STUDY OF THE RELATIONSHIP BETWEEN THE COTTONWOOD LIMESTONE AND THE NEVA LIMESTONE STRUCTURES

by

HUGH OTIS MCMILLAN

B. S., Kansas State College
of Agriculture and Applied Science, 1939

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Geology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1947

TABLE OF CONTENTS

INTRODUCTION

The area of this study lies in the southeast part of Riley County, Kansas, in the vicinity of the City of Manhattan. The area is approximately eight miles long and four miles wide (Fig. 1).

In a preliminary study made of the stratigraphy of the area a considerable amount of thickening and thinning was noted within the formations and members. A correlation of the results shows that this variation is much greater in the shales than in the limestones. Of the shale formations, the Eskridge has the greatest thickening and thinning with a variation of 10 feet. Where a limestone formation shows a relatively wide variation, it is the shale member within the formation that is primarily responsible for the change. An example of this is to be observed in the Red Eagle limestone formation which shows a variation of 2.6 feet. The Red Eagle formation contains the Glenrock limestone member at its base and the Howe limestone member at its top with the Bennett shale member in between. The Bennett shale member varies 2.5 feet whereas the Howe and Glenrock limestone members show a change of only 0.8 and 0.5 feet, respectively. Of the more massive limestones measured, the Neva limestone member has the greatest variation, 3 feet. This seems considerable for a formation that appears to be largely limestone, but when all of the

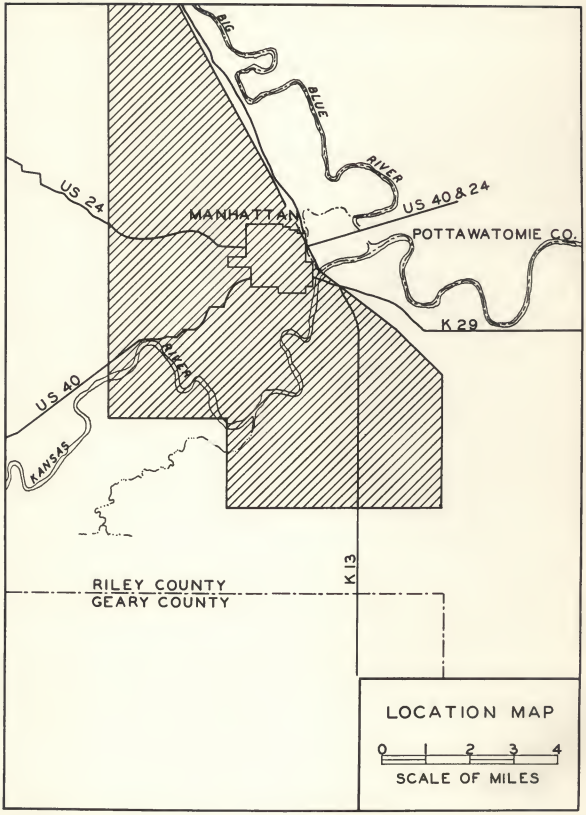

Fig. 1. Location map.

numerous thin shale zones were taken into account, it was found that the Neva varied from 10 to 27 percent shale, indicating again that it is the shale that produces the variation rather than the limestone. A tabular correlation of this study is shown in Fig. 2. The sections upon which this table is based are given in the Appendix.

With these observed facts, it was decided to investigate what effect the thickening and thinning of shales had upon the structures of overlying limestones. Since the greatest thickness variation was found in the Eskridge shale, it and the overlying Cottonwood limestone and the underlying Neva limestone were made the object of this study. Both the Cottonwood and Neva structures were mapped and a comparison made between them to determine (1) in what way they were related genetically, (2) how the variation in the thickness of the Eskridge modified the Cottonwood structure with respect to the Neva structure, and (3) the cause of the basic or fundamental structure.

STRATIGRAPHY AND GEOLOGY OF THE AREA

The outcropping formations are mainly of the Council Grove group, of the Permian system, and include all of the stratigraphic units from the base of the Americus to the top of the Cottonwood limestone. This, however, is not true for the south and southeast part of the area where the strati-

FORMATIONS AND MEMBERS	MEASURED SECTIONS													VARIATION	CORRELATION	
	1	2	3	4	5	6	7	8	9	10	11	12	13		SHALE	LIMESTONE
BEATTIE LIMESTONE FM.																
MORRILL LIMESTONE MB.																
FLORENA SHALE MB.					7.5'											
COTTONWOOD LIMESTONE MB.		6.0'	5.3'		5.6'					6.5'	5.0'	5.5'	5.6'	1.5'		1.5'
ESKRIDGE SHALE FM.		30.8'	34.6'		31.5'	36.0'			32.0'	26.0'	34.8'	29.0'	27.8'	10.8'	10.6'	
GRENOLA LIMESTONE FM.		31.1'		29.5'	33.8'	35.5'		32.3'					32.2'	6.0'		6.0'
NEVA LIMESTONE MB.		15.0'	17.8'	20.8'	18.0'	18.0'		24.0'	17.3'	16.1'		25.1'	15.8'	3.0'		3.0'
SALEM POINT SHALE MB.	8.0'	8.1'	8.0'		7.8'	9.0'			8.4'	8.0'			8.7'	1.2'	1.2'	
BURR LIMESTONE MB.	8.2'	8.0'		8.7'	8.0'	8.5'		8.3'					7.7'	1.0'		1.0'
ROCA SHALE FM.	22.1'	25.0'		24.5'	24.5'	25.0'		24.0'						2.9'	2.9'	
RED EAGLE LIMESTONE FM.	16.1'	16.6'		16.8'		16.7'		16.8'						2.6'		2.6'
HOWE LIMESTONE MB.	5.2'	4.4'		4.4'		4.8'		5.0'						0.8'		0.8'
BENNETT SHALE MB.	9.3'	10.4'		10.5'		11.8'		10.0'						2.5'	2.5'	
GLENROCK LIMESTONE MB.	1.6'	1.8'		1.9'		2.1'		1.8'						0.5'		0.5'
JOHNSON SHALE FM.	16.0'	18.5'		15.9'		13.2'	13.5'	15.0'						5.3'	5.3'	
FORAKER LIMESTONE FM.	48.5'	50.7'												2.2'		2.2'
LONG CREEK LIMESTONE MB.	8.0'	8.6'		9.1'			10.2'	10.1'						2.2'		2.2'
HUGHES CREEK SHALE MB.	37.4'	38.5'												1.1'	1.1'	
AMERICUS LIMESTONE MB.	3.1'	3.6'												0.5'		0.5'

Fig. 2. Tabular correlation.

graphic column is extended upward to include the Threemile limestone of the Chase group. For a more complete description of the outcropping rocks of the area, reference is made to the detailed measured sections in the Appendix of this report.

The Cottonwood and Neva limestones were ideally suited for study because of their ease of identification, and their outcrops were persistent throughout the area. A generalized stratigraphic section of the units with which this study is primarily concerned is shown in Fig. 3.

The Cottonwood limestone, a gray, massive limestone containing chert nodules and an abundance of fusulinids, forms a prominent outcrop throughout the area. The Cottonwood limestone is easily identified by the large massive blocks, the chert nodules, and the abundance of fusulinids. These characteristics are more pronounced in the weathered outcrops. In general the member is composed of one or two beds of limestone but in some observed sections the lower portion is shaly and grades into the underlying Eskridge shale.

The Eskridge shale is a varicolored calcareous shale containing thin impure limestones throughout. Where exposed on the hills, these limestones may form small benches, however, they are not persistent and most of them cannot be traced any great distance. One thin limestone in the lower portion of the formation contains an abundance of pelecypods, these have

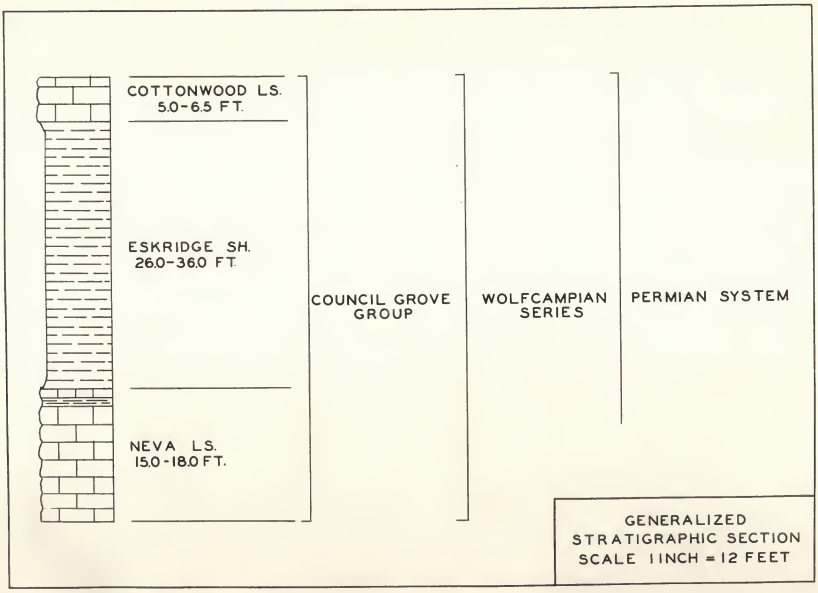

Fig. 3. Generalized stratigraphic section.

been identified as Aviculopectin and Myalina. Where exposed on a weathered slope some of the thin calcareous zones in the lower portion may be mistaken for the top of the underlying Neva limestone. For a more detailed description of the formation reference is made to the measured section of Bluemont Hill in the Appendix.

The Neva limestone forms the next prominent outcrop beneath the Cottonwood limestone. The top portion of the Neva is composed of thin limestones and shales, underlying this is a massive, gray, solution pitted (honeycombed) limestone that weathers buff. It is this portion of the Neva that forms the more prominent outcrop. Underlying this is a buff shale of varying thickness and a thin limestone forming the base of the Neva limestone. This lower limestone weathers rather readily and is usually found only in slightly weathered exposures and fresh cuts. Although definite proof is lacking, it is thought by the author that the thickening and thinning observed in the Neva may be caused by the variation in the thickness of this lower shale. The shale was observed to vary from 0.6 to 3.5 feet.

The Cottonwood limestone, Eskridge shale, and Neva limestone are mostly of marine origin and were layed down in an epeiric sea that had its outlet to the south through Oklahoma. Sea level apparently fluctuated considerably as is indicated by the variation in composition from shales to limestones and from the color variation within the Eskridge shale. It

is possible that some of the red zones in the Eskridge shale were deposited subaerially or in a near subaerial environment.

STRUCTURE

To study the relationship between the Cottonwood limestone and the Neva limestone, elevations were established for the top of the Cottonwood and the base of the Neva over the entire area. This was accomplished by the use of aerial photographs and a plane table. The aerial photographs were used primarily to spot the location of the rock shots and occasionally to determine the horizontal distance factor needed to determine elevation differences. Shots on the top of the Cottonwood were relatively easily obtained but most of the Neva base shots had to be dug out. More than 50 elevation determinations were made on the Neva alone. Other Neva elevations were obtained from highway plans prepared by the State Highway Commission. From these data structural contour maps were drawn for the top of the Cottonwood and base of the Neva limestones. An isopach map was constructed based on the thickness interval between these two datums so that a comparison could be made between the two structures and their relationships to the areas of thickening and thinning.

In studying the structural maps of the Cottonwood and Neva limestones (Figs. 4 and 5), it is apparent that the

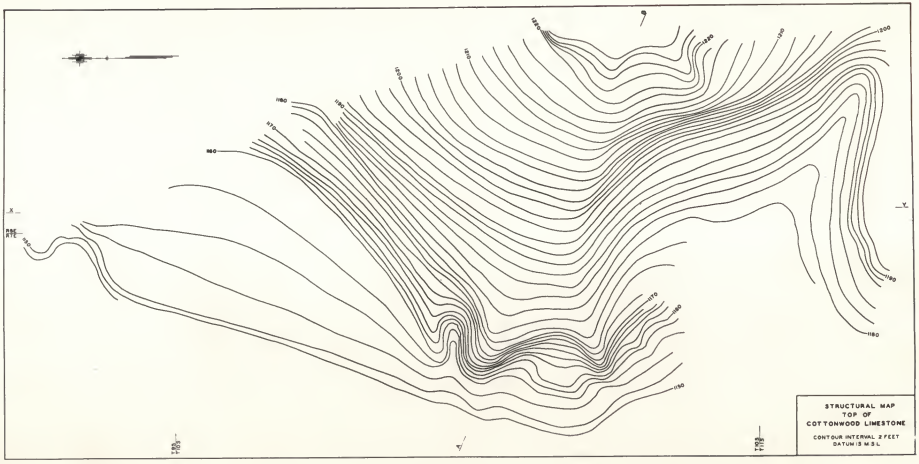

Fig. 4. Structural map, top of Cottonwood limestone.

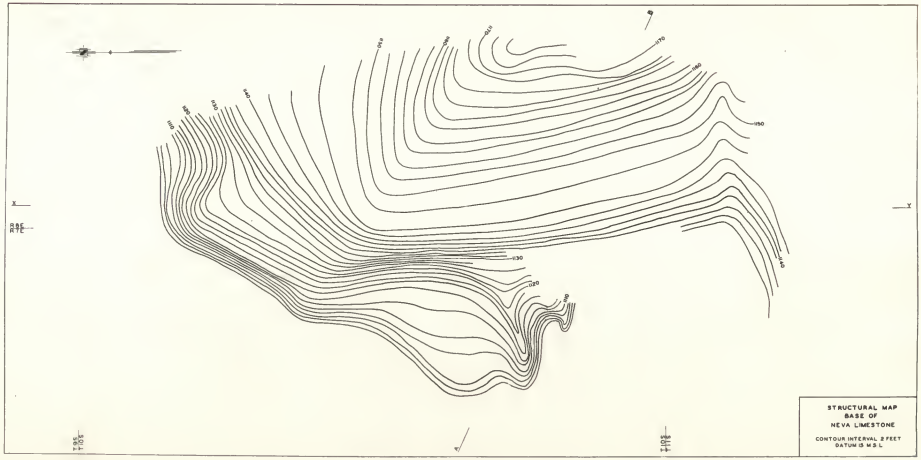

Fig. 5. Structural map, base of Neva limestone.

structures are similar in character, both are pitching anticlines with small synclines to the south. It will be noted that the two structures do not directly overlie each other; that is, the two anticlinal axes do not coincide. The Cottonwood anticline pitches to the west at a rate of 19 feet per mile. The Neva anticline has a NW - SE trend and pitches northwest at the rate of approximately 21 feet per mile. The Cottonwood syncline has a NW - SE trend and pitches northwest approximately 9.5 feet per mile. The Neva syncline trends almost directly east and west with an approximate pitch of 14 feet per mile to the west. The Cottonwood anticline is not as sharp a flexure as the Neva, and is more irregular. When the Cottonwood flexure is superposed on the Neva, it is noted that both the Cottonwood anticlinal and synclinal axes lie to the south of the Neva anticlinal and synclinal axes. The minor anticlines and synclines on the west fringe of the Cottonwood structure cannot be correlated definitely with those on the west fringe of the Neva structure.

Since the Neva and Cottonwood limestones are relatively constant in thickness as compared with the Eskridge shale, the isopach map is essentially a reflection of the thickness disposition of the Eskridge shale. The isopach map should, therefore, give some clue as to the environment under which the Eskridge shale was deposited. If it is assumed that where the Eskridge is now the thickest, the water was the deepest, it will be observed, by referring to the isopach map (Fig. 6),

that there are several lagoonal like basins the deepest of which is at the west edge of the map where the 70 foot index contour appears. To the east, over the 50 foot saddle is another somewhat shallower basin. To the north and south of these two lagoonal basins and trending roughly in a north - south direction shallower water existed. Thus, during Esk-ridge times a north - south barrier separated an east west lagoon. These features indicate what the post Neva surface was like before the imposition of the forces that produced the basic or fundamental Neva structure.

When the Cottonwood and Neva structures were superposed in turn upon the isopach map the following relationships were observed:

(1) The Neva anticlinal axis was located approximately along the north edge of the east - west lagoons.

(2) The westward break (steepening) in the dips of the Neva paralleled the north - south barrier ridge.

(3) The Cottonwood anticlinal axis was located approximately over and slightly to the south of the east - west lagoonal axis.

(4) The minor structures on the west fringe of the Cottonwood flexure were located in part over the east lagoon and the sharp minor ridge immediately to the south.

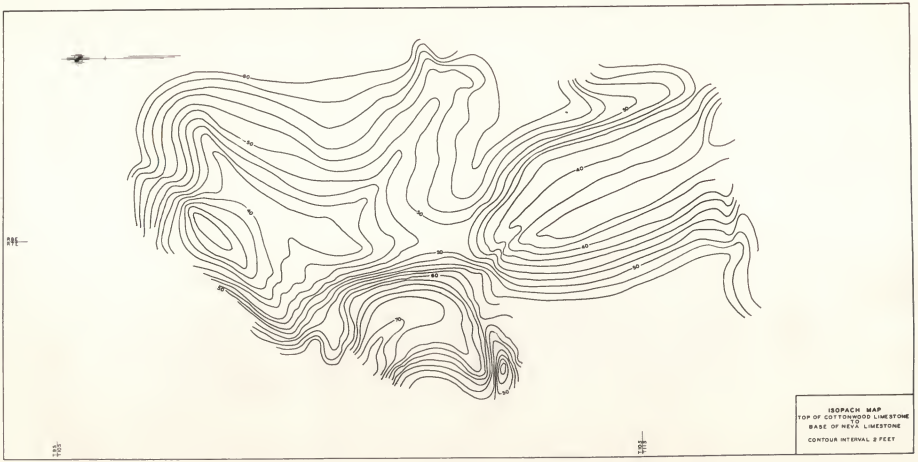

Fig. 6. Isopach map, top of Cottonwood limestone to base of Neva limestone.

INTERPRETATION OF THE STRUCTURES

It was immediately apparent from the study of the structural maps that the Neva and Cottonwood anticlines were not produced by compressive forces. If the structures had been produced by such compressive forces, it would be impossible to explain the divergence in the anticlinal trends of the Neva and Cottonwood. It would also be impossible to explain the minor folds on the fringes of the major structures. It is a known fact that in any area of compression, the type of folding that developes is determined by the strongest, most competent bed. Since the Neva is the thicker and stronger of the two limestones, it would determine the size and shape of the structure, and the resolved tangential forces acting parallel to its flanks would serve to mold the Cottonwood to itself, tending to wipe out all minor irregularities due to other causes. The possibility of two separate periods of compression is not likely because of the absence of an unconformity.

Since compressive forces could not have produced the structures, differential vertical movements are the only remaining possibilities to a solution of the problem. From the data available, it was impossible to determine whether the fundamental structure was due to active (upward) stresses originating from below or whether the fundamental structure was a result of the differential (downward) compaction of

sediments. Since the effect in both cases would be the same, the point is of minor significance in this particular study. However, since the characteristics of the major folds in this general region do conform with those established by Athy (1934) for structures due to differential compaction, it will be assumed that the fundamental structure in the Neva was produced by the differential compaction of the sediments that underlie it. This, plus the primary configuration of the upper Eskridge surface, plus the differential compaction of the Eskridge under the weight of the Cottonwood and the sediments overlying it, serves to explain the Neva structure and why the Cottonwood does not conform to it. If the Eskridge shale had been deposited uniformly in thickness, it would have compacted the same number of feet at all points and the Cottonwood structure would have been a perfect reflection of the Neva structure. This, however, was not the case. The Cottonwood anticlinal axis does not coincide with that of the Neva because when the Neva structure developed, the thickest Eskridge deposit was located to the south of the Neva anticlinal axis along the area of the east - west lagoonal basins. This thick Eskridge zone determined the location of the Cottonwood axis, or rather prevented the Cottonwood axis from developing over the Neva crest. The cross section X-Y (Fig. 7) reveals this situation. The westward break or steepening in the dip of the Neva is not reflected

in the Cottonwood structure because in the direction of this steepening the Eskridge becomes thicker and serves to diminish the dip in the Cottonwood. The cross section A-B (Fig. 7) shows this relationship. The minor structures on the west fringe of the Cottonwood flexure are probably the result of the differential compaction of the Eskridge in the zone of the east lagoon and the minor ridge immediately to the south.

CONCLUSIONS

On the basis of the maps and cross section interpretations together with studies made in the field, the Neva and Cottonwood structures are genetically related. The fundamental or Neva structure is reflected in the Cottonwood flexure. The variation between the Cottonwood and the Neva structure is determined entirely by the thickness disposition of the Eskridge shale. The Eskridge shale was not deposited uniformly over the Neva because of the initial surface configuration of the top of the Neva as lagoonal basins. When this irregular lagoonal surface was unkinked, presumably by the differential compaction of the sediments under the Neva, the present structures were developed.

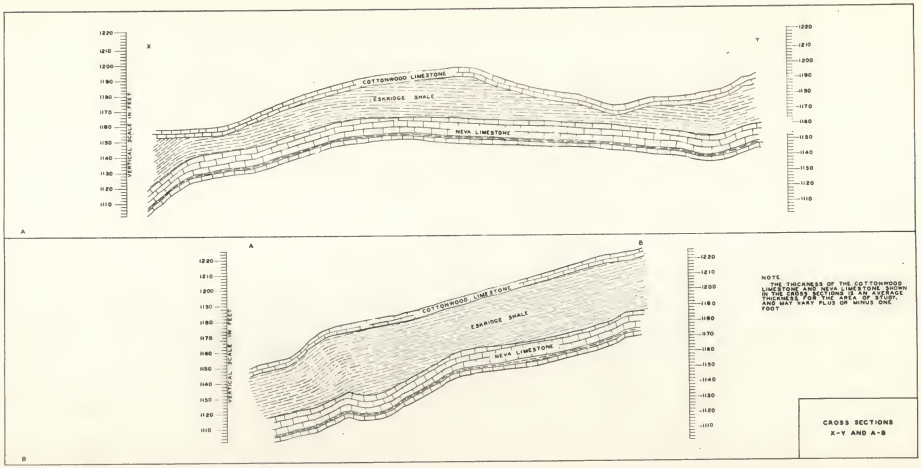

Fig. 7. Cross sections, X-Y and A-B.

ACKNOWLEDGMENT

The writer is indebted to Professor Joseph R. Cholikowsky for his inspiration and for his valuable assistance in the field and in the preparation of this manuscript. Sincere thanks are also expressed to the staff of the Department of Geology for their help and consideration.

BIBLIOGRAPHY

Athy, L. F.
Compaction and its effect on local structures. In Problems of Petroleum Geology. Amer. Assoc. Petrol. Geol. 811-823. 1934.

Moore, R. C., J. C. Frye and J. M. Jewett.
Tabular description of outcropping rocks in Kansas. Kans. Geol. Survey Bul. 52, Part 4, 133-168. 1944.

Jewett, J. M.
The geology of Riley and Geary Counties, Kansas. Kans. Geol. Survey Bul. 39. 164 p. 1941.

Schuchert, Charles and Carl O. Dunbar.
A textbook of geology, Part II - Historical geology. New York. John Wiley. 544 p. 1941.

Hedberg, H. D.
The effect of gravitational compaction on the structures of sedimentary rocks. Amer. Assoc. Petrol. Geol. 10: 1035-1072. 1926.

Nevin, C. M. and R. M. Sherrill.
Studies in differential compaction. Amer. Assoc. Petrol. Geol. 15: 1-22. 1935.

Nevin, Charles Merrick.
Principles of structural geology. New York. John Wiley. 348 p. 1936.

Davis, R. E. and F. S. Foote.
Surveying theory and practice. New York. McGraw-Hill. 1032 p. 1941.

APPENDIX

R-HILL, BUG OF MRVR SEC.28 12-5

SCALE 1"=5'

BLUEMONT HILL NEAR SEC 7 10-6

SCALE 1 INCH = 5 FEET

K HILL SECTION
E1/2 of NW1/4 of NW1/4 sec 20, T10S R8E

PALEOZOIC
Permian system
Wolfcampian series
Council Grove group

		Feet
Grenola limestone		
Neva limestone member		
1.	Covered	
2.	Limestone, buff	
Salem Point shale member (8.0')		
	Shale, mostly covered	8.0
Burr limestone member (8.2')		
3.	Limestone, gray, weathers buff	3.0
4.	Shale, buff	2.5
5.	Covered	2.7
Roca shale (22.1')		
6.	Covered	4.8
7.	Limestone, gray	0.7
8.	Covered	10.0
9.	Limestone	0.3
10.	Shale, green and red	6.3
Red Eagle limestone (16.1')		
Howe limestone member (5.2')		
	Limestone, chalky, silty at bottom	5.2
Bennett shale member (9.3')		
11.	Shale, buff, silty at bottom calcareous near the top, Echinoid spines and Brachiopod fragments	1.6
12.	Shale, brown to black, clay to silty, (silty near top)	3.0
13.	Limestone, buff to gray, massive, contains fusulina	1.7
14.	Shale, gray to black	3.0
Glenrock limestone member (1.6')		
	Limestone, gray, clayey	1.6
Johnson shale (16.0')		
15.	Shale and limestone, broken, interformational breccia	0.7
16.	Shale, gray to brownish (lignitic brown), silty	1.0

17.	Limestone, nodular, broken	0.6
18.	Shale, greenish, clay, 0.5 foot limy, green shale in middle	3.9
19.	Shale, dark gray to greenish gray, clayey	2.5
20.	Limestone, gray	0.8
21.	Covered, mostly green shale	6.5

Foraker limestone (48.5')

Long Creek limestone member (8.0')

	Limestone, buff, thin bedded, chalky	8.0

Hughes Creek shale member (37.4')

22.	Limestone, argillaceous, upper part more shaly than limy, fusulina	1.8
23.	Shale, buff, calcareous, upper part abundant fusulina	1.9
24.	Shale, gray to black clay	2.8
25.	Shale, gray calcareous, numerous fusulina	1.8
26.	Limestone, clayey, fusulina, and ambolcelia	0.8
27.	Shale, black, clayey	2.1
28.	Limestone, buff, hard	1.0
29.	Shale, gray to buff, black on surface, clayey	5.5
30.	Shale, gray to buff, calcareous, numerous Spirifer and crinoids	3.3
31.	Limestone, with 0.2 foot green to black shale parting 0.2 foot from top, fossiliferous, Marginifera and Dictyoclostus	1.0
32.	Shale, buff, clay	0.7
33.	Limestone, dense, gray, (mottled gray and black)	0.9
34.	Covered	11.3
35.	Shale, dark gray to black, clay	2.0
36.	Shale, greenish gray, calcareous	0.5

Americus limestone (3.1')

37.	Limestone, gray to pinkish, no partings, hard, numerous crinoid stems	1.0
38.	Shale, gray to black, lower part dark gray clay, thin black zone at top 0.1 foot thick	1.4
39.	Limestone, gray to pink, lens like bands or wavy zones in the lower portion	0.7

BLUEMONT HILL SECTION
E 1/2 of Sec 7, T1S R8E

PALEOZOIC
Permian system
Wolfcampian series
Council Grove group

	Feet
Beattie limestone	
Cottonwood limestone member	
Limestone, gray, massive, many fusulinids, chert	6.0
Eskridge shale (30.8')	
1. Shale, calcareous, gray to buff, grading to thin limestone at top	2.3
2. Shale, covered, exposed part greenish, upper part calcareous	7.7
3. Limestone, gray, no fossils	0.6
4. Shale, covered, exposed portion green	7.3
5. Shale, red	1.3
6. Shale, gray and green	4.6
7. Limestone, gray, fossiliferous, Bellerophons and Aviculopectins	0.2
8. Shale, buff	0.5
9. Limestone, gray	0.2
10. Shale, greenish, thin calcareous zone in the middle	6.1
Grenola limestone (31.1')	
Neva limestone member (15.0')	
11. Limestone, gray to buff	0.7
12. Shale, calcareous, buff	0.3
13. Limestone, gray, thin-bedded, slabby	4.8
14. Shale, buff, calcareous	0.6
15. Limestone, gray, solution pitted (honeycombed), weathers buff	7.0
16. Shale, buff	0.6
17. Limestone, gray	1.0
Salem Point shale member (8.1')	
18. Shale, buff	4.5
19. Limestone, gray to buff	0.6
20. Shale, buff	3.0
Burr limestone member (8.0')	
21. Limestone, gray to buff, weathers to thin beds	4.6
22. Shale, black, fissil	1.2
23. Limestone, gray, weathers buff, fossiliferous	2.2

Roca shale (25.0')

24.	Shale, gray, fissil	4.8
25.	Limestone, gray, weathers buff, fossil fragments, Echinoids	1.1
26.	Shale, green, calcareous zone below the middle, contains calcareous nodules, appears to be broken up shale	6.4
27.	Shale, red green and gray, fragmental, calcareous, interformational breccia	2.0
28.	Shale, gray, nodular, calcareous	0.8
29.	Shale, gray (mudstone)	0.8
30.	Limestone, argillaceous, zone of red and green fragments (nodular)	0.8
31.	Shale, red and green, fragmental	0.8
32.	Shale, green at base grading into chocolate	1.0
33.	Limestone, gray, fine textured, no fossils observed	0.4
34.	Shale, red, silty, upper 0.4 feet green, contains mud cracks	2.5
35.	Shale, gray to green	2.0
36.	Limestone, gray nodular	0.6
37.	Shale, green	1.0

Red Eagle limestone (18.6')

Howe limestone member (4.4')

	Limestone, massive, buff, chalky, contains Brachiopods	4.4

Bennett shale member (10.4')

38.	Shale, gray to buff, locally black zones	4.7
39.	Limestone, mottled gray and buff, fragmental, fusulina	0.8
40.	Shale, lower part buff, upper gray and buff, locally black	4.9

Glenrock limestone member (1.8')

	Limestone, gray, clay, weathers to thin beds	1.8

Johnson shale (18.5')

41.	Shale and limestone, broken, interformational breccia	0.4
42.	Shale, brown (lignitic brown)	1.0
43.	Limestone, nodular	1.2
44.	Shale, green, clay, thin lime zone in the middle	1.4
45.	Shale, gray, clay	1.3
46.	Shale, green	2.5
47.	Limestone, shaly	1.5

48.	Shale, green	2.0
49.	Limestone, gray, argillaceous	2.0
50.	Shale, green, covered	5.2

Foraker limestone (50.7')
Long Creek limestone (8.6')
Limestone, buff, thin bedded chalky, locally thin shaly zone 8.6

Hughes Creek shale (38.5')

51.	Shale, brown to buff, silty, upper part lighter brown	1.6
52.	Shale, gray to buff, calcareous, abundant fusulina	0.8
53.	Limestone, buff, abundant fusulina	1.0
54.	Shale, dark gray, clay, upper one-half dark gray and calcareous, abundant fusulina	4.9
55.	Shale, gray, calcareous, abundant fusulina	1.6
56.	Limestone, gray, very fossiliferous, fusulina	0.7
57.	Shale, black, grading into dark gray calcareous	2.0
58.	Limestone, gray, dense, abundant fossil fragments	1.2
59.	Shale, gray to buff, no fossils	5.2
60.	Shale, gray calcareous, very fossiliferous, Dictyoclostus and Bryozoans	3.0
61.	Limestone, gray, clayey	0.2
62.	Shale, gray	0.3
63.	Limestone, argillaceous	0.3
64.	Shale, covered	1.2
65.	Limestone, gray, dense, massive	1.0
66.	Shale, greenish gray to dark gray clay	2.1
67.	Limestone, buff, full of brachioped fragments (broken fragmental appearance)	1.4
68.	Shale, gray and black clayey	0.5
69.	Limestone, gray, argillaceous	0.3
70.	Shale, gray, calcareous	0.2

Americus limestone member (3.6')

71.	Limestone, gray, massive, contains crinoid stems	1.0
72.	Shale, gray to black	0.2
73.	Shale, gray, limy	0.3
74.	Shale, gray to black, clayey	1.3
75.	Limestone, gray, lens like bands or wavy zones lower portion	0.8

SUNSET PARK SWNW SEC 13 10-7

SCALE 1 INCH = 5 FEET

CEDAR BEND NWNW SEC. 13, 10-7

SUMMIT PARK SECTION
SW1/4 of Sec 19, T10S R7E

PALEOZOIC
Permian system
Wolfcampian series
Council Grove group

	Feet
Beattie limestone	
Cottonwood limestone member	
Limestone, gray, massive, many fusulinids, chert	5.5
Eskridge shale (34.6')	
Lower one third greenish shale with thin limestone zones, middle one third reddish calcareous shale, upper one third buff shale	34.6
Grenola limestone	
Neva limestone member (17.8')	
1. Limestone, gray, slabby	8.6
2. Limestone, gray, solution pitted (honey-combed)	6.0
3. Shale, gray to buff	2.5
4. Limestone, gray, weathers buff, Crinoid stems	0.7
Salem Point shale member (8.0')	
Shale, buff, thin limestone in middle	8.0
Burr limestone	
Limestone, gray, weathers buff	

CEDAR BEND SECTION
NW1/4 Sec 13, T10S R6E

PALEOZOIC
Permian system
Wolfcampian series
Council Grove group

	Feet
Grenola limestone (29.5')	
Neva limestone and Salem Point shale members (20.8')	
1. Top of slabby zone in Neva limestone	5.2
2. Top of honeycombed (solution pitted) zone in Neva limestone . .	15.6
Burr limestone member (8.7')	
3. Limestone, thin bedded, shaly, more massive near top. Bands of very fine limestone in upper layer. Upper surface appears to have ripple marks	5.0
4. Shale, gray to black, weathers buff	1.5
5. Limestone, gray, weathers buff .	2.2
Roca shale (24.5')	
6. Shale, buff	4.8
7. Limestone, gray, massive . .	1.0
8. Shale, greenish, somewhat calcareous	4.0
9. Shale, broken, lower part red upper part green	5.3
10. Limestone, gray, clayey . .	0.8
11. Shale, broken, red grading upward into chocolate . . .	2.7
12. Limestone, gray, nodular . .	0.2
13. Shale, covered, upper 2 feet red grading into green . .	6.0
Red Eagle limestone (16.8')	
Howe limestone member (4.4')	
Limestone, buff, massive, chalky .	4.4
Bonnett shale member (10.8')	
14. Shale, black grading upward into gray, calcareous. Upper part contains Composita and Marginifera	3.7
15. Limestone, gray to buff . .	1.3
16. Shale, gray to black . . .	5.5
Glenrock limestone member (1.9')	
Limestone, thin bedded, clayey .	1.9
Johnson shale (15.9')	
17. Shale and limestone, broken .	0.4

18.	Shale, dark brown (lignitic brown)	0.7
19.	Limestone, gray, nodular, shaly	1.0
20.	Shale, green	1.2
21.	Shale, gray to green, thin lime zone at top	4.8
22.	Limestone, thin bedded with shale partings	2.8
23.	Shale, buff to green	5.0

Foraker limestone
Long Creek limestone member (9.1')

24.	Limestone, buff, thin bedded, upper 1 foot more massive	6.5
25.	Limestone, gray, clayey, abundant Celestite geodes	2.6

Hughes Creek shale member (14.5' exposed)

26.	Shale, black	1.5
27.	Limestone, gray, hard, no fossils apparent	0.6
28.	Shale, gray, calcareous upper part more limy, fusulina	3.6
29.	Covered, upper part black shale, thin limy zone at top	4.8
30.	Limestone, gray, fusulina	0.6
31.	Shale, black, upper 0.7 foot gray calcareous shale containing Marginifera. Black shale contains Orbiculoidea	2.2
32.	Limestone, gray, abundant fusulina	1.2

(Note: Section ends at water surface of Wild Cat Creek.)