STRUCTURAL GEOLOGY OF THE NEMAHA RIDGE IN KANSAS

by

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INTRODUCTION

The pre-Cambrian Nemaha Ridge trends northeast-southwest across eastern Kansas, extending into southern Nebraska and northern Oklahoma. For the most part the Ridge is a Kansas feature and in making this study of its structure, an area extending from the Kansas-Nebraska state line on the north, south to the Kansas-Oklahoma state line, and paralleling the Ridge approximately 30 miles east and west of its axis was chosen. Total area covered is approximately 12,000 square miles, covering all or parts of 21 Kansas counties. The four corners of the area are T. 1 S., R. 6 E. in the northwest; T. 1 S., R. 18 E. in the northeast; T. 35 S., R. 8 E. in the southeast; and T. 35 S., R. 4 W. in the southwest.

Though mainly a Kansas feature, the Nemaha Ridge does extend north into Nebraska and south into Oklahoma. From a regional viewpoint it is located between the Ozark Dome in the east, the Central Kansas Uplift in the west, the Sioux Uplift in the north, and the Arbuckle Mountains in the south. In Kansas and Nebraska, the Forest City Basin is adjacent to the Ridge on the east and the Salina Basin lies to the west. The Cherokee Basin flanks the Ridge on the east in southern Kansas and northern Oklahoma. The Arkansas Basin and the Anadarko Basin lie to the east and west, respectively, in southern Oklahoma. The area of en echelon faults in central Oklahoma is east of the Ridge.

Almost from the time that the Nemaha Ridge was known to traverse Kansas, normal faulting in post-Mississippian times has been postulated for its origin (Fath, 1920; Thomas, 1927; Lee, 1943). The amount of relief on the east flank and the nearly straight alignment of the Ridge strongly suggest this mode of origin. This study was undertaken (1) to obtain as complete as possible a structural picture of the Nemaha Ridge, (2) to determine if this structural picture supports the theory of normal faulting in post-Mississippian times as the time and mode of origin of the Nemaha Ridge, and (3) if the Nemaha Ridge did not come into existence as previously proposed, to propose a more feasible time and mode of origin.

MAPPING PROCEDURE

Units Mapped

In making this study it was necessary to know the configuration of more than just the pre-Cambrian surface. Not only is the structural attitude of all overlying rocks directly related to the structural history of the pre-Cambrian rocks and hence aid in the interpretation of the pre-Cambrian structural events, but, also, the attitude of overlying rocks reflects the attitude of the pre-Cambrian rocks and thereby aids in the definition of the pre-Cambrian surface in areas of sparse control. For example, if erosional high areas exist on the pre-Cambrian surface, these highs will be reflected in the overlying strata as supratenuous folds. If high areas on the pre-Cambrian surface are not erosional, but due to structural movement, the overlying strata will reflect the same structural movement, but to a lesser extent. In examining the available data, it was found that sufficient control existed to contour the pre-Cambrian surface and three horizons above it; one of which overlies the pre-Cambrian surface entirely, and the other two only partially covering the pre-Cambrian surface. These three horizons are the Arbuckle limestone erosion surface, the Mississippi limestone erosion surface, and the top of the Lansing limestone. The Lansing limestone is the only contoured unit that entirely overlies the pre-Cambrian surface.

Source of Data

All data for contouring came from drilling records of oil wells drilled within the problem area and consist of elevations, above or below the datum, sea level. These data were gathered from three sources: (1) location and well log maps published by the Herndon Map Service, Oklahoma City, Oklahoma; (2) well records from the well log library of the State Geological Survey of Kansas, Lawrence, Kansas; and (3) master's thesis, K.S.C., Nelson, 1952. Control for the pre-Cambrian surface consisted of datum elevations from 122 wells (Table 1, Appendix); for the Arbuckle surface, datum elevations from 1283 wells; for the

Mississippi surface, datum elevations from 3640 wells; and for the top of the Lansing, datum elevations from 2178 wells.

Map Data

A scale of four miles to the inch was chosen as the mapping scale. This scale was considered sufficiently large to adequately depict the regional structure of the area, yet small enough so as not to make the maps unwieldy to work on and to handle. A contour interval of 100 feet was selected as an interval that could readily be used for mapping at a scale of four miles to the inch and would adequately bring out the regional structure of the formations within the area. Well locations were plotted on the basis of quarter, quarter, section; no closer plotting of location was deemed feasible or necessary at the selected map scale and contour interval.

EVALUATION OF DATA

Well Data

The accuracy of the elevations determined from well logs is affected mainly by human error. This human error can occur in three ways: (1) misidentifying a formation when examining well samples, (2) mislocating a well when plotting its position on a map, and (3) miscopying or mis-calculating the correct datum elevation of a formation.

Since no well samples were examined, there was no direct check made on the correct identification of the four horizons contoured from the well samples. However, it is believed that error from this source would be at a minimum for three of the contoured horizons, the pre-Cambrian, the Arbuckle, and the Mississippi, as each of these is quite distinct in its section of the stratigraphic column. The Lansing, on the other hand, is subject to frequent misidentification in the southwest portion of the area. The reason for this being that the Lansing changes in lithology, a facies change, in the southern part of Kansas and in Oklahoma. It is no longer the distinct unit it is in northern Kansas (Lukert, 1949). Consequently, different units are picked and logged as the Lansing in this area. The Stalnaker sandstone, the Kansas City limestone, and the Layton sandstone are the most frequent formations logged as the Lansing. The Stalnaker is above the Lansing in the stratigraphic column and the Kansas City and Layton are below the Lansing. The Layton is within the Kansas City and overlies the Ladore shale. Of these three, the Stalnaker is best-suited for logging as the Lansing for it correlates with the Stranger formation directly overlying the Lansing in the north. When the Lansing was contoured, the structure of it in Sedgwick, Sumner, and Cowley counties was radically different than that existing in the Mississippi and Arbuckle limestones. Since deformed overlying formations are known to reflect the structure of underlying formations, the control on the

Lansing was assumed to be in error and a check was made of the elevations in Cowley, Sumner, and Sedgwick counties. This check was made from the records in the well log library of the State Geological Survey of Kansas, since the control in this area was taken from the maps of the Herndon Map Service. It was found that in many cases the Kansas City limestone and Layton sandstone logged in the records of the well log library had been logged as the Lansing on the Herndon maps. In several of the wells being checked, the Stalnaker sandstone was also logged in the well log records, and had it been picked as the Lansing, its elevation would have been consistent with the regional structure of the underlying Mississippi and Arbuckle limestones. Therefore, the Stalnaker elevations were substituted for Lansing elevations where possible and the low Lansing elevations, those of the Kansas City and Layton, were discarded as erroneous and the area recontoured on the basis of the higher Stalnaker control. The area in Sedgwick and northern Sumner counties was not recontoured for it shows the results, in the way of anomolous structures, of misidentifying formations from well samples. Also it is not a critical area affecting the interpretation of the structural geology of the Nemaha Ridge, and, as such, the anomolous structures did not affect the interpretation or conclusions in this paper.

The errors from mislocating a well on the maps and miscopying or mis-calculating the correct datum elevation can be kept to a minimum by careful work. Since care was exercised during these operations and any deviation of elevations from the regional trend was suspected of error and checked against proper location and correct elevation, it is believed that errors from these sources are relatively few.

Control on pre-Cambrian Surface

Control on the pre-Cambrian surface was spotty and in large areas, non-existent. Consequently the configuration of the pre-Cambrian surface is hypothetical in many areas and is controlled by elevations of the overlying Arbuckle limestone. Where good control existed, as in Chase and northern Butler counties, the pre-Cambrian surface is well reflected by the Arbuckle limestone. Since deformed overlying formations do reflect structures of underlying formations, and where good control on the pre-Cambrian surface does exist, its structure is well reflected in the Arbuckle limestone, it was assumed that the pre-Cambrian surface would, on a regional scale, be everywhere reflected in the Arbuckle limestone. On this assumption the pre-Cambrian surface was contoured in areas of little or no control.

STRUCTURE OF PRE-CAMBRIAN NEMAHA RIDGE

General Description

The pre-Cambrian Nemaha Ridge (Fig. 4, Appendix) is the most prominent structural feature in eastern Kansas. It is a deformed erosion surface, a combination of structural and topographic features. Although not a straight line, the crest of the Nemaha can be said to trend generally N 15° E. from T. 29 S., R. 3 E. in Butler county to T. 2 S., R. 12 E. in Nemaha county. It is asymmetrical in cross section (Figs. 1, 2, and 3, Appendix), with the steeper dips on the east flank. The Ridge parallels two synclines to the east, the Forest City Basin in the north, and an unnamed syncline in the south. These two synclines are separated by the Bourbon Arch. The Forest City Basin plunges gently to the northeast, the southern syncline gently to the southwest. Maximum relief on the east side of the Ridge occurs in Nemaha county where the crest is 3200 feet above the floor of the Forest City Basin. The minimum relief on the east side, except where the Ridge levels out toward the axis of the Chautauqua Arch, is 900 feet in central Butler county. The amount of relief varies along the Ridge, but generally it can be said to decrease to a minimum in the southwest part of Butler county (Table 2, Figs. 1, 2, and 3, Appendix). The west side of the Ridge is gently dipping and imparts a regional westward dip to the east flank of the Salina Basin.

Topography

Topographically, though actually a combination of topographic and structural features, the Nemaha Ridge can be divided into two distinct areas or provinces, a northern province extending from T. 2 S. south to T. 10 S. and a southern province extending from T. 10 S. to T. 34 S.

The northern province is characterized by an almost smooth, gently dipping west side and a steeper, equally smooth east side. The crest of the Ridge in this province is fairly sharp and well-defined as a result of the smoothness and contrasting dips of the east and west sides. The east side of the Ridge is almost completely lacking in re-entrants. Only in T. 2 S., R. 13 E. is the smooth character of the east side interrupted by an eastward swing of the contour lines around a local high, resulting in a local low to the west. The uniform westward dip of the west side is interrupted by a gentle west plunging nose in T. 7 S. and T. 8 S. This nose swings to the southwest in T. 8 S., R. 5 E., T. 8 S., R. 4 E., and T. 9 S., R. 4 E. This nose in Riley county and the westward regional dip in Marshall county have been interrupted by a fault, the nature of which is discussed below. Also a high in T. 4 S., R. 9 E., trending north-south, and a high in T. 7 S., R. 9 E., trending northwest-southeast, provide local variations on the otherwise smooth, gently dipping surface.

The southern province is characterized by numerous hills or domes separated from one another by valleys or synclines. Most, if not all, of the domes are asymmetrical, the east flank having the greatest amount of dip. In general they are elongate in a northeast-southwest direction and, together, exhibit a definite linear alignment. Their combined axes form the crest of the Nemaha Ridge in the southern province. The valleys or synclines between the domes are quite distinctive. Most of them are located to the west of the crest of the Ridge and are long and open to the west. Only a few short valleys, opening to the east, are found in the east side of the Ridge.

Only one dome, the Zeandale dome in T. 10 S., R. 9 E., has been shown to be faulted (Fig. 1). This fault occurred along its east flank. In T. 31 S., R. 2 E. and T. 32 S., R 2 E. two highs occur which are in line with the crest of the Ridge but are separated from the Ridge proper. These highs appear to be upthrown fault blocks.

The names and locations of the major domes are as follows:

Name	Location
Zeandale dome	T. 10 S., R. 9 E.
Elmdale dome	T. 20 S., R. 7 E.
Florence-Urschel fold	T. 21 S., R. 5 E.
Burns dome	T. 23 S., R. 5 E.
El Dorado anticline	T. 25 S., R. 5 E. and T. 26 S., R. 5 E.
Augusta anticline	T. 27 S., R. 4 E. and T. 28 S., R. 4 E.

Two major domes are located in T. 14 S., R. 8 E. and T. 16 S., R. 7 E., but have been given no special names. They are included as part of the Nemaha Ridge and so designated.

Faulting

Only a few major subsurface faults have been indicated within the area. These are found in northwest Riley county and southwest Marshall county, northwest Wabaunsee county, northwest Chase county, and east and southeast Sumner county. The fault in Riley and Marshall counties strikes northeast-southwest, roughly paralleling the crest of the Nemaha Ridge. This fault appears to be a rotational fault, with the west side having been elevated to the south in Riley county and depressed to the north in Marshall county. It underlies the axis of the Abilene anticline. The fault in northwest Wabaunsee county has occurred along the east flank of the Zeandale dome and also parallels the crest of the Nemaha Ridge (Fig. 1). It is a normal fault with the east side the down-thrown block. Maximum throw is 900 feet. The down-thrown block is an east plunging nose whose axis is closely aligned with the axis of an east plunging nose of the up-thrown block. It is possible the fault occurred as the Zeandale dome was being uplifted and elongated in an east-west direction. A much smaller fault is the one in northwest Chase county. Its existence is conjectural, having been based on one well drilled to the overlying Arbuckle limestone. It was interpreted as a normal fault that strikes northeast-southwest. The east side is the up-thrown block. Two fault blocks, forming positive features, occur in eastern Sumner county. Both blocks are bounded on the west and south by normal faults and each represents the up-thrown block to the east and north. The faults on the west sides strike northeast-southwest and the faults on the south sides, though not exactly parallel to each other, strike east-west. The existence of the fault in southeast Sumner county is based on one well drilled to the overlying Mississippi limestone. Though good control was lacking, the fault was mapped as a normal fault striking northeast-southwest with the up-thrown block to the east.

Summary

The Nemaha Ridge is a prominent high in the pre-Cambrian rocks of eastern Kansas. It is an asymmetrical ridge with a gently dipping west flank and a steeper dipping east flank. The crest strikes N 15° E. As a structural unit, the Ridge plunges to the southwest. It levels out in southwest Butler county but reappears again in eastern Sumner county as two up-thrown fault blocks. In the northern one-third of eastern Kansas the Ridge is smooth and has a sharp crest. To the south it takes on a knobby character and is a series of aligned domes with intervening synclines. Only a few major subsurface faults have occurred within the Ridge area and for the most part all are aligned parallel to the crest of the Ridge. Two of the faults parallel the east-west regional trend of the pre-Mississippian Chautauqua Arch.

FAULTING AS ORIGIN OF NEMAHA RIDGE

Erosional History

In determining whether the Nemaha Ridge originated from faulting in post-Mississippian time, it was necessary to examine the erosional and depositional history of the Ridge. Since no isopach maps were constructed of the area, publications of the State Geological Survey of Kansas (Lee, 1939, 1943, 1948) were used as a source of this information.

Prior to deposition of the first Cambrian sediments, the pre-Cambrian rocks were undoubtedly subjected to extensive erosion. This erosion would definitely result from and be controlled by structural movements. The Lamotte sandstone of Upper Cambrian age was the product of this erosion and it is believed to have been more extensive than it is today. Originally it was probably laid down over the entire area. If no subsequent structural movements occurred, other than subsidence, the attitude of the pre-Cambrian rocks today (Fig. 4) would reflect the extent of structural deformation to Upper Cambrian times only. No overlying formations should be deformed. However, Figs. 5, 6, and 7 (Appendix) indicate deformation as late as Missourian times of the Pennsylvanian Period. Therefore, the present ridge resulted from much later deformation.

Following the erosion and subsidence that produced the Lamotte sandstone, the pre-Cambrian rocks remained stable and low-lying during the deposition of the Bonneterre dolomite. As the pre-Cambrian highs were eroded and the area subsided, the Lamotte transgressed until it finally covered the area. It was followed, conformably, by the widespread deposition of the Bonneterre. The Lamotte is transitional into the overlying Bonneterre.

After Bonneterre deposition the area was elevated and subjected to erosion several times prior to Middle Ordovician St. Peter times. Unconformities occurred between the Upper Cambrian Bonneterre and Eminence dolomites and the Eminence and Lower Ordovician Van Buren dolomites. A minor unconformity separated the Van Buren and Gasconade dolomites, as well as the Gasconade and Roubidoux dolomites and the Roubidoux and Cotter-Jefferson City dolomites. Although these erosional periods, as represented by unconformities, were significant in causing thinning and even absence of some formations, none was extensive enough to expose and sculpture the underlying pre-Cambrian rocks.

At the end of Lower Ordovician times (deposition of the Cotter-Jefferson City dolomites) the northern portion of the area was uplifted and subjected to extensive erosion. This erosion removed all sediments in Marshall, western Nemaha, and northern Riley and Pottawatomie counties. Pre-Cambrian rocks were exposed and once again eroded. The St. Peter sandstone of Middle Ordovician age resulted from this period of erosion and it rests unconformably on the eroded Lower Ordovician and pre-Cambrian rocks.

Following the deposition of the St. Peter sandstone, the northern portion of the area subsided and formed the North Kansas Basin. This basin persisted as a depositional area until at least Mississippian times. Accompanying the formation of the North Kansas Basin was the uplift of southeast Kansas, forming the Chautauqua Arch. This arch formed the dominant positive feature in eastern Kansas until the advent of the Nemaha Ridge.

The subsidence of the North Kansas Basin was not continuous. Several fluctuations occurred, exposing formations to erosion, producing unconformities. Thinning of some formations, absence of others occurred during the periods of uplift. The fluctuations in Middle Ordovician times caused the Platteville formation to be deposited unconformably on the St. Peter sandstone and the Viola limestone to rest unconformably on the Platteville. Upper Ordovician Sylvan shale is unconformable on the Viola as a result of uplift at the end of Middle Ordovician deposition. An unconformity separates the Sylvan and the Silurian Chimneyhill limestone. Silurian and Devonian rocks have an unconformable relationship. The Upper Devonian Chattanooga shale was laid down unconformably on a well-developed Upper Devonian peneplain. Though some of these erosion periods were extensive and significantly affected the stratigraphy of the area, none exposed the pre-Cambrian rocks to erosion.

The Chautauqua Arch was subject to fluctuations prior to deposition of the Mississippian limestones. Cambrian, Ordovician, Silurian, and Devonian sediments all have been beveled by erosion on the sides of the Arch. Major unconformities occurred between the Silurian and Devonian limestones and the Devonian limestones and Upper Devonian Chattanooga shale. Again, none of these erosional periods exposed the pre-Cambrian rocks while modifying eastern Kansas stratigraphy.

Mississippian limestones were laid down more or less conformably on the smooth Chattanooga depositional surface. During the period of Mississippian deposition, minor fluctuations occurred that caused erosion of the tops of some formations prior to the deposition of succeeding formations. The initial movements of the present Nemaha Ridge are inferred from these fluctuations. Mississippian deposition was widespread, covering the Chautauqua Arch as well as adding to the sediments in the North Kansas Basin.

At the end of Mississippian deposition, major structural movements took place which elevated an area in Nemaha, Marshall, Pottawatomie, Riley, and western Wabaunsee counties and extended as a finger southwest into Morris and Chase counties (Fig. 4). This area was subjected to extensive erosion. Smaller areas in Marion, Butler, Cowley, and Sumner counties also were elevated and eroded. The erosion that ensued was of such a nature as to completely remove all sediments from atop the pre-Cambrian rocks in the northern portion of the area (Figs. 1, 2, 5, and 6). In the smaller areas to the south, the Mississippian limestones were either removed (Fig. 6) or thinned (Fig. 3) by erosion, but the pre-Cambrian rocks were not exposed.

Following post-Mississippian deformation and erosion the area subsided and the Pennsylvanian sediments were deposited. Not all of the area was inundated in early Pennsylvanian times. An area in northern Nemaha and Marshall counties remained high and subject to erosion until late Missourian times.

Post-Pennsylvanian deformation has occurred and is represented by the structure of the Lansing limestone (Fig. 7). Most of this deformation is pre-Cretaceous but it is the total, to the present, of all structural movement since deposition of the Lansing. Erosion accompanying this deformation has not exposed any rocks older than Pennsylvanian.

The pre-Cambrian rocks have been subjected to three periods of erosion. The period preceding the deposition of the first Cambrian sediments affected the entire area and today would only be reflected in the structural features of the southern portion of the area, since the pre-Cambrian rocks in that area were never subsequently subjected to erosion. The second period of erosion affected only an area in the four northwest counties of the area. At that time, prior to deposition of the St. Peter sandstone, all previously deposited sediments, totaling over 700 feet to the southwest, were removed from atop the pre-Cambrian rocks and the pre-Cambrian rocks again cut down by erosion. The amount of erosion that took place on the pre-Cambrian rocks during the second period of erosion is not exactly determinable, but the area is believed to have been essentially peneplained. Isopach maps of pre-St. Peter deposition show no sharp irregularities, thereby suggesting that the original pre-Cambrian surface prior to any deposition was low-lying. Also there is no indication of rapid uplift. Erosion most probably kept pace with the uplift, eventually exposing the pre-Cambrian rocks and then continuing to bevel the relatively flat surface that was in existence at the end of Lamotte times. The third period of erosion affected an area in eastern Marshall and western Nemaha counties and extended southwest to the Zeandale dome in northwest Wabaunsee county. This period was by far the largest and removed all the Mississippian sediments plus from 900 to 1300 feet of older sediments from atop the pre-Cambrian rocks. This period of erosion took place at the close of the Mississippian Period. In the exposed areas to the south, in Morris, Chase, Marion, Butler, Cowley, and Sumner counties, only the Mississippian sediments were eroded plus up to 450 feet of older sediments. The pre-Cambrian rocks were not exposed. The southern exposed areas subsided in early Pennsylvania times but the northern area continued to be slowly uplifted and the exposed sediments eroded. This longer period of erosion allowed a greater amount of sediments to be removed and the underlying peneplained pre-Cambrian rocks to be exposed and again subjected to erosion.

The greater period of erosion that took place in the northern portion of the area at the close of the Mississippian period is believed to have been responsible for denuding the pre-Cambrian rocks but not to have materially altered their surface. There are no re-entrants on the east flank of the Ridge that would suggest such erosion. The peneplained pre-Cambrian surface is most probably a result of the two preceding erosional periods that exposed the pre-Cambrian surface. Hence it is believed that the present configuration of the Nemaha Ridge is a product of pre-Mississippian erosion and post-Mississippian deformation. It is not believed to be an eroded post-Mississippian scarp.

Movement Along the Nemaha Ridge

An analysis of the amount of relief of three of the contoured horizons, the pre-Cambrian, Arbuckle limestone, and Lansing limestone surfaces, was made in order to examine the nature of the movement or movements that took place along the Nemaha Ridge (Table 2). The fourth contoured horizon, the Mississippi limestone surface, was not used in the analysis for all rocks have been eroded from the high areas along the Ridge. Ten high areas along the crest of the Ridge and ten low areas 12 miles to the east were chosen for determining the amount of relief in each area. The 12 mile distance to the east was chosen (1) in order to have a low point in the adjacent syncline for comparison with each high point on the Ridge and (2) to have a uniform basis for determining the amount of relief. The amount of relief was ascertained by subtracting the elevation of the low point from the elevation of the adjacent high point, the difference being the amount of relief between the two points.

The conclusions that were made from this analysis were modified by the erosional history of the area. The Arbuckle limestone was partially eroded from seven of the high areas and probably completely removed from the other three highs. This erosion would reduce the amount of relief as compared to the relief between the same two points on the pre-Cambrian surface. All Mississippi rocks were removed from the highs and therefore it was impossible to include the relief of the Mississippi surface in the analysis.

A comparison of the relief of the pre-Cambrian surface and the relief between the same two points on the Arbuckle surface shows a minor difference between corresponding values. The Arbuckle values are less but this is probably due to the effect of erosion and the fact that the amount of movement can be expected to die out upward. The movement that took place in the pre-Cambrian rocks also, at the same time, deformed the Arbuckle limestone a comparable amount.

Although an analysis of the Mississippi limestone was impossible, it is believed that the values for relief would be very similar to the corresponding values on the Arbuckle and pre-Cambrian surfaces (Fig. 3). The fact that the Mississippi limestone has been completely removed by erosion from the highs means that they would have had to have been displaced to a higher elevation than that which now exists on the corresponding Arbuckle highs. This amount of displacement was probably the result of the same movement that took place in the underlying Arbuckle and pre-Cambrian rocks but could be expected to be less because the movement would tend to die out upward.

The relief of the Lansing limestone surface shows a decided difference with that of the Arbuckle and pre-Cambrian surfaces. The Lansing relief values are much less than the corresponding Arbuckle and pre-Cambrian values, and thus indicate that the major vertical movement took place prior to the deposition of the Lansing limestone.

A comparison of the relief values on each surface with each other indicates an increase in the amount of relief from south to north. This means that maximum movement took place in the north and the Nemaha Ridge can be said to level out to the south.

From this analysis it was concluded that the major vertical movement took place after the deposition of the Mississippi limestone and prior to the deposition of the Lansing limestone. Movement also occurred after Lansing deposition but to a lesser extent. Also, maximum vertical movement occurred to the north, both before and after Lansing deposition. These conclusions agree with the movements postulated by Lee and brought out in the discussion of erosional history above.

Rate of Dip Along East Flank

The examination of the rates of dip along the east flank of the Nemaha Ridge was considered important in light of the erosional history of the Ridge. Most normal faults are high angle faults and in order for the east flank to be a fault scarp, it would necessarily have to be steep.

The areas of steepest dip were most significant in this analysis. These areas should represent the fault scarp if the Ridge originated by faulting. The maximum dips occur (Fig. 4) in T. 2 S., R. 13 and 14 E. and along the east flank of the Elmdale dome in Chase county. The entire east flank of the Ridge from T. 2 S., south to the Zeandale dome in Wabaunsee county is a region of comparatively steep, uniform dip. The Burns dome in Butler county presents a steep east flank in contrast to the regional dip to the west.

The dip for the area in T. 2 S. is 652 feet per mile measured over a 4.6 mile distance. In degrees this would represent a dip of 7 degrees, 45 minutes. The Elmdale dome has a comparable east dip. In T. 19 S., R. 8 E. the dip is 643 feet per mile measured over a distance of 1.4 miles. Translated in degrees, this would be a dip of 6 degrees 55 minutes. In T. 20 S., R. 7 and 8 E. the dip is 590 feet per mile or 6 degrees, 23 minutes over a distance of 1.4 miles. The region of strikingly uniform dip from T. 2 S. south to the Zeandale dome dips 296 feet per mile for 8.6 miles in T. 4 S., 217 feet per mile for 10.6 miles in T. 5 and 6 S., 274 feet per mile for 8.4 miles in T. 7 and 8 S., and 350 feet per mile for 4.0 miles in T. 9 S. In degrees, these figures would be 3 degrees, 13 minutes, 2 degrees, 21 minutes, 2 degrees, 58 minutes, and 3 degrees, 48 minutes, respectively. The increase in dip in T. 9 S. is probably due to the influence of the fault along the Zeandale dome to the south.

The Burns dome dips 448 feet per mile on its east flank in T. 23 S. over a distance of 2.9 miles. In degrees this dip would be 4 degrees, 52 minutes.

Normal faults commonly dip 45 degrees or greater. Particularly do those normal faults of the magnitude as is thought to have occurred along the east flank of the Nemaha Ridge, tens of miles long and hundreds of feet in displacement. The west side of the Oquirrh Range of central Utah is broken by normal faults that dip from 40 to 64 degrees and average 57 degrees. The stratigraphic throw is 3500 feet. In the Wasath Range of Utah, the normal faults have been observed to dip 50 degrees. The net slip on the major faults is 6500 to 7800 feet (Billings, 1942). The fault on the east side of the Oklahoma City field in Oklahoma is nearly vertical. It has a displacement of 2400 feet (Lalicker, 1949). The steepest dips on the Nemaha Ridge in Kansas as listed above do not approach these magnitudes and thereby strongly suggest that the Ridge is not a normal fault scarp.

CONCLUSIONS

The Nemaha Ridge is an asymmetrical structural high in eastern Kansas that plunges to the southwest. It exhibits a remarkedly straight northeast-southwest alignment and has a maximum relief of 3200 feet on its steeper east flank. Its configuration resembles a normal fault scarp.

The Nemaha Ridge resulted from uplift in post-Mississippian times. The initial movements of the Ridge began in Mississippian times and were followed by the major uplift at the close of Mississippian times. Subsequent uplift has occurred since late Missourian times of the Pennsylvanian period. Faulting has occurred along the east flank in northwest Wabaunsee county. In light of the erosional history of the pre-Cambrian rocks and their rates of dip along the east flank, it is concluded that the Ridge is not a normal fault scarp throughout its entire length and consequently it is believed that it did not originate by normal faulting.

The Nemaha Ridge most probably is a result of vertical uplift that was differential in character and occurred along an extended zone of weakness. This zone of weakness probably was first manifested in the uplift that took place at the close of Lower Ordovician times. It later controlled the post-Mississippian uplift of the Ridge.

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APPENDIX

Table 1. Pre-Cambrian well data.

Location	Datum elevation
NW¼ SW¼ sec. 20, T. 1 S., R. 6 E.	-1342
SW¼ NW¼ sec. 34, T. 2 S., R. 8 E.	-1048
Sec. 34, T. 2 S., R. 8 E.	- 387
Sec. 29, T. 2 S., R. 9 E.	- 127
NW¼ sec. 34, T. 2 S., R.12 E.	+ 531
SE¼ SW¼ sec. 16, T. 2 S., R.13 E.	+ 454
NE¼ SW¼ sec. 3, T. 2 S., R.14 E.	-2612
SW¼ NW¼ sec. 13, T. 2 S., R.14 E.	-2673
NE¼ SW¼ sec. 22, T. 3 S., R. 7 E.	- 984
NW¼ SW¼ sec. 25, T. 3 S., R.13 E.	-1670
NW¼ NW¼ sec. 26, T. 3 S., R.13 E.	-1167
Sec. 4, T. 4 S., R. 7 E.	- 937
Sec. 10, T. 4 S., R. 7 E.	- 880
Sec. 22, T. 4 S., R. 9 E.	- 83
Sec. 24, T. 4 S., R. 9 E.	- 198
NW¼ NE¼ sec. 34, T. 4 S., R.13 E.	-1620
SW¼ NE¼ sec. 27, T. 5 S., R. 6 E.	-1187
Sec. 3, T. 5 S., R. 7 E.	-1270
SE¼ SW¼ sec. 30, T. 5 S., R. 7 E.	-1088
NE¼ NE¼ sec. 23, T. 5 S., R.13 E.	-1630
Sec. 25, T. 6 S., R. 9 E.	- 252
NW¼ NE¼ sec. 33, T. 6 S., R. 9 E.	- 427
Sec. 34, T. 6 S., R.11 E.	+ 196
NE¼ NW¼ sec. 15, T. 7 S., R. 5 E.	-1205
SW¼ SE¼ sec. 8, T. 7 S., R. 9 E.	- 364
NE¼ SW¼ sec. 12, T. 7 S., R. 9 E.	- 400
SE¼ SE¼ sec. 1, T. 7 S., R.10 E.	- 84
Sec. 4, T. 7 S., R.10 E.	- 240
NE¼ NE¼ sec. 29, T. 7 S., R.10 E.	- 312
Sec. 24, T. 8 S., R. 4 E.	-1402
NW¼ SW¼ sec. 29, T. 8 S., R. 5 E.	-1317
NW¼ NW¼ sec. 21, T. 8 S., R. 6 E.	-1418
NE¼ SW¼ sec. 32, T. 8 S., R. 9 E.	- 874
SE¼ SE¼ sec. 1, T. 8 S., R.10 E.	- 878
NW¼ NE¼ sec. 7, T. 8 S., R.10 E.	- 455
NE¼ SE¼ sec. 14, T. 8 S., R.11 E.	-2194
NW¼ SW¼ sec. 22, T. 8 S., R.12 E.	-2332
NW¼ SW¼ sec. 29, T. 8 S., R.12 E.	-2329
NE¼ NE¼ sec. 11, T. 9 S., R. 4 E.	-1522
SW¼ NE¼ sec. 14, T. 9 S., R. 4 E.	-1544
NW¼ NW¼ sec. 20, T. 9 S., R. 8 E.	-1095
NW¼ NW¼ sec. 16, T. 9 S., R. 9 E.	- 824
Sec. 34, T. 9 S., R. 9 E.	- 739
NE¼ NE¼ sec. 32, T. 9 S., R.10 E.	- 626
NE¼ NE¼ sec. 36, T. 9 S., R.10 E.	-2011

Table 1 (cont.).

Location	Datum elevation
SW¼ SW¼ sec. 7, T. 9 S., R.12 E.	-2348
SE¼ SE¼ sec. 16, T. 10 S., R. 8 E.	- 983
Sec. 26, T. 10 S., R. 9 E.	+ 56
NW¼ NW¼ sec. 28, T. 10 S., R. 9 E.	+ 155
Sec. 28, T. 10 S., R. 9 E.	+ 49
Sec. 28, T. 10 S., R. 9 E.	- 13
SW¼ SE¼ sec. 32, T. 10 S., R.10 E.	- 642
SW¼ SE¼ sec. 33, T. 10 S., R.10 E.	-1623
Sec. 1, T. 11 S., R. 9 E.	- 28
Sec. 24, T. 11 S., R. 9 E.	- 213
Sec. 5, T. 11 S., R.10 E.	- 389
Sec. 5, T. 11 S., R.10 E.	-1396
SW¼ NE¼ sec. 6, T. 11 S., R.10 E.	- 144
SE¼ SE¼ sec. 10, T. 12 S., R. 7 E.	-1508
SE¼ NW¼ sec. 13, T. 13 S., R. 2 E.	-2121
NE¼ NE¼ sec. 36, T. 13 S., R. 5 E.	-1685
NW¼ SE¼ sec. 2, T. 13 S., R.10 E.	-2183
NE¼ NE¼ sec. 12, T. 14 S., R. 1 E.	-2227
NE¼ SW¼ sec. 5, T. 14 S., R. 8 E.	-1130
SE¼ SW¼ sec. 6, T. 15 S., R. 7 E.	-1548
SE¼ SW¼ sec. 24, T. 15 S., R. 7 E.	-1121
SE¼ SE¼ sec. 24, T. 16 S., R. 5 E.	-1594
NW¼ SE¼ sec. 11, T. 16 S., R. 7 E.	- 413
NE¼ SE¼ sec. 6, T. 16 S., R.10 E.	-1874
NE¼ SE¼ sec. 16, T. 16 S., R.11 E.	-1718
NE¼ NE¼ sec. 34, T. 17 S., R. 7 E.	- 979
NW¼ SE¼ sec. 34, T. 17 S., R. 7 E.	- 995
SE¼ NW¼ sec. 5, T. 18 S., R. 6 E.	-1022
NE¼ SW¼ sec. 19, T. 18 S., R. 6 E.	- 964
SW¼ SE¼ sec. 25, T. 18 S., R. 6 E.	- 609
NE¼ SE¼ sec. 27, T. 18 S., R. 6 E.	- 825
NE¼ SW¼ sec. 32, T. 18 S., R. 7 E.	- 914
NW¼ NW¼ sec. 36, T. 18 S., R. 7 E.	- 881
SE¼ NW¼ sec. 7, T. 19 S., R. 6 E.	-1299
SW¼ SE¼ sec. 21, T. 19 S., R. 6 E.	-1033
SW¼ SW¼ sec. 34, T. 19 S., R. 7 E.	- 782
SE¼ NE¼ sec. 35, T. 19 S., R. 7 E.	- 598
SE¼ NE¼ sec. 25, T. 20 S., R. 5 E.	-1690
SW¼ NW¼ sec. 2, T. 20 S., R. 6 E.	-1117
NE¼ NE¼ sec. 1, T. 20 S., R. 7 E.	-1385
NW¼ NE¼ sec. 2, T. 20 S., R. 7 E.	- 464
SE¼ NE¼ sec. 7, T. 20 S., R. 7 E.	- 734
SE¼ SW¼ sec. 15, T. 20 S., R. 7 E.	- 846
SW¼ NW¼ sec. 16, T. 20 S., R. 7 E.	- 503
SE¼ NE¼ sec. 26, T. 21 S., R. 1 E.	-2460
SE¼ NE¼ sec. 29, T. 21 S., R. 3 E.	-2167

Table 1 (concl.).

Location	Datum elevation
SE¼ NE¼ sec. 17, T. 21 S., R. 4 E.	-1804
NW¼ NW¼ sec. 12, T. 22 S., R.10 E.	-2059
SE¼ NE¼ sec. 17, T. 23 S., R. 4 E.	-2179
SE¼ SW¼ sec. 16, T. 23 S., R. 5 E.	-1227
NW¼ NW¼ sec. 23, T. 23 S., R. 5 E.	- 775
NE¼ SW¼ sec. 24, T. 23 S., R. 5 E.	- 880
SW¼ NW¼ sec. 26, T. 23 S., R. 5 E.	-1099
CS½ SE¼ sec. 21, T. 23 S., R.11 E.	-1972
W½ NE¼ sec. 6, T. 24 S., R. 5 E.	-1917
NE¼ SW¼ sec. 4, T. 24 S., R.10 E.	-2110
SE¼ SW¼ sec. 3, T. 25 S., R. 5 E.	-1960
SE¼ NW¼ sec. 8, T. 25 S., R. 5 E.	-1675
NE¼ NW¼ sec. 1, T. 26 S., R. 1 W.	-2838
NE¼ NW¼ sec. 14, T. 26 S., R. 2 E.	-2625
SW¼ SE¼ sec. 12, T. 26 S., R. 4 E.	-1431
SW¼ NE¼ sec. 22, T. 26 S., R. 4 E.	-2015
SE¼ NE¼ sec. 16, T. 26 S., R. 8 E.	-2191
SW¼ SE¼ sec. 1, T. 27 S., R. 1 W.	-3060
NE¼ SW¼ sec. 16, T. 27 S., R. 4 E.	-1782
NE¼ SW¼ sec. 35, T. 27 S., R. 8 E.	-2033
NW¼ NE¼ sec. 14, T. 28 S., R. 4 E.	-2135
SE¼ SE¼ sec. 22, T. 29 S., R. 3 E.	-2741
SW¼ SE¼ sec. 9, T. 30 S., R. 1 W.	-3695
NW¼ SW¼ sec. 15, T. 30 S., R.10 E.	-2159
SW¼ NW¼ sec. 36, T. 31 S., R. 2 E.	-2153
NW¼ NW¼ sec. 8, T. 31 S., R.11 E.	-1919
NE¼ NE¼ sec. 14, T. 32 S., R. 2 E.	-2790
SE¼ SW¼ sec. 14, T. 32 S., R. 2 E.	-2163
SE¼ NW¼ sec. 18, T. 33 S., R. 7 E.	-2823
SE¼ SW¼ sec. 26, T. 34 S., R.11 E.	-2039
NE¼ SW¼ sec. 9, T. 35 S., R. 6 E.	-3278

Table 2. Comparison of relief along Nemaha Ridge.

Location	Horizon	Elevation	Location	Horizon	Elevation	Relief
Sec. 4,T. 3S.,R.12E.	Pre-Cambrian	+ 500'	Sec. 4,T. 3S.,R.14E.	Pre-Cambrian	-2610'	3110'
	Lansing	+ 690'		Lansing	- 15'	705'
Sec.12,T.6S.,R.11E.	Pre-Cambrian	+ 200'	Sec.12,T. 6S.,R.13E.	Pre-Cambrian	-2000'	2200'
	Lansing	+ 550'		Lansing	- 110'	660'
Sec.21,T.10S.,R.9E.	Pre-Cambrian	+ 150'	Sec.21,T.10S.,R.11E.	Pre-Cambrian	-2090'	2240'
	Lansing	+ 400'		Lansing	- 30'	430'
Sec.17,T.14S.,R.8E.	Pre-Cambrian	- 750'	Sec.17,T.14S.,R.10E.	Pre-Cambrian	-2125'	1375'
	Arbuckle	- 600'		Arbuckle	-1950'	1350'
	Lansing	+ 100'		Lansing	- 150'	250'
Sec.14,T.16S.,R.7E.	Pre-Cambrian	- 450'	Sec.15,T.16S.,R.9E.	Pre-Cambrian	-2030'	1580'
	Arbuckle	- 410'		Arbuckle	-1950'	1540'
	Lansing	+ 50'		Lansing	- 190'	240'
Sec. 2,T.20S.,R.7E.	Pre-Cambrian	- 550'	Sec. 3,T.20S.,R.9E.	Pre-Cambrian	-2135'	1585'
	Arbuckle	- 540'		Arbuckle	-1670'	1130'
	Lansing	+ 50'		Lansing	- 110'	160'
Sec.14,T.23S.,R.5E.	Pre-Cambrian	- 750'	Sec.14,T.23S.,R.7E.	Pre-Cambrian	-2400'	1650'
	Arbuckle	- 730'		Arbuckle	-1725'	995'
	Lansing	- 150'		Lansing	- 250'	100'
Sec.11,T.25S.,R.5E.	Pre-Cambrian	-1350'	Sec.11,T.25S.,R.7E.	Pre-Cambrian	-1940'	590'
	Arbuckle	-1050'		Arbuckle	-1575	525'
	Lansing	- 390'		Lansing	- 230'	160'
Sec.16,T.27S.,R.4E.	Pre-Cambrian	-1650'	Sec.16,T.27S.,R.6E.	Pre-Cambrian	-2480'	830'
	Arbuckle	-1150'		Arbuckle	-1750'	600'
	Lansing	- 525'		Lansing	- 400'	125'
Sec.17,T.28S.,R.4E.	Pre-Cambrian	-1750	Sec.17,T.28S.,R.6E.	Pre-Cambrian	-2580'	830'
	Arbuckle	-1150'		Arbuckle	-1785'	635'
	Lansing	- 450'		Lansing	- 350'	100'

Table 3. Location of wells in cross sections A-B, C-D, and E-F.

Well	Location
1.	NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 8 S., R. 5 E.
2.	NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 21, T. 8 S., R. 6 E.
3.	SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 16, T. 10 S., R. 8 E.
4.	Sec. 28, T. 10 S., R. 9 E.
5.	SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 6, T. 11 S., R.10 E.
6.	SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 32, T. 10 S., R.10 E.
7.	SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 33, T. 10 S., R.10 E.
8.	SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 8, T. 11 S., R.12 E.
9.	SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 4, T. 12 S., R.14 E.
10.	NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 21, T. 19 S., R. 3 E.
11.	CNW$\frac{1}{4}$ sec. 18, T. 19 S., R. 5 E.
12.	SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T. 19 S., R. 5 E.
13.	SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 34, T. 19 S., R. 7 E.
14.	NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 2, T. 20 S., R. 7 E.
15.	NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 1, T. 20 S., R. 7 E.
16.	Sec. 6, T. 20 S., R. 8 E.
17.	SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 14, T. 20 S., R. 9 E.
18.	NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 17, T. 20 S., R.11 E.
19.	SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 24 S., R. 1 E.
20.	NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 12, T. 25 S., R. 2 E.
21.	NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 32, T. 24 S., R. 4 E.
22.	SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 35, T. 24 S., R. 5 E.
23.	SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 12, T. 25 S., R. 5 E.
24.	NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 36, T. 25 S., R. 6 E.

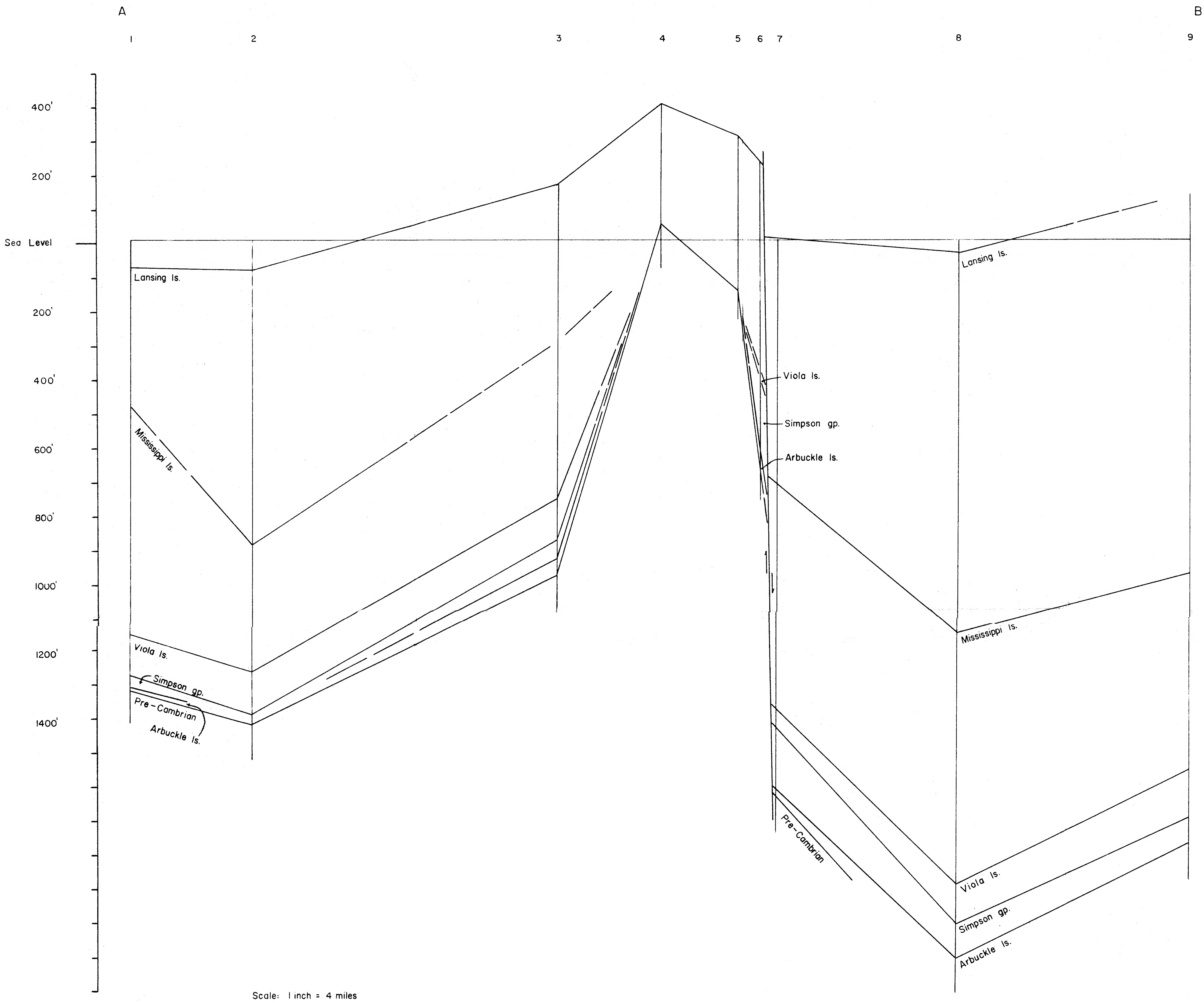

Fig. 1. Cross section A-B.

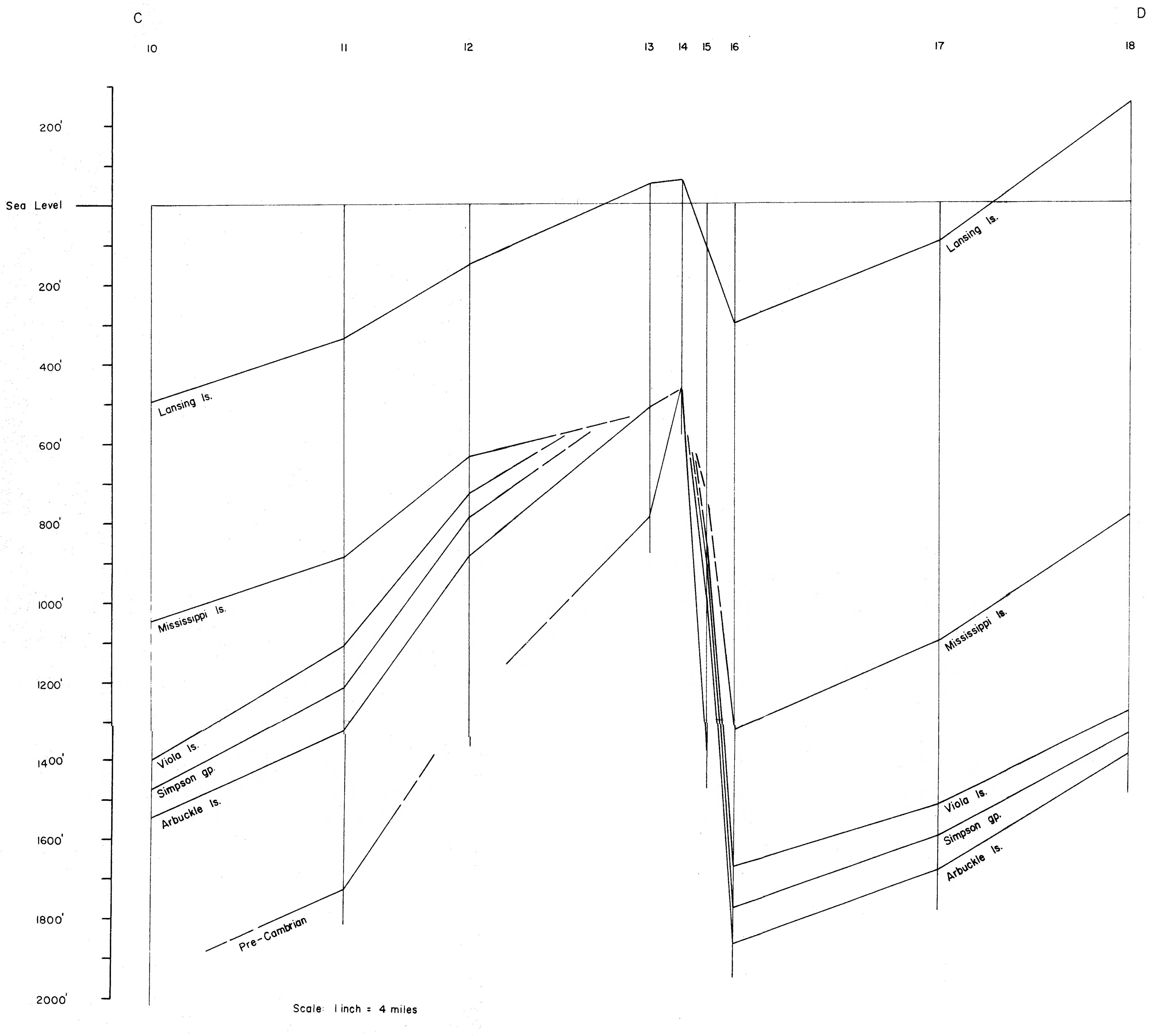

Fig. 2. Cross section C-D.

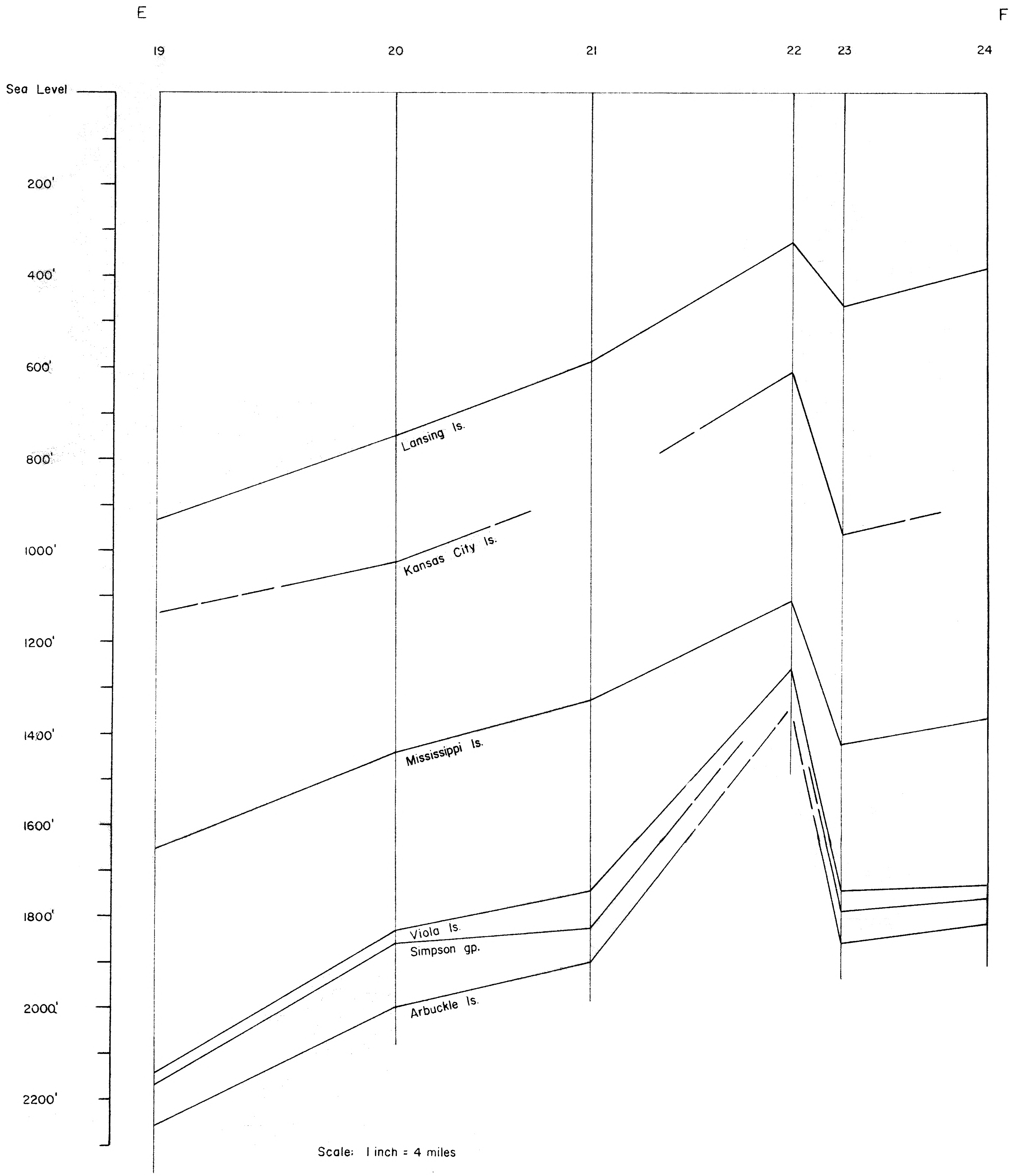

Fig. 3. Cross section E-F.

STRUCTURAL GEOLOGY OF THE NEMAHA RIDGE IN KANSAS

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1950

AN ABSTRACT OF A THESIS

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OF AGRICULTURE AND APPLIED SCIENCE

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The Nemaha Ridge is the most prominent positive structural feature in eastern Kansas. It trends northeast-southwest. The amount of relief on the east flank and the linear alignment of the Ridge suggest that it is a result of normal faulting. This study was undertaken to obtain a structural picture of the Ridge and to determine if the Ridge did originate as a result of normal faulting in Mississippian times.

The pre-Cambrian surface and three younger horizons, the Arbuckle, Mississippi, and Lansing limestone surfaces, were mapped. Elevations from wells drilled within the problem area were used for control. For the regional picture desired, a map scale of 4 miles to the inch and a contour interval of 100 feet were used.

The Nemaha Ridge is an asymmetrical structural ridge that plunges to the southwest. Its east flank is much steeper than its west flank. In southwest Butler county the Ridge levels out into the Chautauqua Arch, but reappears in Sumner county. The northern portion of the Ridge is quite smooth, with no major irregularities on either flank. The southern portion is quite knobby in character and consists of a series of aligned domes with intervening synclines. The relief is the greatest in the northern portion of the area and decreases in amount to the south.

Three times have the pre-Cambrian rocks been subjected to erosion. The entire problem area was eroded prior to deposition of the first Cambrian sediments. Twice later were portions of the area in the north uplifted and eroded, eventually de-nuding and eroding the pre-Cambrian rocks. The third erosional period was a result of the major uplift that closed the Mississippi Period and brought into existence the Nemaha Ridge. The first erosional period essentially peneplained the pre-Cambrian rocks and the two subsequent erosional periods did not materially alter the peneplain.

An examination of the greatest dips on the east flank of the Nemaha Ridge revealed that the greatest dip was 7 degrees, 45 minutes. This dip is far less than is common for normal faults, particularly those associated with structures of the magnitude of the Nemaha Ridge.

Considering the erosional history of the pre-Cambrian rocks and the rate of dip of the east flank of the Nemaha Ridge, it was concluded that the Ridge did not result from normal faulting. More probably it was the result of differential vertical uplift along an extended zone of weakness at the close of the Mississippian Period.