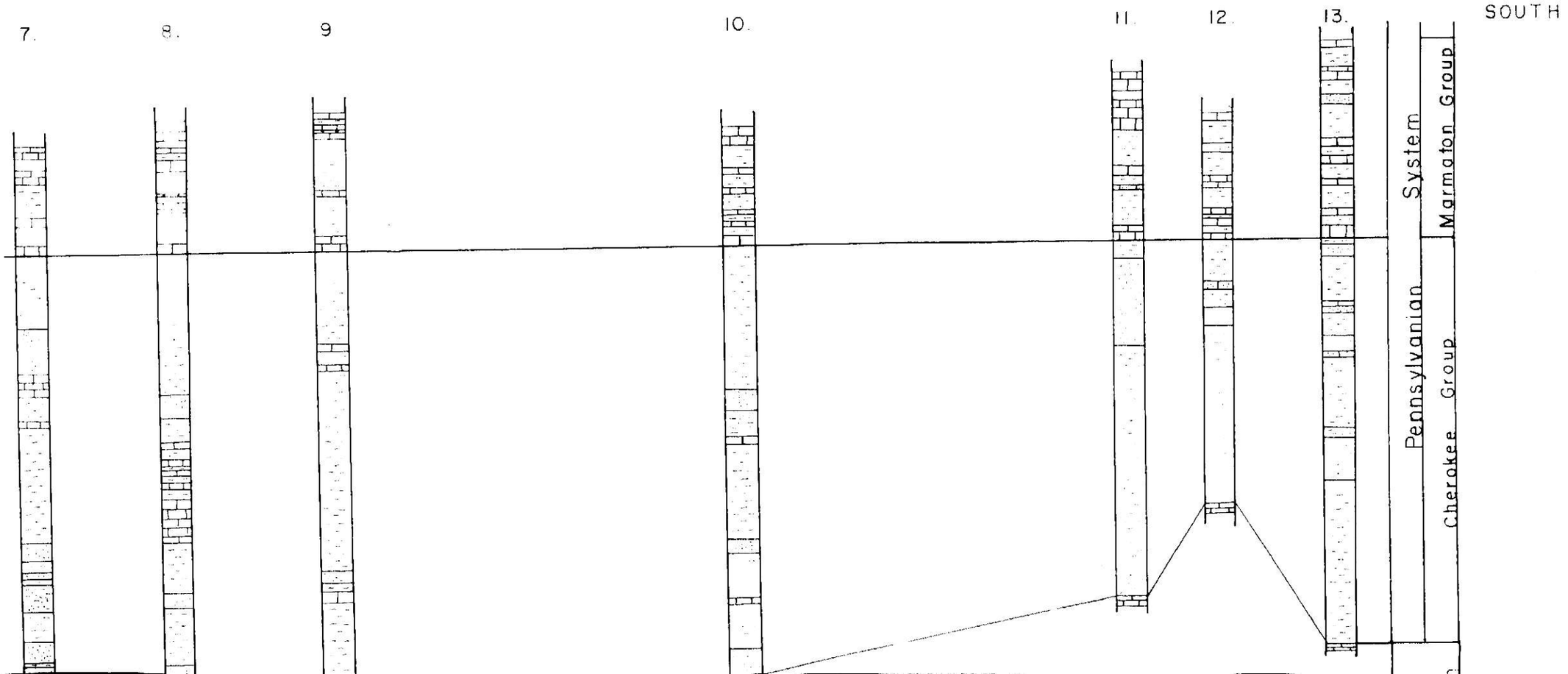
Marion L. Maderak

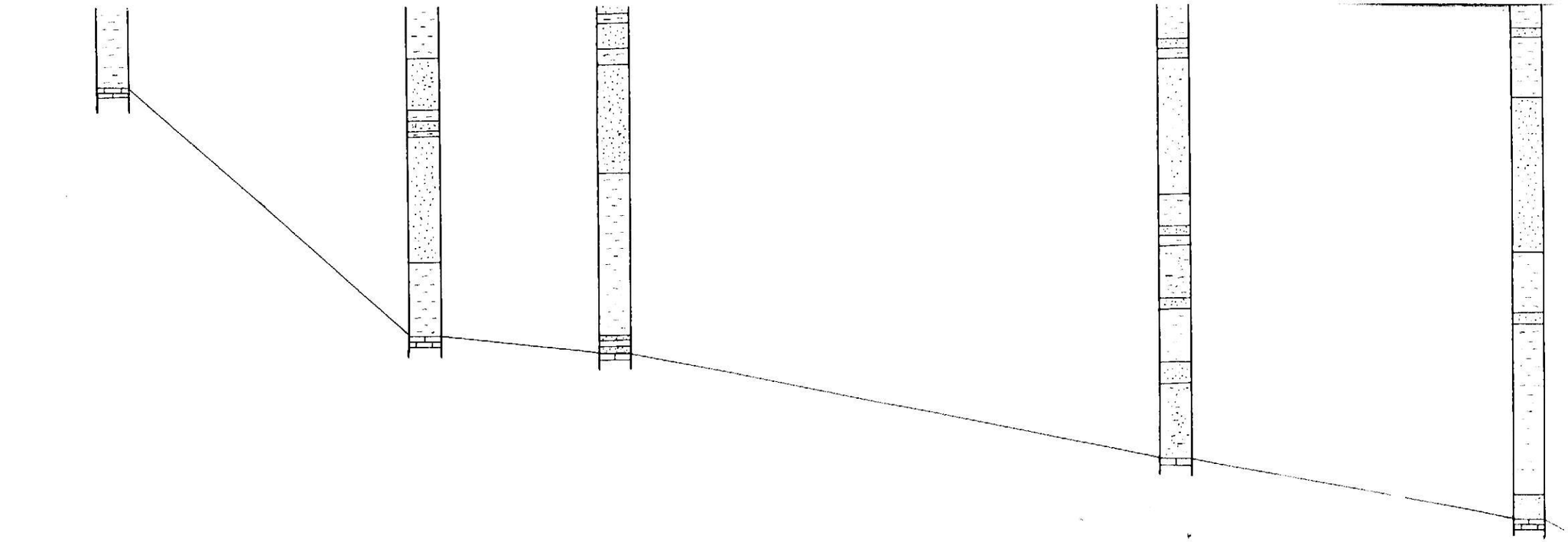
1960

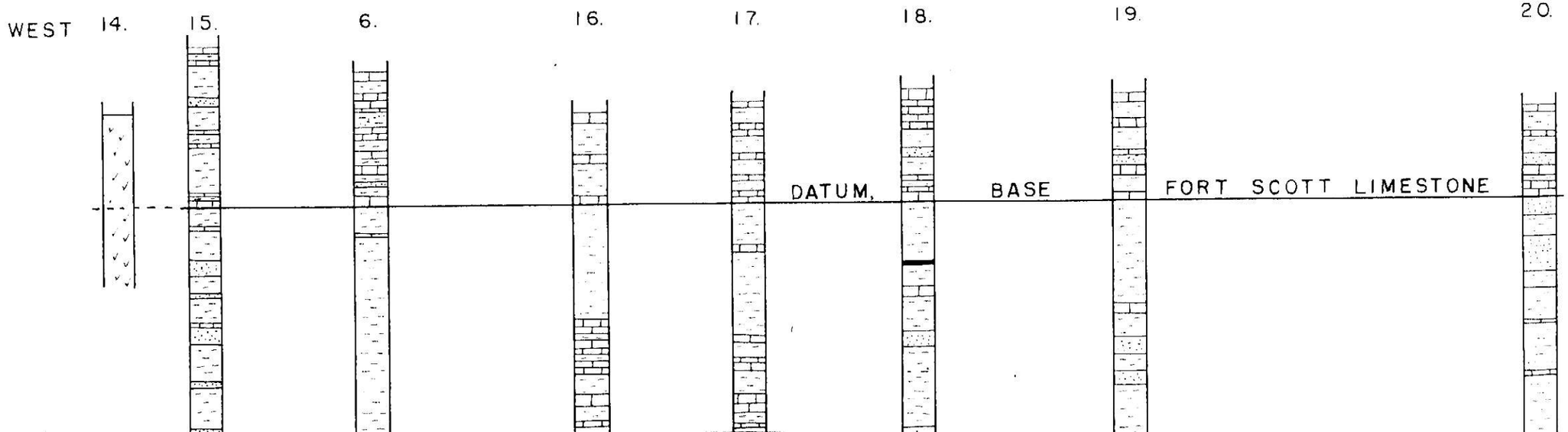

NORTH 1.
2.
3.
4.
5.

# CROSS SECTION




7.
8.
9
10.
11.
12.
13.
SOUTH
Pennsylvanian System
Marmaton Group
Cherokee Group

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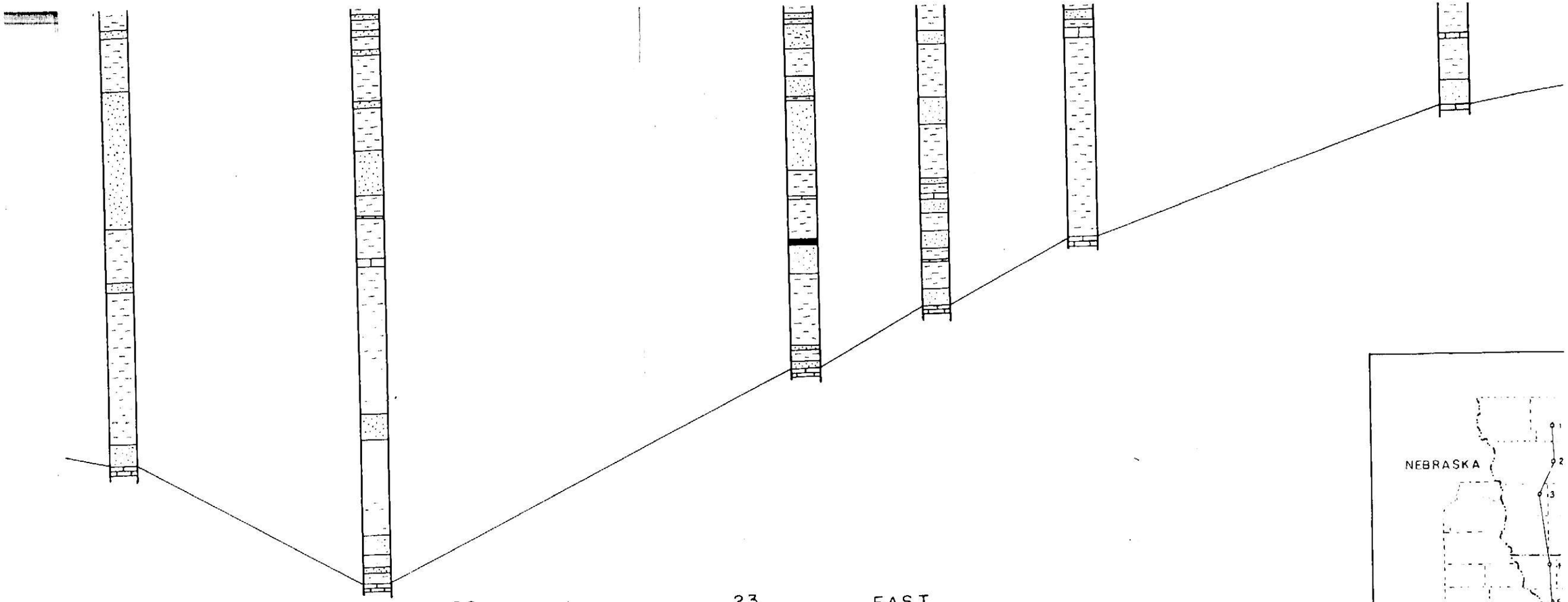
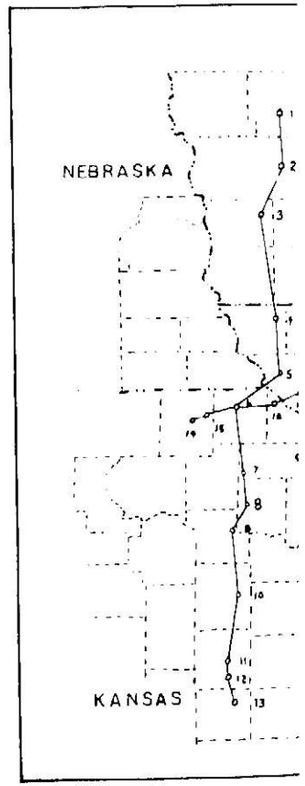
6.
16.
17.
18.
19.
20.
DATUM, BASE FORT SCOTT LIMESTONE


20.
21.
22.
23.
EAST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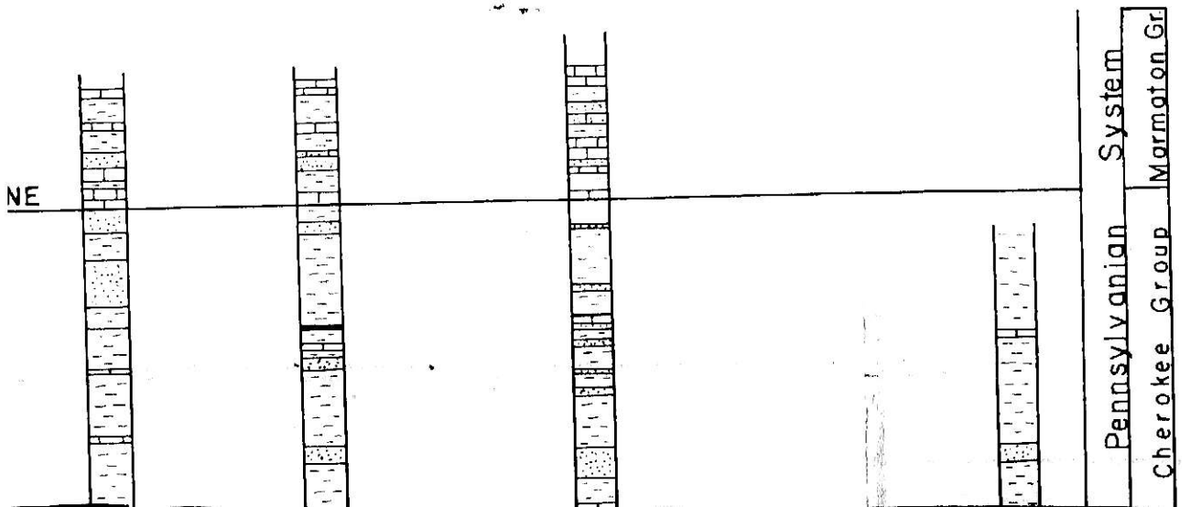
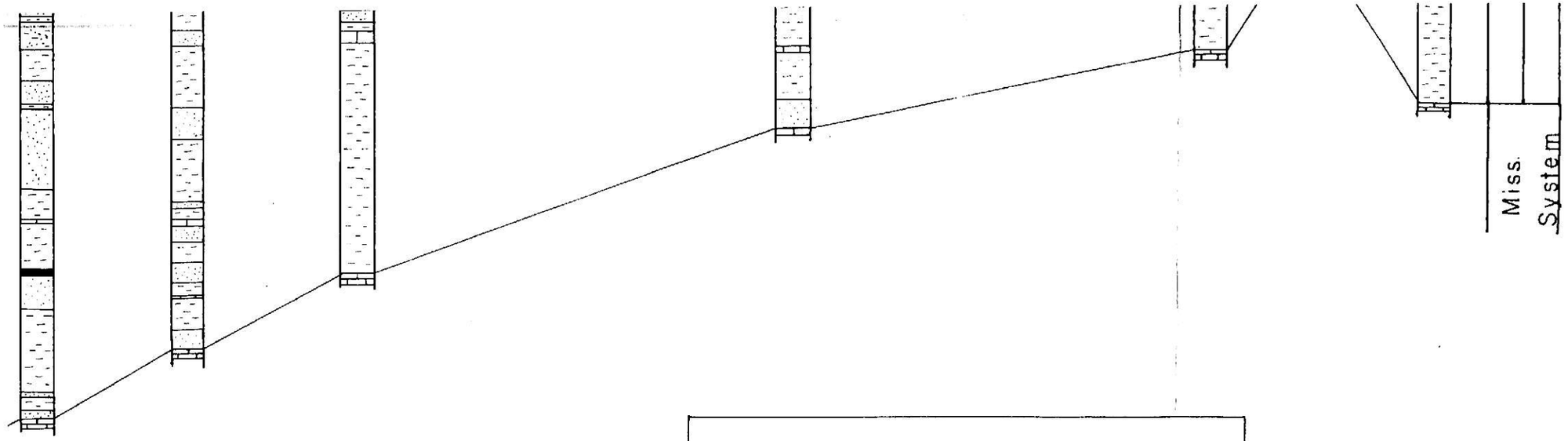
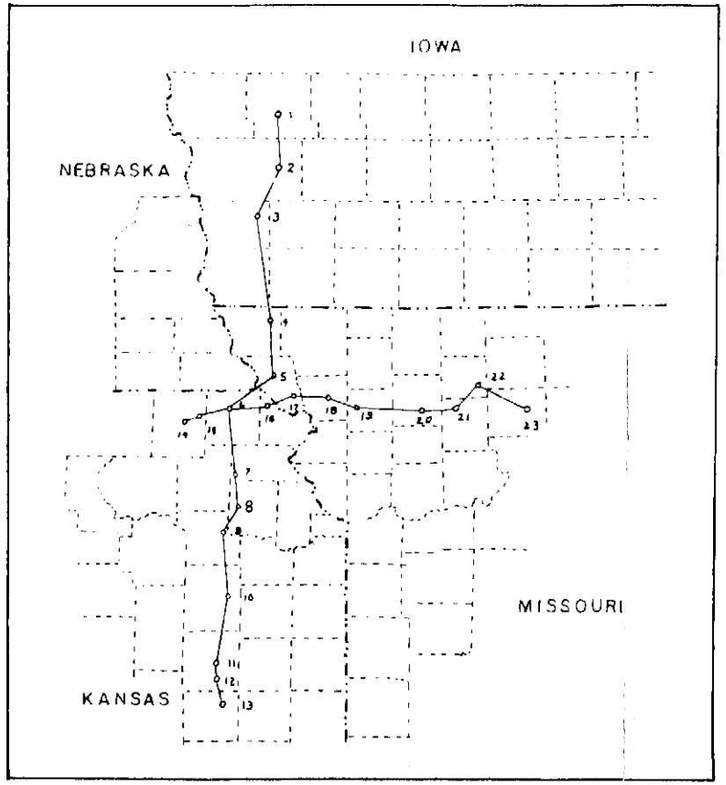
KANSAS


NE
Pennsylvanian System
Cherokee Group
Marmaton Gr


Miss.
System

EAST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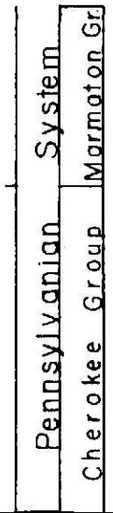
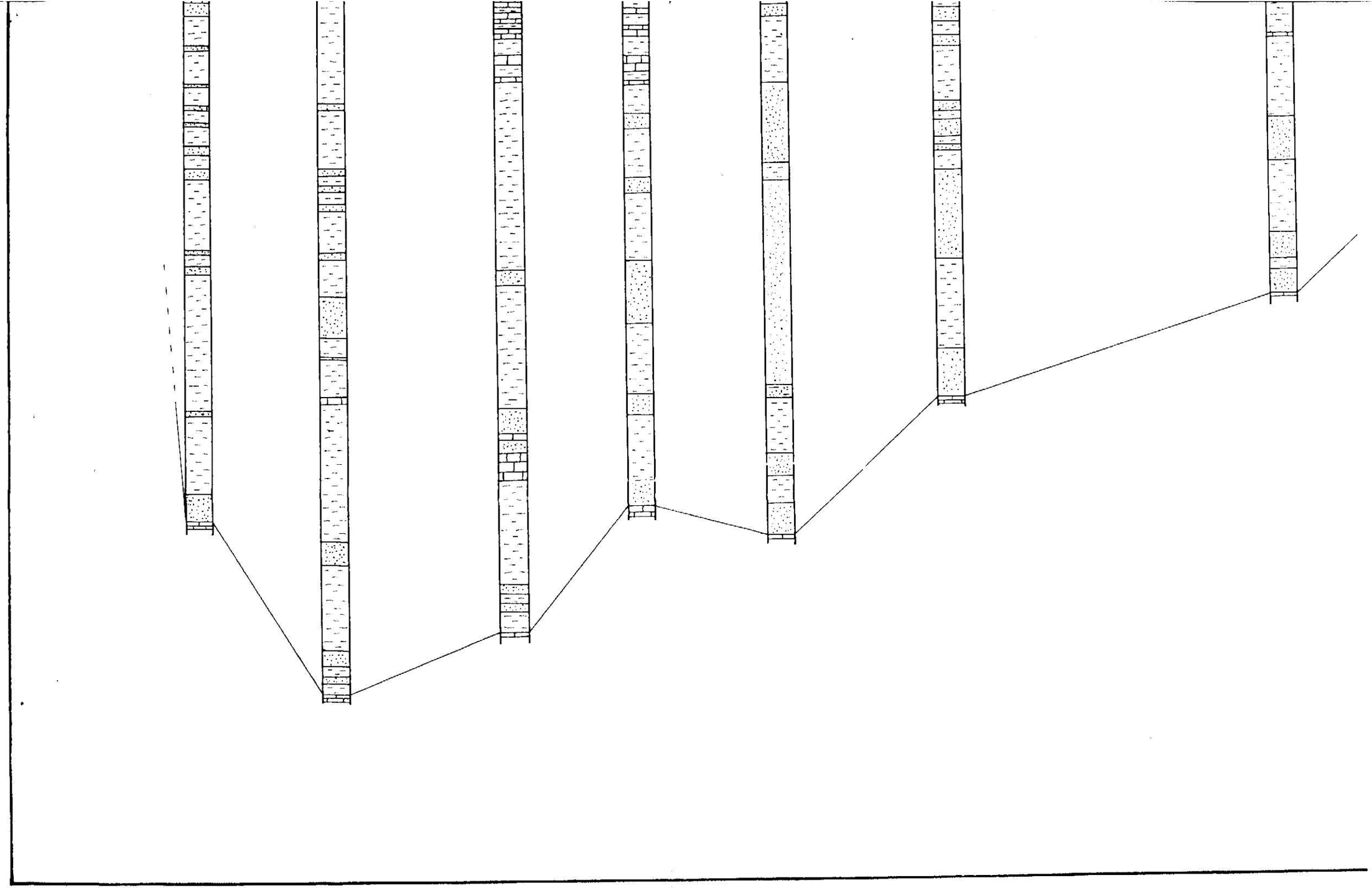
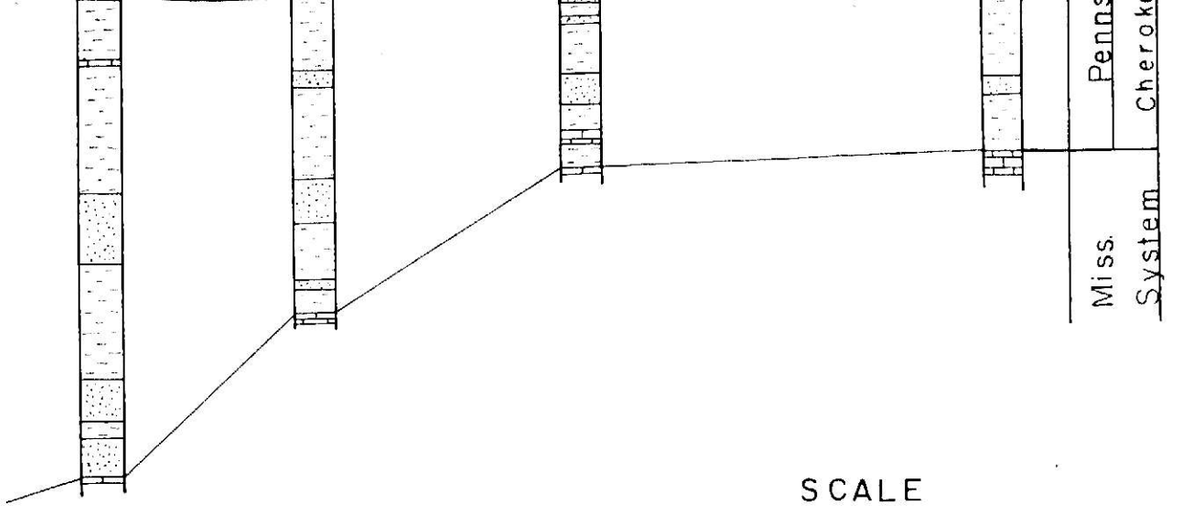
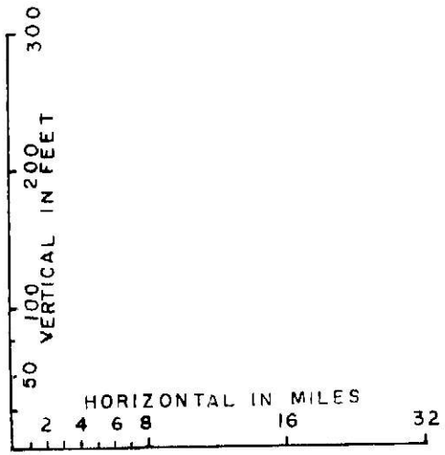
NEBRASKA
MISSOURI
KANSAS


Pennsylvanian System
Cherokee Group
Marmaton Gr






SCALE




## Well Locations

| | | |
|---|---|---|
| 1. | Shelby Co., Iowa | sec 18, T. 79 N., R. 38 W |
| 2 | Pottawattamie Co., Iowa | sec. 11, T. 75 N, R 39 W |
| 3. | Mills Co., Iowa | sec. 15, T. 73 N., R. 40 W |
| 4 | Atchison Co., Mo | sec. 12, T 66 N., R. 39 W |
| 5 | Holt Co., Mo. | sec. 30, T 62 N, R. 39 W |
| 6 | Brown Co., Kans. | sec. 15, T. 1 S., R. 16 |
| 7. | Atchison Co, Kans. | sec. 19, T. 7 S., R. 17 |
| 8 | Jefferson Co., Kans. | sec. 8, T 9 S., R. 17 |
| 9. | Shawnee Co., Kans. | sec. 14, T. 11 S, R. 16 |
| 10. | Osage Co., Kans. | sec. 14, T. 16 S, R 16 |
| 11. | Coffey Co., Kans. | sec. 13, T. 21 S, R 15 |
| 12. | " " " | sec. 19, T 22 S., R 16 |
| 13. | Woodson Co., Kans. | sec. 8, T 24 S, R. 16 |
| 14. | Nemaha Co., Kans. | sec. 16, T. 2 S, R 13 |
| 15. | " " " | sec. 3, T. 2 S, R 14 |
| 16. | Doniphan Co., Kans. | sec 21, T. 1 S, R. 19 |
| 17 | Holt Co., Mo. | sec 32, T 60 N., R. 37 |
| 18. | Andrew Co., Mo. | sec 28, T 60 N, R 35 |
| 19. | Dekalb Co., Mo. | sec 18, T 59 N, R. 32 |
| 20. | Daviess Co., Mo. | sec 28, T 59 N., R 27 |
| 21. | Livingston Co., Mo. | sec. 16, T 59 N., R 25 W |
| 22. | Grundy Co, Mo. | sec 12, T 60 N., R. 23 |
| 23. | Linn Co., Mo. | sec. 30, T 57 N, R. 18 |

Penns. | Cherok
Miss. | System

## Well Locations

| | | |
|---|---|---|
| 1. | Shelby Co., Iowa | sec. 18, T. 79 N., R. 38 W. |
| 2 | Pottawattamie Co., Iowa | sec. 11, T. 75 N, R. 39 W. |
| 3. | Mills Co., Iowa | sec. 15, T. 73 N., R. 40 W. |
| 4. | Atchison Co., Mo. | sec. 12, T 66 N., R. 39 W. |
| 5. | Holt Co., Mo. | sec. 30, T 62 N, R. 39 W |
| 6 | Brown Co., Kans. | sec. 15, T. 1 S., R. 16 E. |
| 7. | Atchison Co, Kans. | sec. 19, T. 7 S., R. 17 E. |
| 8 | Jefferson Co., Kans. | sec. 8, T 9 S., R. 17 E. |
| 9. | Shawnee Co., Kans. | sec. 14, T. 11 S, R. 16 E. |
| 10. | Osage Co., Kans. | sec. 14, T. 16 S., R 16 E |
| 11. | Coffey Co., Kans | sec. 13, T 21 S., R 15 E |
| 12. | " " " | sec. 19, T. 22 S., R. 16 E. |
| 13. | Woodson Co., Kans. | sec. 8, T 24 S, R. 16 E |
| 14. | Nemaha Co., Kans. | sec. 16, T. 2 S, R 13 E. |
| 15. | " " " | sec. 3, T. 2 S, R 14 E |
| 16. | Doniphan Co., Kans. | sec 21, T. 1 S, R. 19 E |
| 17. | Holt Co., Mo. | sec 32, T 60 N., R. 37 W. |
| 18. | Andrew Co., Mo. | sec. 28, T 60 N, R 35 W |
| 19. | Dekalb Co., Mo. | sec 18, T 59 N, R. 32 W. |
| 20. | Daviess Co., Mo. | sec 28, T 59 N., R 27 W. |
| 21. | Livingston Co., Mo. | sec. 16, T 59 N., R. 25 W. |
| 22. | Grundy Co., Mo. | sec 12, T 60 N., R. 23 W |
| 23. | Linn Co., Mo. | sec. 30, T. 57 N., R. 18 W. |

32
L

Figure 1

# FOREST CITY BASIN
## Des Moines Series

Lithology

- sandstone
- sandy-shale
- shale
- shaly-limestone
- limestone
- coal
- granite

Drawn by

Marion L. Maderak

1960

FIGURE 2

Figure 2

# FOREST CITY BASIN

## Cherokee Group

### Combined Sand-Shale Ratio and Isopach Map

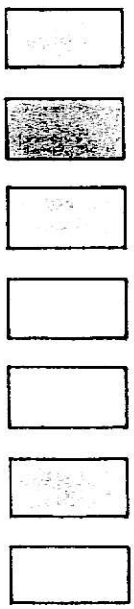
Legend

Isopachous Lines ————

Isolith Lines – – – – –

Isopach Contour Interval 50ft.

Sand-Shale Ratio



More Than 8

2 — 8

1 — 2

.5 — 1

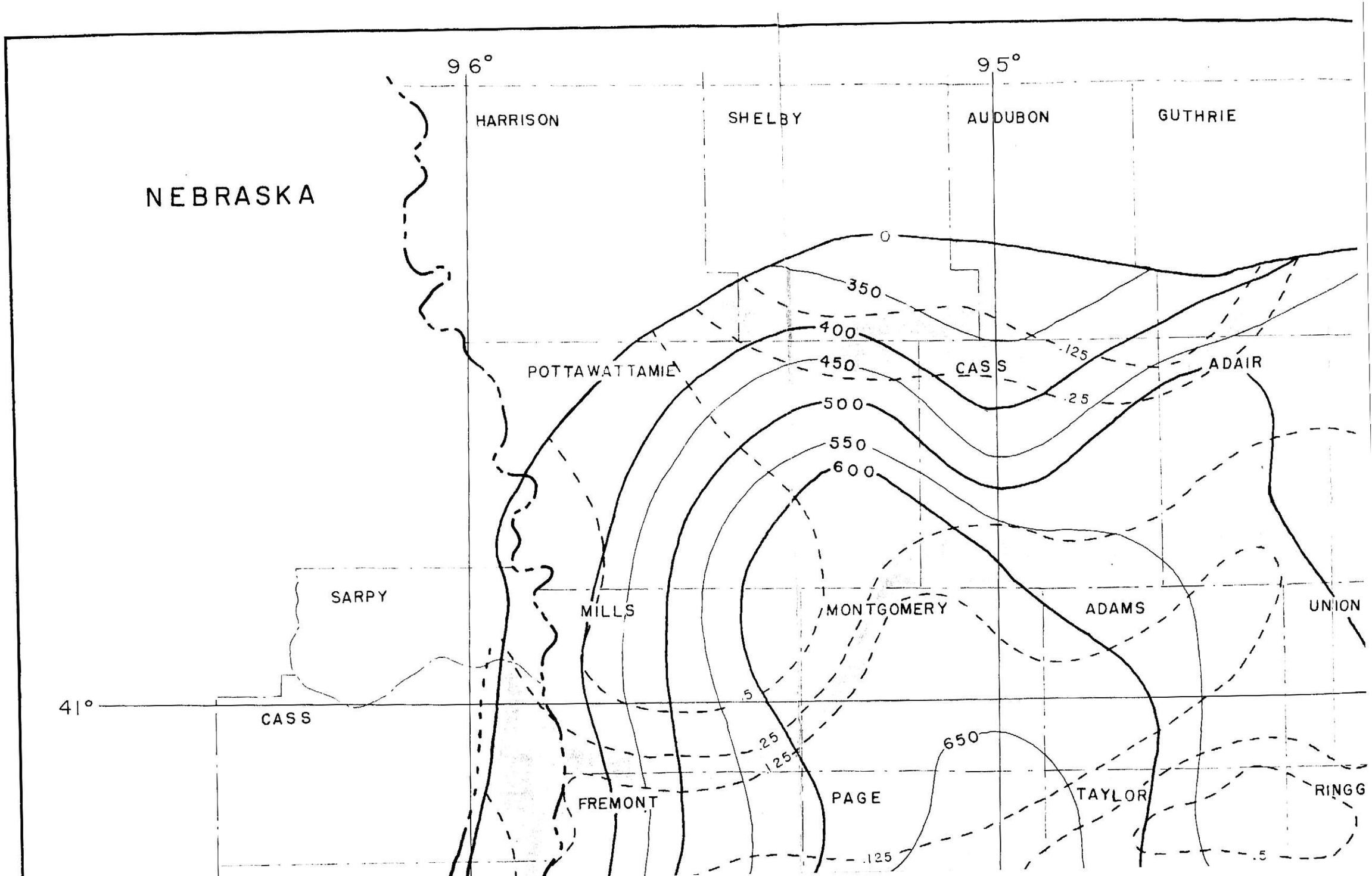
.25 — .5

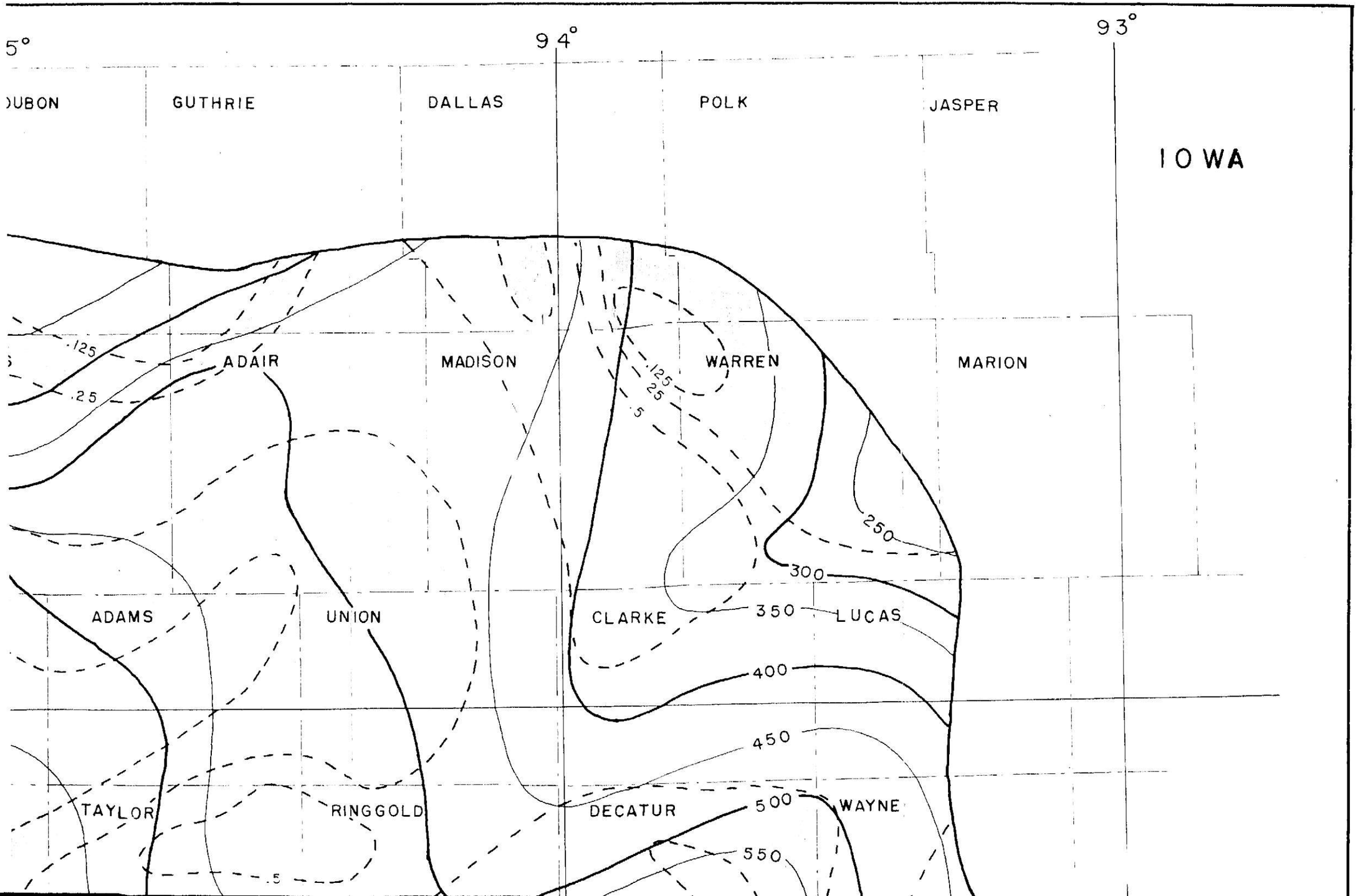
.125 — .25

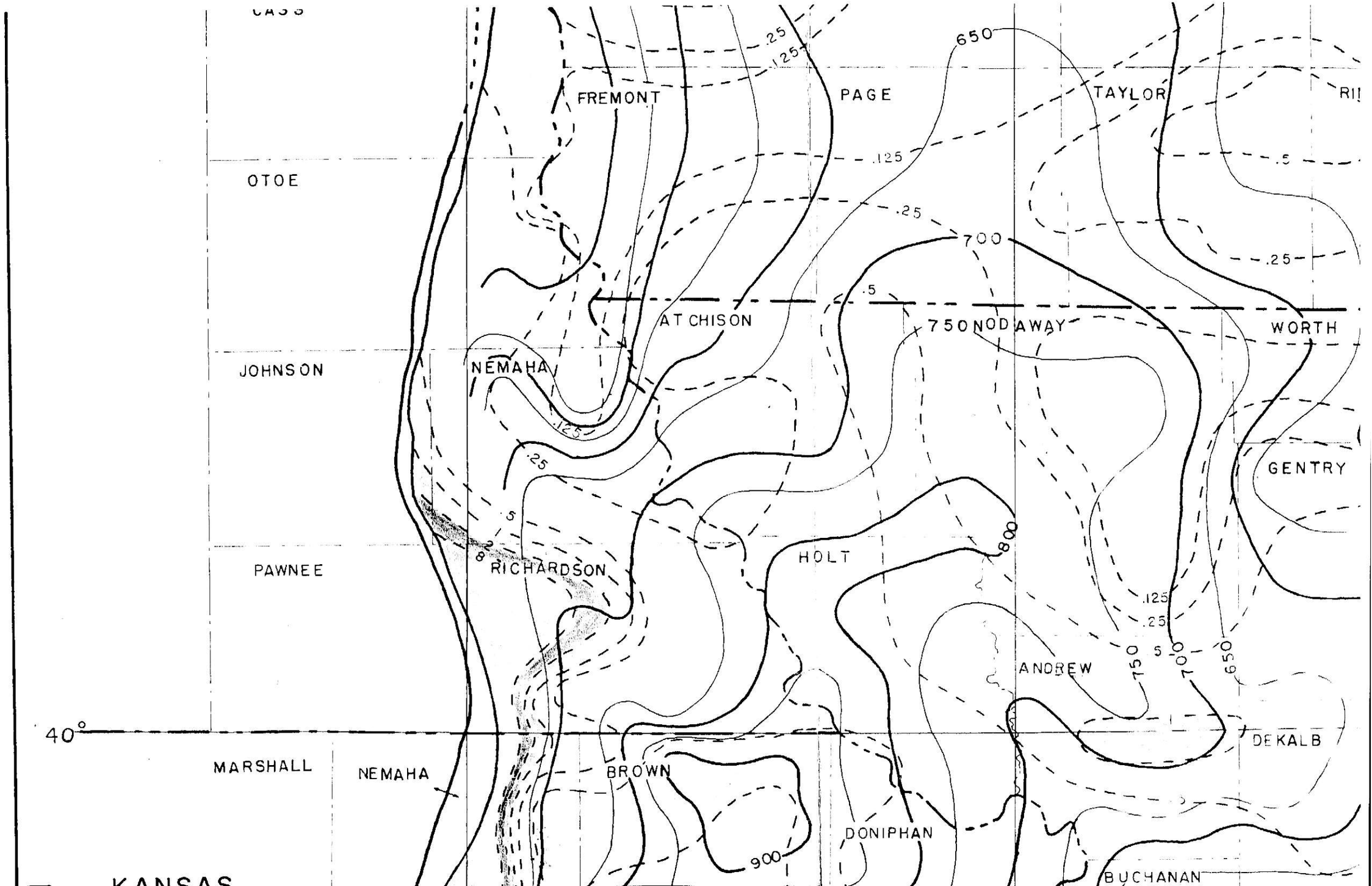
Less Than .125

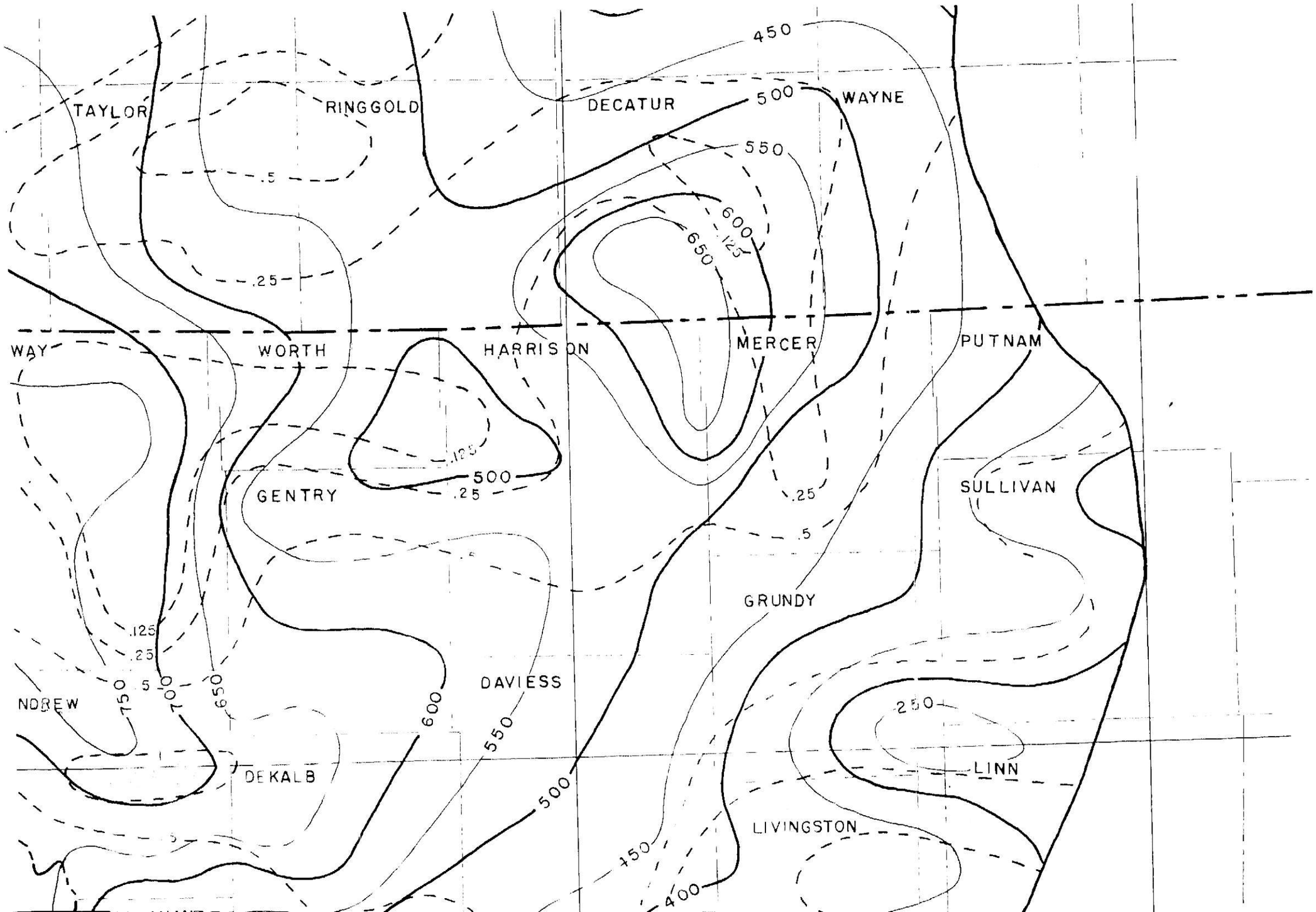
Scale 1:500,000

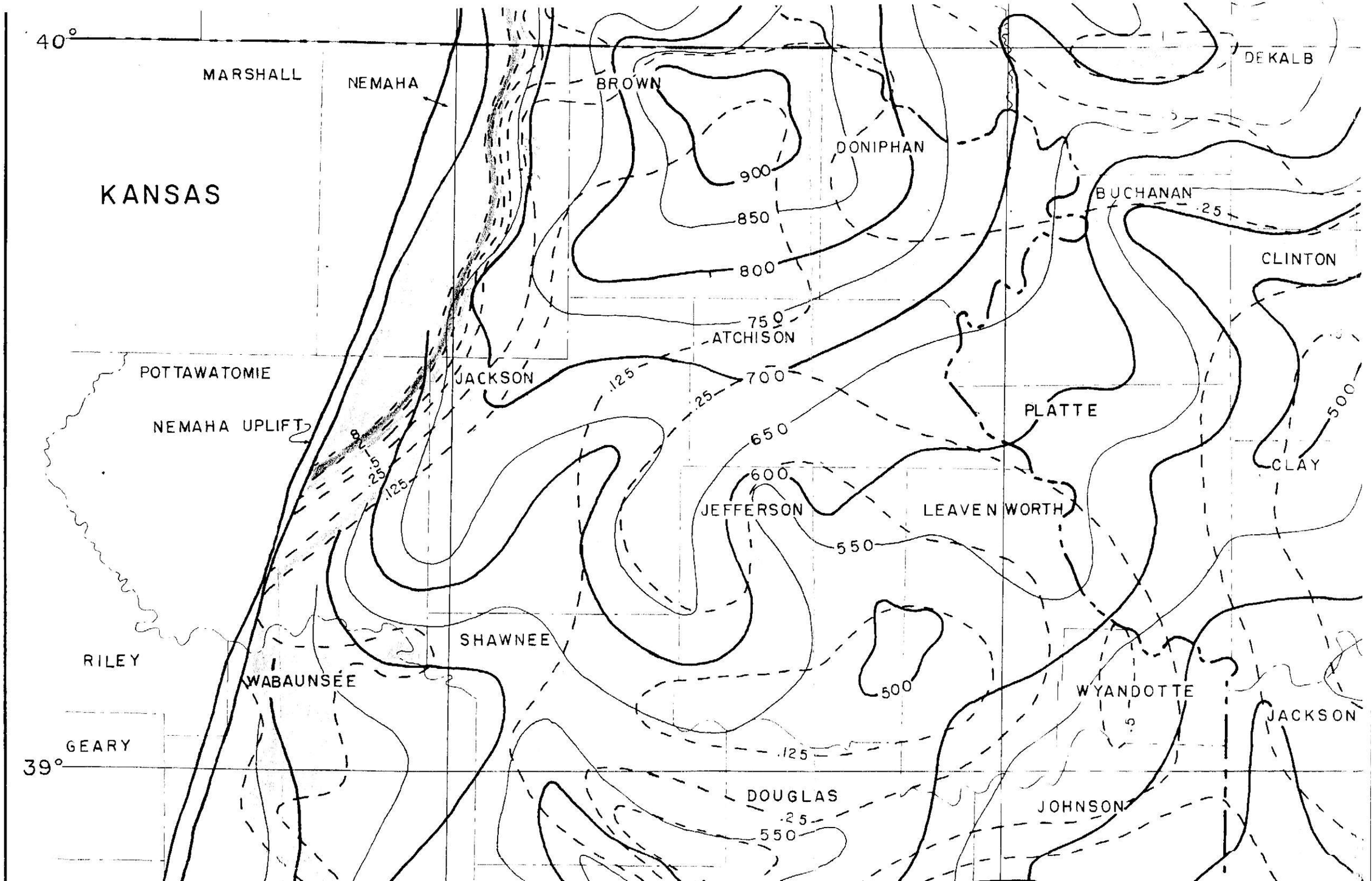
Drawn by M.L. Maderak, 1960


96°
95°
HARRISON
SHELBY
AUDUBON
GUTHRIE
NEBRASKA
0
350
400
450
500
550
600
650
.125
.25
.5
POTTAWATTAMIE
CASS
ADAIR
SARPY
MILLS
MONTGOMERY
ADAMS
UNION
41°
CASS
FREMONT
PAGE
TAYLOR
RINGG


95°
94°
93°
DUBON
GUTHRIE
DALLAS
POLK
JASPER
IOWA
ADAIR
MADISON
WARREN
MARION
ADAMS
UNION
CLARKE
LUCAS
TAYLOR
RINGGOLD
DECATUR
WAYNE
.125
.25
.5
250
300
350
400
450
500
550


CASS
FREMONT
PAGE
TAYLOR
OTOE
JOHNSON
NEMAHA
ATCHISON
NODAWAY
WORTH
GENTRY
PAWNEE
RICHARDSON
HOLT
ANDREW
40°
DEKALB
MARSHALL
NEMAHA
BROWN
DONIPHAN
BUCHANAN
KANSAS
.25
.125
650
700
750
800
900
.5


TAYLOR
RINGGOLD
DECATUR
WAYNE
WAY
WORTH
HARRISON
MERCER
PUTNAM
GENTRY
SULLIVAN
GRUNDY
DAVIESS
NDREW
DEKALB
LINN
LIVINGSTON
450
500
550
600
650
700
750
400
250
.125
.25
.5


40°
MARSHALL
NEMAHA
BROWN
DONIPHAN
DEKALB
KANSAS
900
850
800
BUCHANAN
.25
CLINTON
750
ATCHISON
POTTAWATOMIE
JACKSON
.125
700
.25
PLATTE
NEMAHA UPLIFT
650
500
.5
.25
.125
600
CLAY
JEFFERSON
LEAVENWORTH
550
SHAWNEE
RILEY
WABAUNSEE
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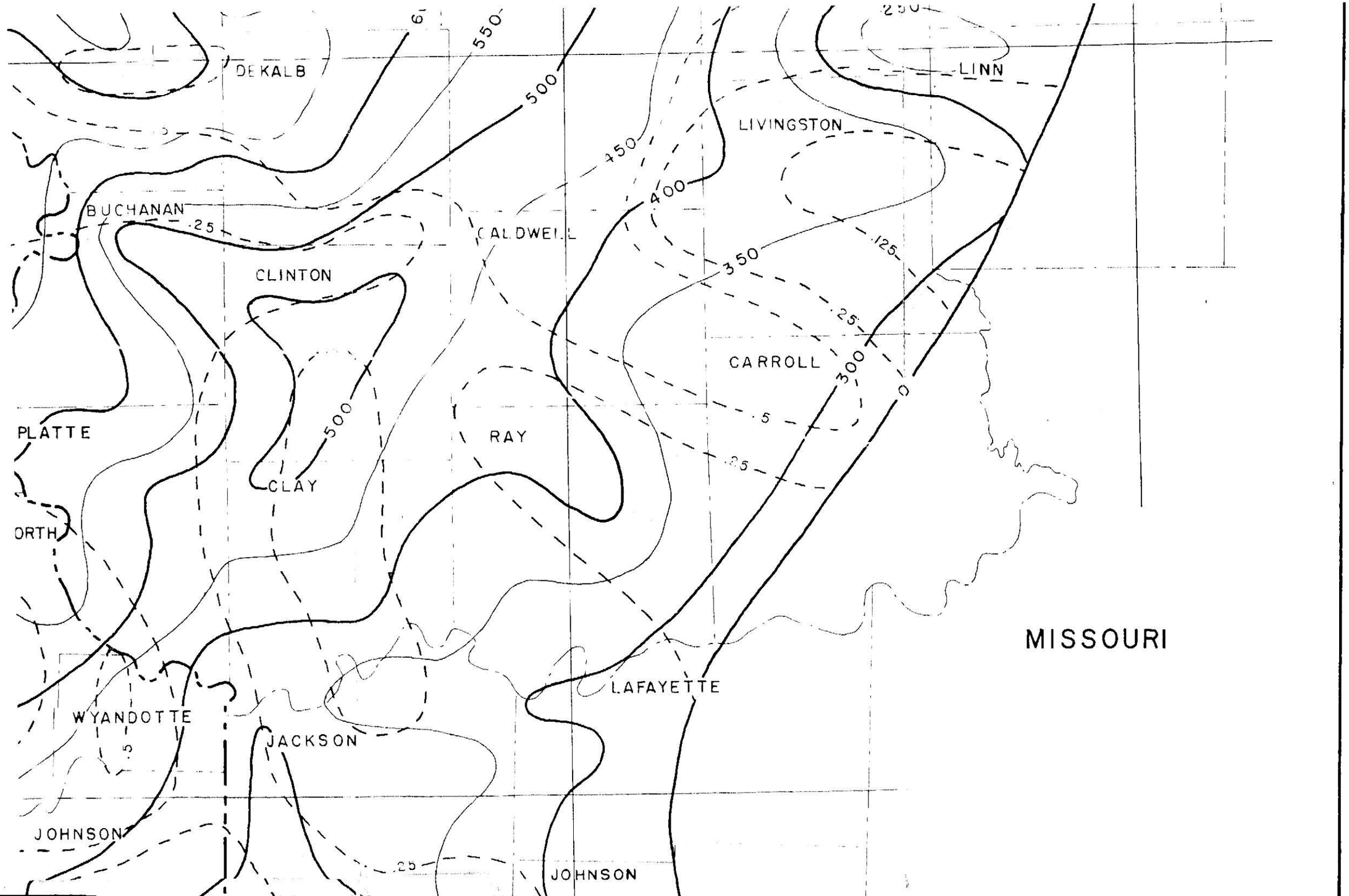
WYANDOTTE
JACKSON
GEARY
39°
.125
DOUGLAS
JOHNSON
.25
550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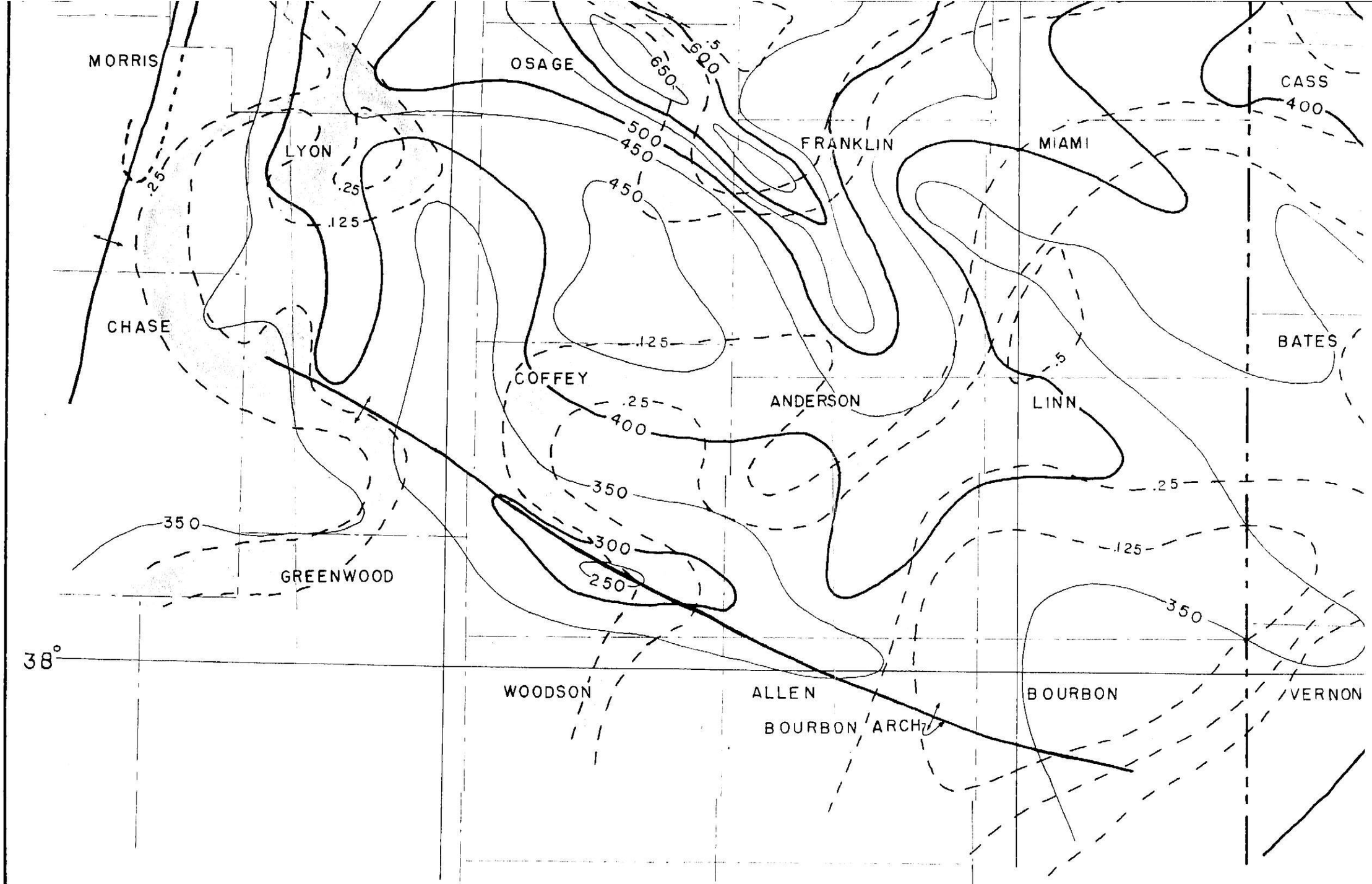
LIVINGSTON
BUCHANAN
CALDWELL
CLINTON
CARROLL
PLATTE
RAY
CLAY
ORTH
MISSOURI
LAFAYETTE
WYANDOTTE
JACKSON
JOHNSON
JOHNSON
550
500
450
400
350
300
250
500
25
125
5
0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OSAGE
LYON
FRANKLIN
MIAMI
CASS
CHASE
COFFEY
ANDERSON
LINN
BATES
GREENWOOD
WOODSON
ALLEN
BOURBON
VERNON
BOURBON ARCH
38°
.5
.25
.125
600
650
500
450
400
350
300
250

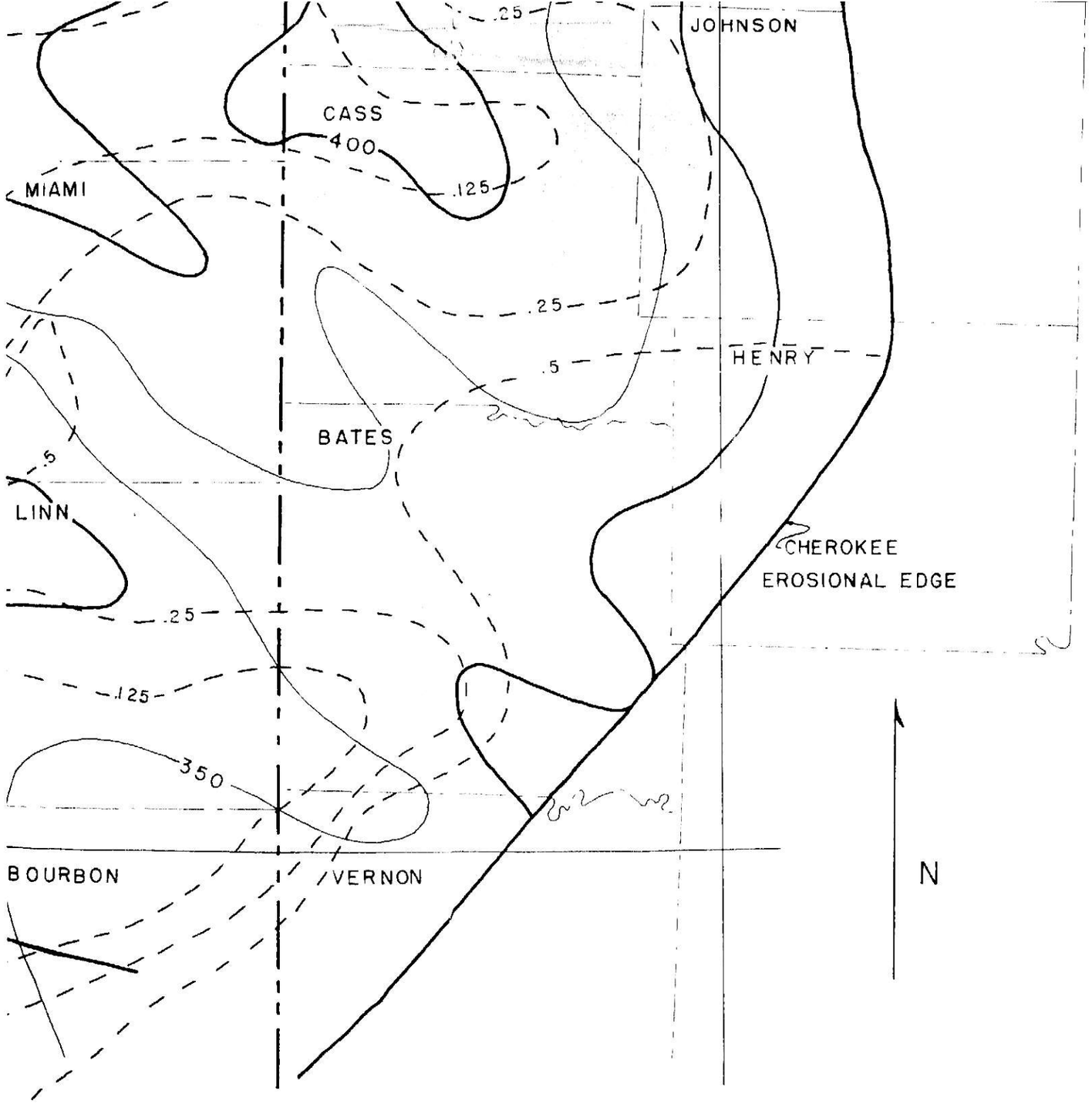



Figure 2

# FOREST CITY BASIN

## Cherokee Group

### Combined Sand-Shale Ratio and Isopach Map

Legend

Isopachous Lines ——————

Isolith Lines – – – – –

Isopach Contour Interval 50ft.

Sand-Shale Ratio

- More Than 8
- 2 — 8
- 1 — 2
- .5 — 1
- .25 — .5
- .125 — .25
- Less Than .125

Scale 1:500,000

10 0 10 20

miles

Drawn by M.L. Maderak, 1960

FIGURE 3

7½x10½
PEERLESS
CLASP
FEDERAL ENVELOPE CO.

Figure 3

# FOREST CITY BASIN

## Marmaton Group

### Combined Clastic Ratio and Isopach Map

**Legend**

Isopachous Lines ———

Isolith Lines – – – –

Isopach Contour Interval 25 ft.

Clastic Ratio

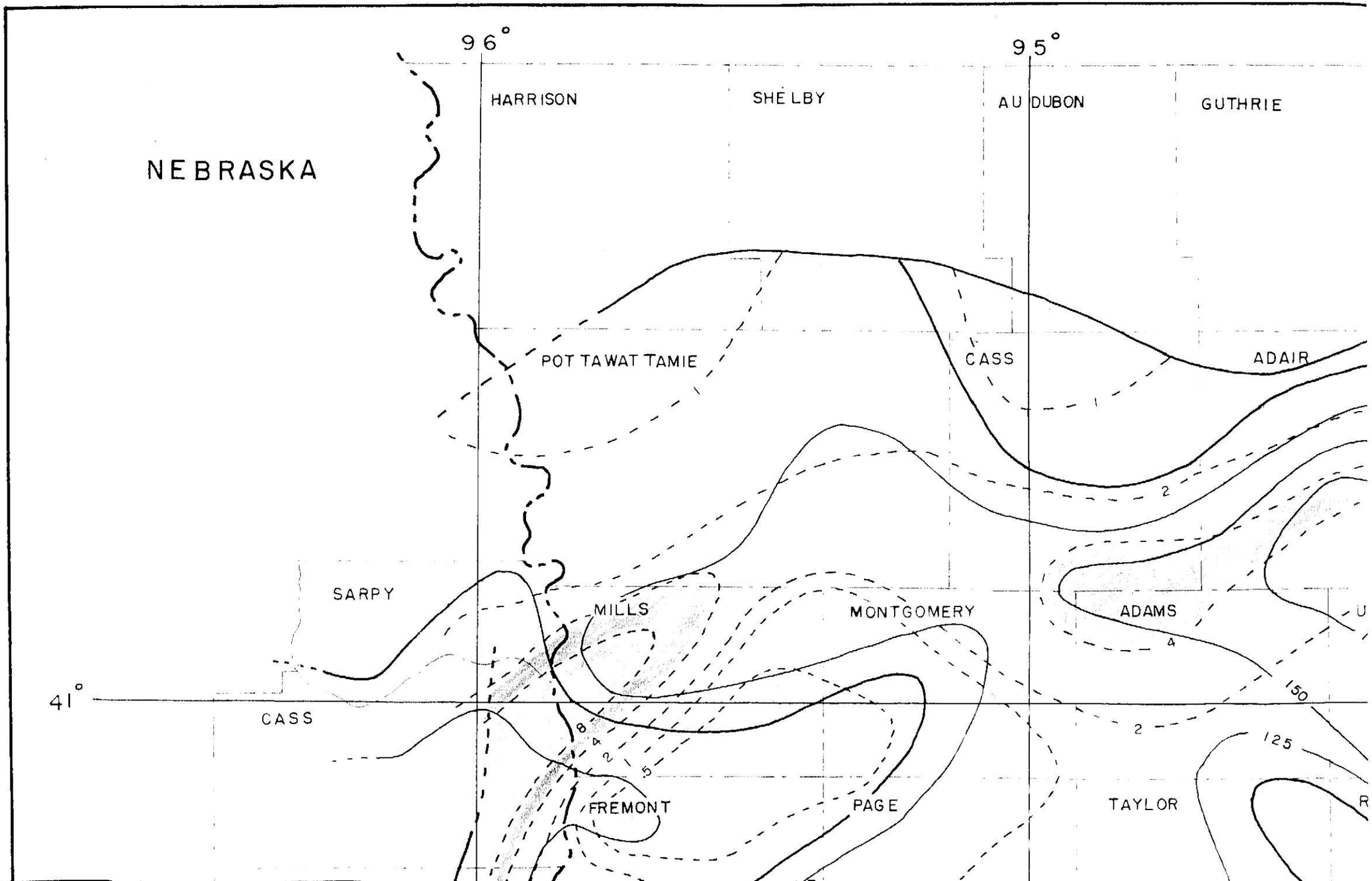
| | |
|---|---|
| | More Than 8 |
| | 4 — 8 |
| | 2 — 4 |
| | 1 — 2 |
| | .5 — 1 |
| | .25 — .5 |
| | Less Than .25 |

Scale 1:500,000

10 0 10 20

miles

Drawn by M.L. Maderak, 1960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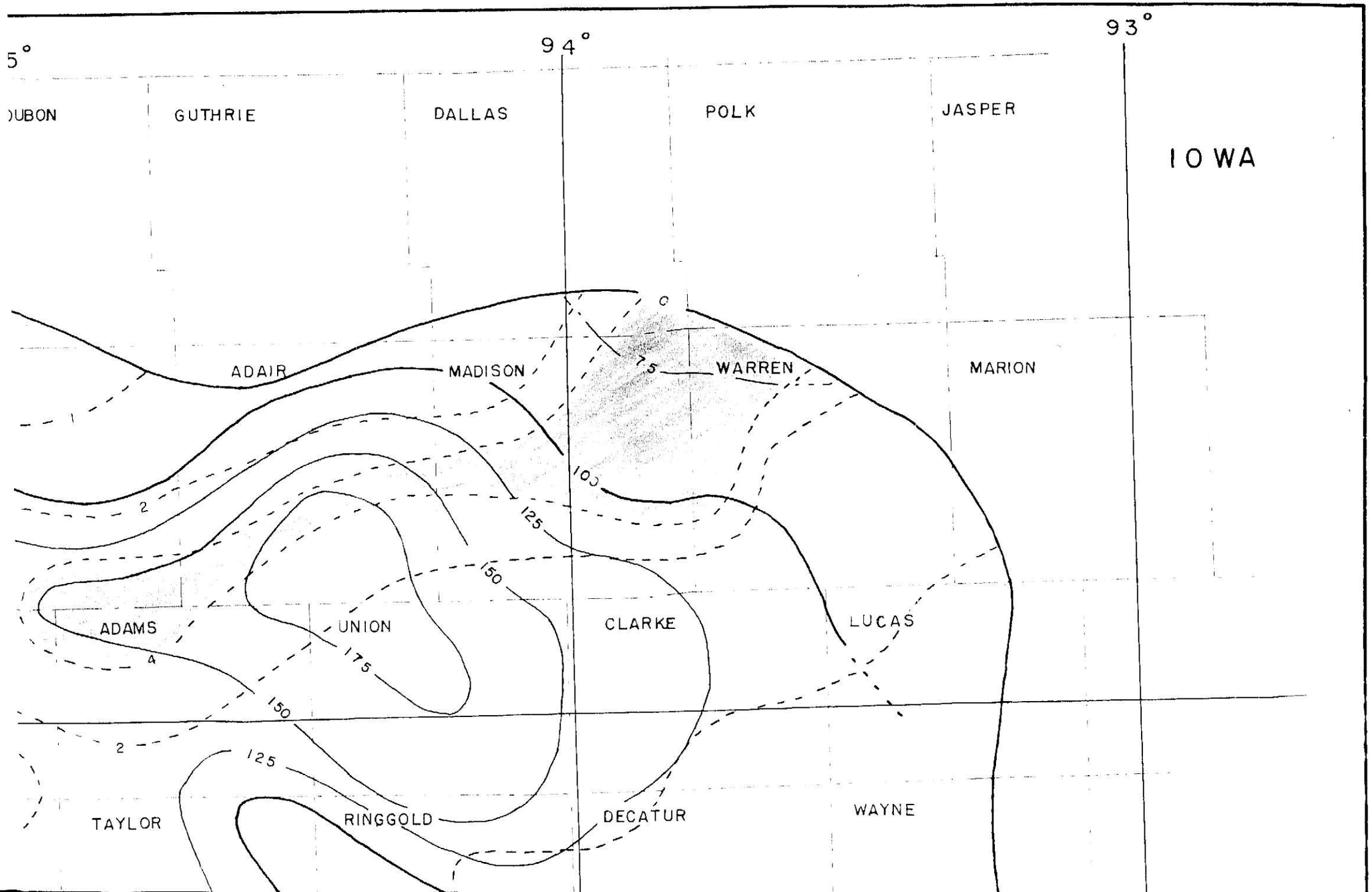
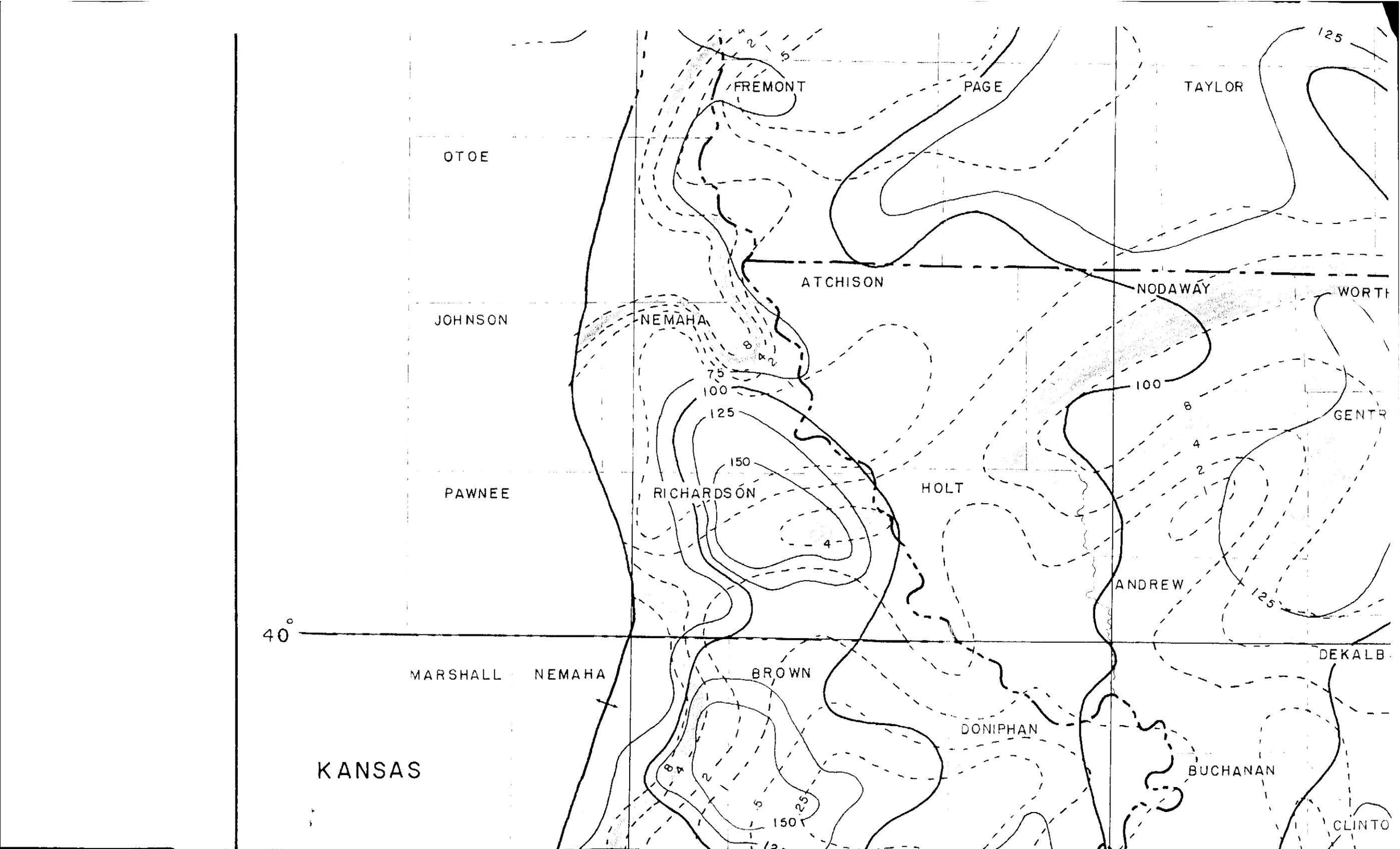
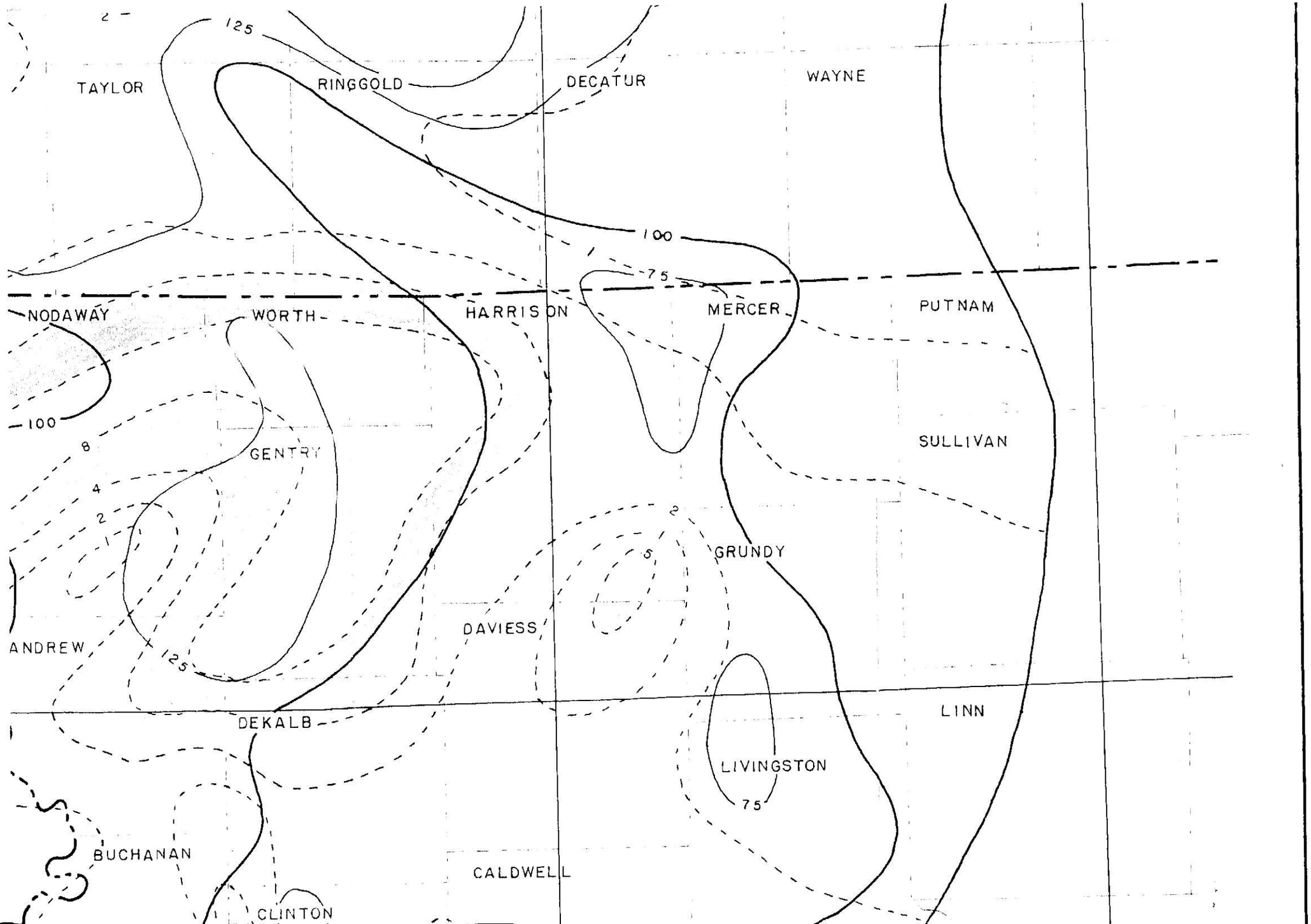
95°
NEBRASKA
HARRISON
SHELBY
AUDUBON
GUTHRIE
POTTAWATTAMIE
CASS
ADAIR
SARPY
MILLS
MONTGOMERY
ADAMS
41°
CASS
FREMONT
PAGE
TAYLOR
8
4
2
5
2
4
150
125
2
2


5°
94°
93°
)UBON
GUTHRIE
DALLAS
POLK
JASPER
IOWA
ADAIR
MADISON
WARREN
MARION
ADAMS
UNION
CLARKE
LUCAS
TAYLOR
RINGGOLD
DECATUR
WAYNE
0
75
100
125
150
175
1
2
4


FREMONT
PAGE
TAYLOR
OTOE
ATCHISON
NODAWAY
WORTH
JOHNSON
NEMAHA
GENTR
PAWNEE
RICHARDSON
HOLT
ANDREW
40°
DEKALB
MARSHALL
NEMAHA
BROWN
DONIPHAN
BUCHANAN
KANSAS
CLINTO


TAYLOR
RINGGOLD
DECATUR
WAYNE
NODAWAY
WORTH
HARRISON
MERCER
PUTNAM
GENTRY
SULLIVAN
GRUNDY
DAVIESS
ANDREW
DEKALB
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LIVINGSTON
BUCHANAN
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CLINTON
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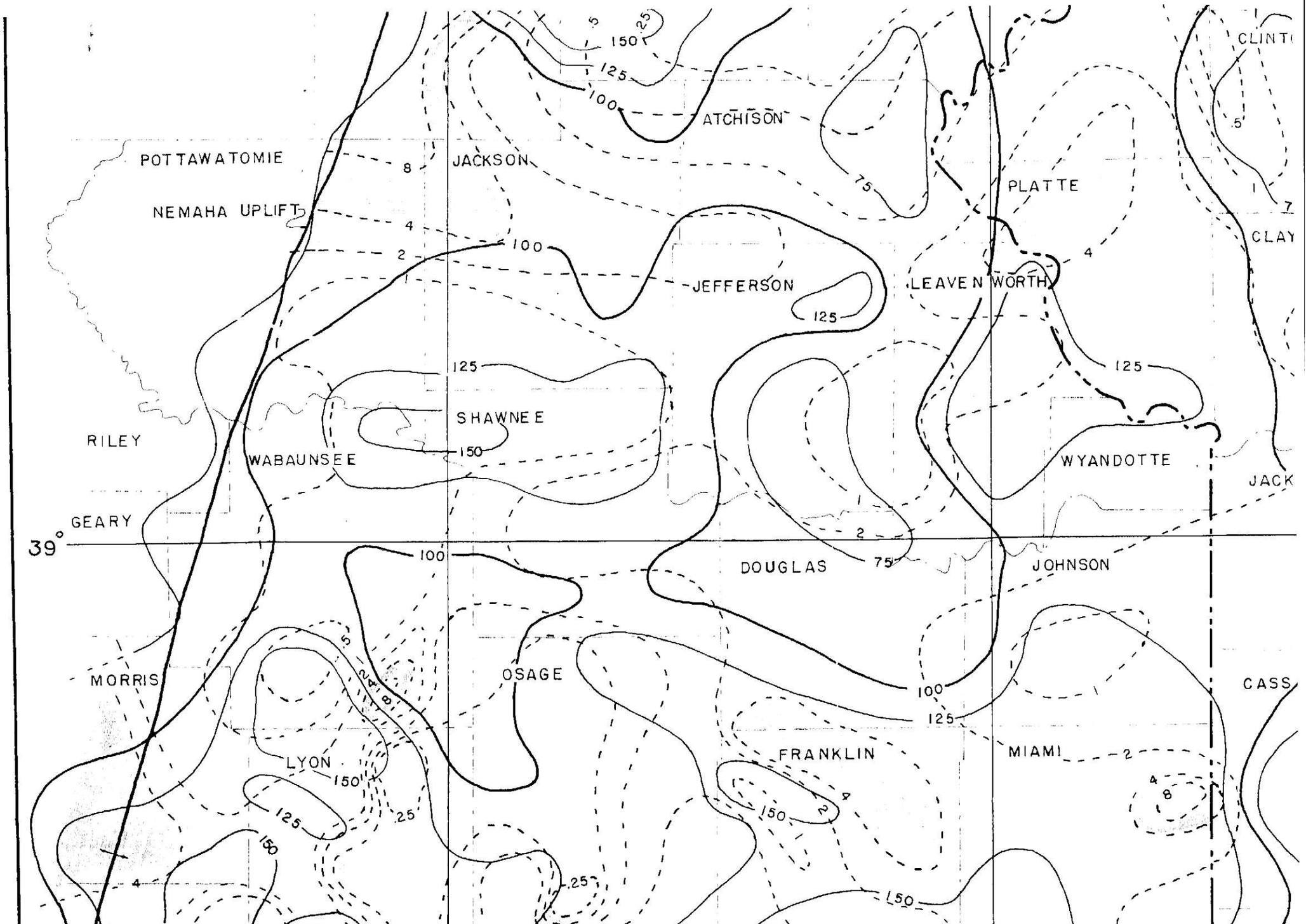
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LEAVENWORTH
RILEY
WABAUNSEE
SHAWNEE
WYANDOTTE
JACK
GEARY
39°
DOUGLAS
JOHNSON
MORRIS
OSAGE
CASS
LYON
FRANKLIN
MIAMI
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4
2
1
.5

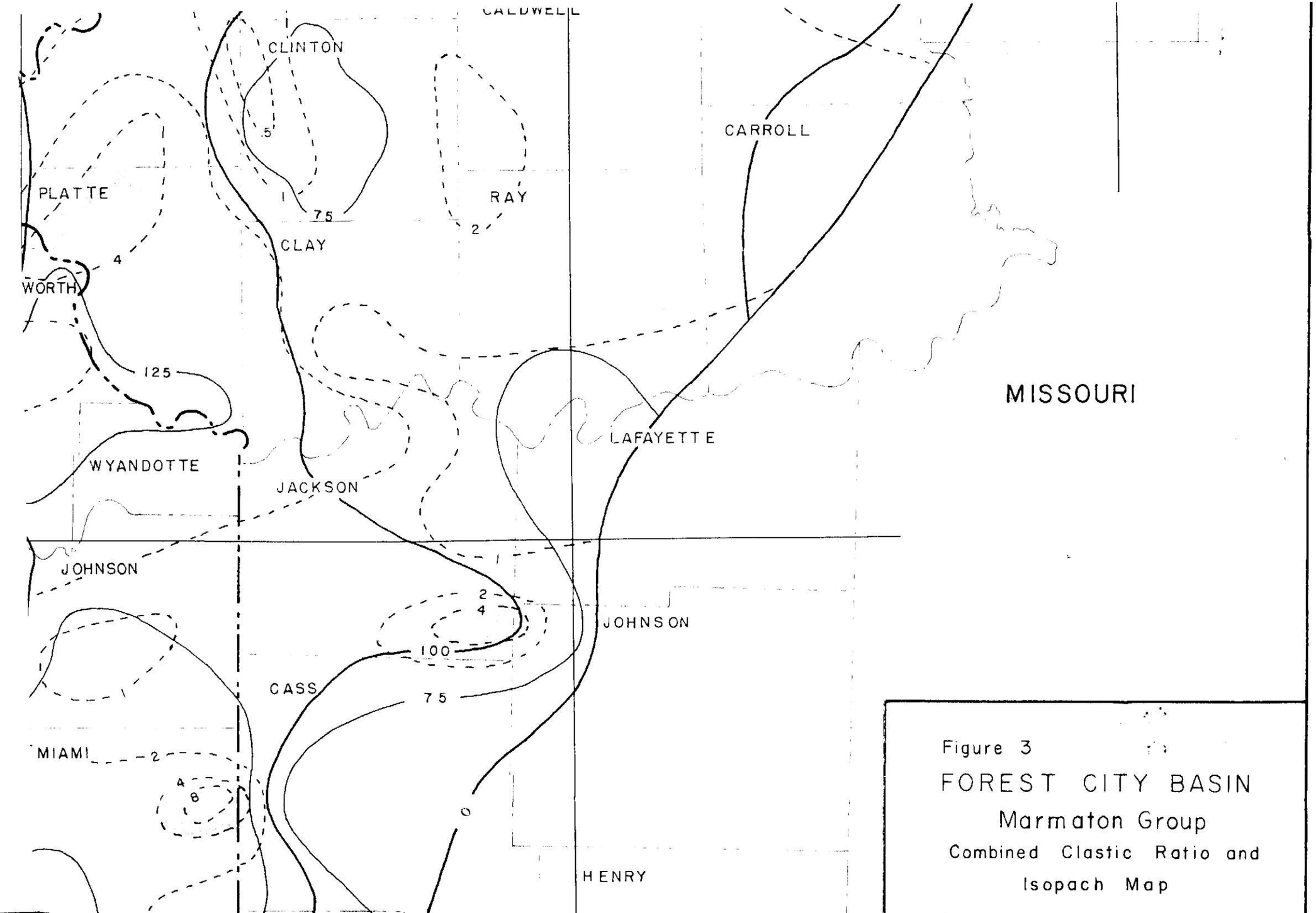
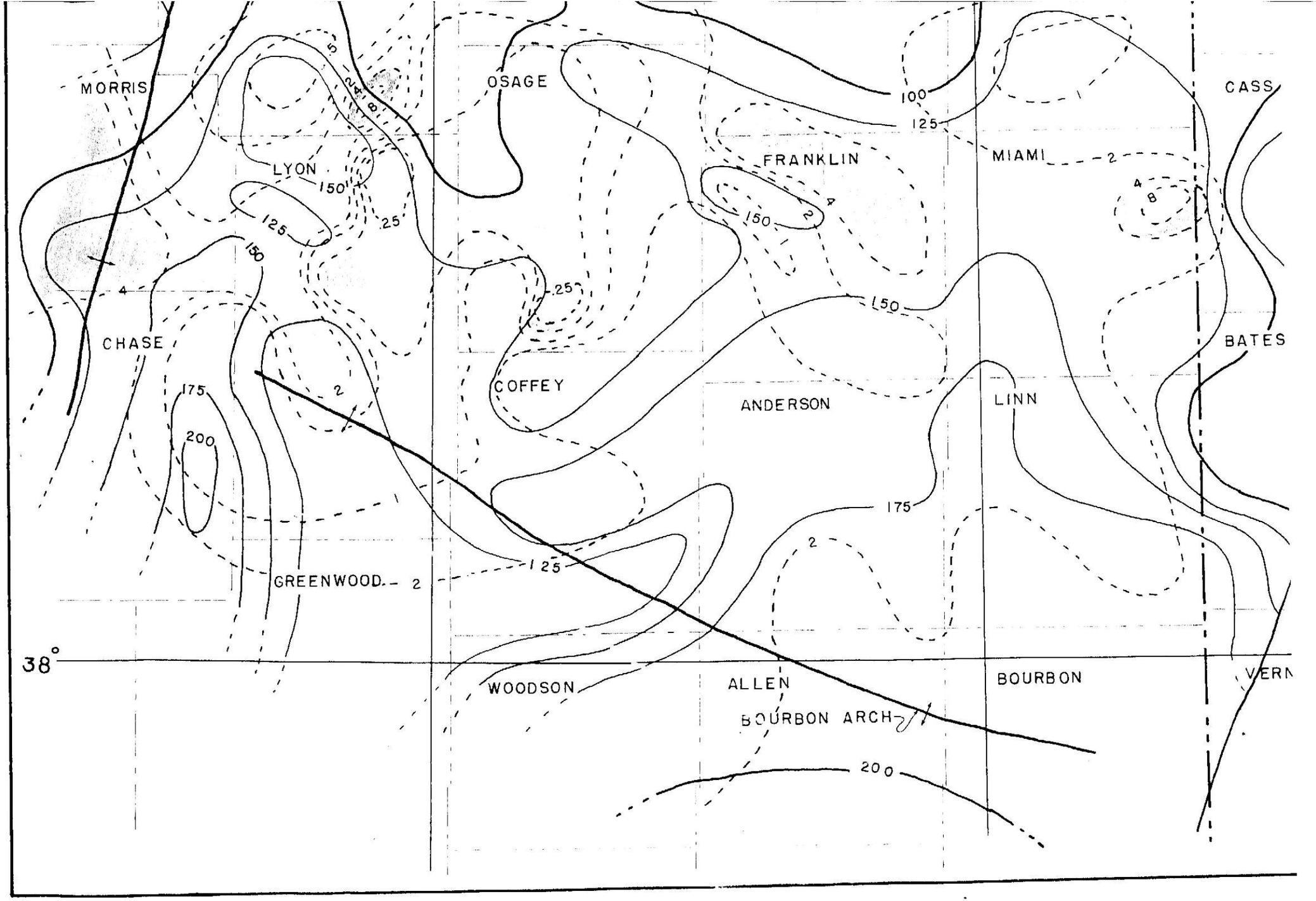



Figure 3

# FOREST CITY BASIN

## Marmaton Group

Combined Clastic Ratio and Isopach Map


MORRIS
OSAGE
CASS
LYON
FRANKLIN
MIAMI
CHASE
COFFEY
ANDERSON
LINN
BATES
GREENWOOD
WOODSON
ALLEN
BOURBON
BOURBON ARCH
38°
100
125
150
175
200
25
2
4
8

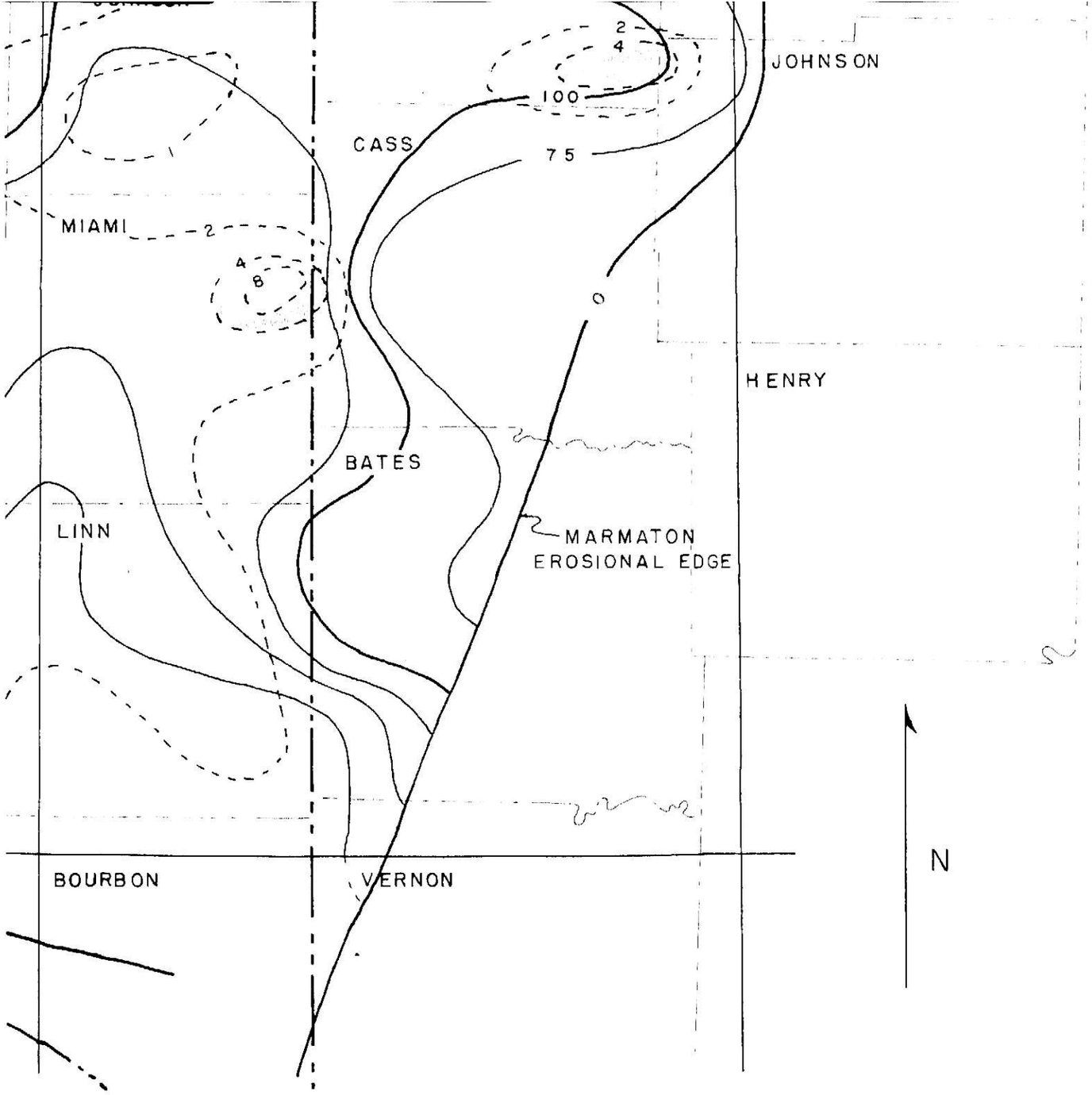



Figure 3

# FOREST CITY BASIN

## Marmaton Group

### Combined Clastic Ratio and Isopach Map

**Legend**

Isopachous Lines ——

Isolith Lines – – – –

Isopach Contour Interval 25 ft.

Clastic Ratio

| | |
|---|---|
| | More Than 8 |
| | 4 — 8 |
| | 2 — 4 |
| | 1 — 2 |
| | .5 — 1 |
| | .25 — .5 |
| | Less Than .25 |

Scale 1:500,000

10 0 10 20

miles

Drawn by M.L. Maderak, 1960

# END

# OF

# OVERSIZED

# MAP

# A FACIES STUDY OF THE DES MOINES SERIES IN THE FOREST CITY BASIN

by

MARION LOUIS MADERAK

B. S., Kansas State University of Agriculture and Applied Science, 1958

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ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

The investigation of the Forest City Basin was undertaken to provide additional information concerning facies variation, source, and the direction of transportation of sediments which comprise the Des Moines Series of the middle Pennsylvanian period. The study of petroleum accumulation in rocks of Cherokee and Marmaton age and its relationship to a specific facies value and structure was also included in the investigation.

The Forest City Basin is located geographically in the central United States, and lies within the boundary of four states, Kansas, Missouri, Iowa, and Nebraska.

The Des Moines Series is sub-divided into the lower Cherokee group and the upper Marmaton group. The Cherokee group consists mainly of shale, many sandstones, and minor amounts of limestones and coal; and the average thickness of the group is about 500 feet. The lower Burgess and McLouth sandstones have a quartzose composition, and the middle Bartlesville sandstone and the upper Squirrel sandstone have a sub-graywacke composition. The Marmaton group is composed mostly of shales and limestones; sandstones are present in minor amounts, and the sandstones are of a sub-graywacke composition. The average thickness of the Marmaton group is about 100 feet.

Facies maps are used to show the geographic variations of lithology in a particular stratigraphic section, and isopach maps are used to show areal variations of thickness by use of contour lines. The Cherokee sediments were deposited on an irregular Mississippian limestone surface which exhibits dendritic drainage patterns as revealed by the Cherokee isopach

map. Evidence gained from the analysis of the Cherokee isopach map indicates the Bourbon Arch served as a barrier which separated the Forest City Basin from the southern Cherokee Basin. The Marmaton group thickens toward the southern part of the Forest City Basin; the southward thickening is the result of the joining of the two basins.

Analysis of the Cherokee facies maps indicates the Nemaha Uplift was not a major source of sediments for the Forest City Basin; however, the main source of sediments for the basin was to the north, and the source area was probably parts of the Canadian Shield and the Trans-Continental Arch.

The oldest sedimentary rock of Cherokee age is an unnamed dark shale which is found in the deeper portion of the Forest City Basin in Brown and Doniphan Counties, Kansas. Marine fossils have been reported in rocks of McLouth age, and evidence gained from the Cherokee facies and isopach map indicates the marine water probably entered the basin by a connection north of the Lincoln fold from the Illinois Basin. The Forest City and Cherokee Basins merged sometime before the deposition of the Bartlesville sandstone. Sandstones within the basin can be either marine or non-marine, and they probably were deposited in a variety of shallow water littoral, lagoonal, deltaic, and coastal plain alluvial environments. Tectonic activity during the deposition of the Des Moines Series was probably limited to intermittent subsidence of the basin, rejuvenation of faulting and uplift of the source areas, and local growing structural elements existed within the basin, synclines and anticlines,

which along with pre-existing topographic and structural elements probably influenced the thickness and the type of deposition. Thus at the end of Marmaton time and prior to regional uplift, the Cherokee, Forest City, and Illinois Basins were part of one large embayment of the encroaching Pennsylvanian sea as revealed by the Marmaton isopach and facies map.

A correlation exists between 1958 oil accumulations of Cherokee age and structural and topographic highs in the underlying Mississippian limestones which are delineated by thinning in the Cherokee stratigraphic interval. Topographic and structural highs in the Mississippian limestones have been reflected by differential compaction of the Cherokee shales to the Marmaton rocks; thus locally differential compaction may have resulted in forming the structural control necessary to cause oil accumulation in Marmaton rocks. More intensive investigations are needed to analyze the relationship between a specific facies value and associated oil accumulations in order to permit facies evaluation of untested areas.