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THE NEVA LIMESTONE IN NORTHERN OKLAHOMA, WITH REMARKS UPON THE CORRELATION OF THE VERTEBRATE FOSSIL BEDS OF THE STATE.

EASTERN OUTCROP OF THE PERMIAN REDBEDS IN OKLAHOMA, WITH A DISCUSSION OF LITHOLOGIC AND COLOR CHANGES.

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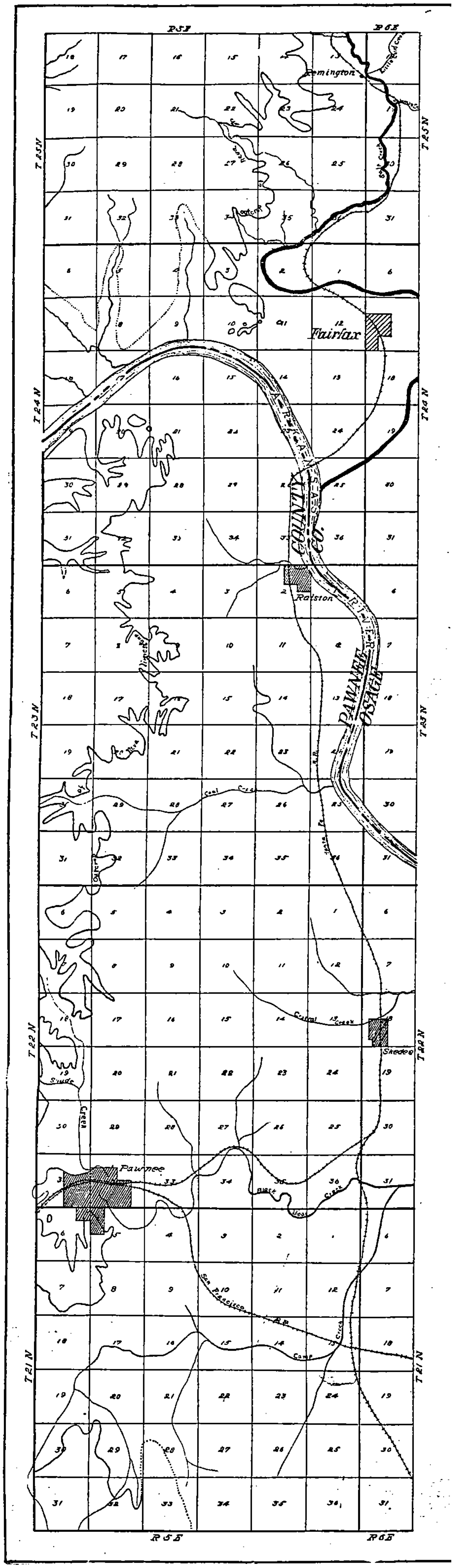
R5E
R6E
T25N
T24N
T23N
T22N
T21N
Remington
Fairfax
Ralston
Skedee
Pawnee
OSAGE
COUNTY
PAWNEE
CO.
Coal Creek
Black Bear Creek
Camp Creek
San Francisco R.R.
R5E
R6E

THE NEVA LIMESTONE IN NORTHERN OKLAHOMA WITH REMARKS ON THE CORRELATION OF THE VERTEBRATE FOSSIL BEDS.

INTRODUCTION.

GENERAL.

On account of the rapid changes which take place in the nature of the strata on passing from Kansas into Oklahoma, and the necessity of having a base in determining the horizon of the rock in drilling for oil, it was thought best to trace some bed of known horizon in Kansas south into Oklahoma. For various reasons it was thought that the Neva limestone would answer this purpose best, since the Wreford limestone changed to a sandstone and was difficult to follow, as well as being west of the oil fields. The Neva limestone is of lower horizon, goes farther south before changing to sandstone, and is closer to the oil fields. The Cottonwood Falls limestone, a strong horizon marker in Kansas dwindles away before reaching the Oklahoma border.

The Neva limestone was first described from the northern and central parts of Kansas, and the correlation with the bed at Hooser, Kans., is the result of Professor J. A. Yates' work in mapping the Cottonwood Falls limestone in 1905.

On account of the similarity of many of the beds associated with this limestone, it is necessary to carry a carefully detailed section of some thickness in doing reconnaissance work, in order to avoid confusion and mistaking one layer for another.

For this reason the section from Cedarvale to Hooser was carefully studied, and a formation easily recognized and well separated from the Neva limestone, was selected. It is a stratum of limestone made up of several beds with shale partings and carrying many *Fusulinae* and chert concretions. It was some 165 feet below the Neva and probably represents the Fusulina horizon just over the Americus limestone. Between this limestone and the Neva there are a great number of thin layers of limestone, many of which are literally composed of pelecypods, and one layer about 9 feet thick, as is shown in the section between Cedarvale and Hooser.

Before taking up the detailed discussion of the sections and the southern continuation of the Neva limestone it is necessary to

call attention to the general structure of the rocks along and near the outcrop.

THE FLINT HILLS MONOCLINE.

In the vicinity of the front of the Flint hills escarpment, for a distance a few miles in width, the dip of the rocks steepens from nearly horizontal, 10 to 20 feet to the mile, to the west, to 20 to 200 feet per mile, depending upon the locality and the local structures which are found throughout its entire extent in Kansas and Oklahoma. No dip was noted in Oklahoma as great as the largest figures given but it is very considerable. A few miles west of this the dip again flattens and becomes quite as low, if not lower than it was east of the monocline.

The dip is, on the whole, nearly due west. In reality a little north of west, if a strike of 250 or 300 miles is taken. For instance, the outcrop in Marshall County, Kans., averages about 50 miles east of the sixth prime meridian, while in Pawnee County, Okla., 250 miles farther south it is about 25 miles east of it. That is, 25 miles in 250, or one mile west in 10 miles south. This leaves the dip one mile north to 10 miles west. However, a fairly large part of the westward swing of the outcrop takes place in the southern one-third of the distance.

The presence of this monocline has frequently caused errors to be made in reconnaissance work. Most of those who have traced strata into this monocline in the southern region have endeavored to carry the outcrop on across it and have discussed the thinning of strata in the region when such was not necessarily the case. Again, noticing the steeper dip has led to errors estimating the thickness of the overlying beds west of it by assuming its continuance for considerable distance.

HISTORICAL.

REVIEW OF PREVIOUS WORK WITH A DISCUSSION OF GEOLOGIC SECTIONS.

Aside from some very general reconnaissances many years ago which are of little interest here, the first work that took up the details of the stratigraphy of the region under discussion was a reconnaissance by N. F. Drake, which was made in 1896.*

After discussing the geology of the Coal Measures of northeastern Indian Territory, he discusses the Permian rocks. He refers a considerable part of the section to the Permian that is now regarded as of the Pennsylvanian age. The main point of interest here is his discussion of the rock of the vicnity of Ralston and Pawnee.

After discussing the stratigraphy between Pawhuska and Cushing, he takes up the section at Pawnee** as follows:

*Drake, N. F., Proc. Amer. Phil. Soc. XXXVI, 1897, pp. 326-419.

**Idem, Page 386.

The following section was compiled from outcrops of strata found 5 to 10 miles south of Pawnee:

Section south of Pawnee.	ft.	in.
1. Red clays at the top		6
2. Limestone	1	6
3. Red, bluish, and gray clays	150	
4. Limestone, (Pawnee limestone)	2	
5. Principally clay shales	100	
6. Pawhuska limestone	5	

In a footnote he states that:

Stratum 4 appears to be the same as the bed of limestone outcropping on the east side of the courthouse grounds at Pawnee, and for convenience it will be called the Pawnee limestone.

The Pawnee limestone outcrop on the east side of the courthouse grounds at Pawnee consists of 3 to 4 feet of hard, evenly textured, tough, bluish limestone underlaid by 5 to 6 feet of yellowish-blue marls. Both the limestones and marls are rich in fossils. The Pawhuska limestone bed which outcrops in the bed of a creek half a mile northeast of Pawnee at an elevation of about 100 feet below the Pawnee limestone, is, at this place, about 5 feet thick; the lower 3 feet is hard and massive, while the upper part of the bed is friable. *Fusulinae* are very abundant in this bed.

In getting from the Cushing region to Pawnee, the Flint Hills monocline with its relatively steep west dip evidently escaped him, and the Pawhuska limestone is here placed, in one case, between the Neva limestone and the Fusulina horizon and in the paragraph just quoted appears to be confused with the Fusulina limestone. His Pawnee limestone seems to be equivalent to number 9 of our section. The Pawhuska limestone is far below the Pawnee section and is probably equivalent to the Deer Creek or Topeka limestone of the Kansas section. On page 387 he mentions a coal bed from 3 to 5 inches thick in the banks of Coal Creek 4 miles south of Ralston, "which appears to be below the Pawnee limestone." This is probably the same coal that occurs in the creek at Ralston, and which is well below the Fusulina horizon.

The following section was compiled from exposures of an escarpment facing the Arkansas River at a point about 2 miles southeast of Ralston.

Section 2 miles southeast of Ralston.

1. Light gray sandstone weathering yellow	15
2. Gray clay shale	4
3. Nodular gray limestone (Pawnee limestone)	3
4. Red clays and light gray, shaly sandstones	100
5. Pawhuska (?) limestone	5

The Pawhuska limestone outcrops along the Gray Horse-Pawhuska road at every creek crossing for 7 to 8 miles from Gray Horse, and also about 5 miles southwest of Pawhuska. At the latter place it is about 10 feet thick, unevenly textured, gray in color, and underlaid by yellowish and bluish clays.

Regarding the section on the southeast of Ralston, on the river, it should be stated that the whole section lies well below the Fusulina horizon.

In 1900 Gould made a reconnaissance that covered part of this region* in which he brings out the translation from light to red color and the general relationships of the strata. No details of the immediate region are given.

In 1901 Adams made a similar trip in which he attempted to trace some formations from the Kansas line southward into Indian Territory.** He, too, carried the outcrop of the limestone across the Flint Hills monocline with the result that he finally at Perkins had it some 700 feet above its horizon.

In Bulletin 211 of the United States Geological Survey, page 64, Adams refers to Drake's Pawnee limestone as follows:

This formation was named by Drake. It is the limestone which outcrops on the east side of the courthouse grounds at Pawnee, Oklahoma. Its line of outcrop was not mapped. The name Pawnee is preoccupied by the Pawnee limestone of Swallow in the Kansas section. This limestone cannot now be correlated with the Kansas section.

In 1910 a paper was published by Gould, Ohern, and Hutchison which was a general classification of the Pennsylvania rocks of Oklahoma.*** The rocks of the region here under discussion were classed in the "Ralston Group" and were defined and discussed as follows:

Area. The Ralston group includes the rocks in the upper part of the Pennsylvanian series, beginning at he base of the Pawhuska formation, and extending to the base of the Wreford limestone and its southern continuation, the Payne sandstone, which has usually been considered the base of the Permian.

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*Gould, C. N., Amer. Jour. Sci., vol. VI., 1901, pp. 185-190.

**Adams, C. I., Amer. Jour. Sci., vol. XII, 1901, pp. 383-386.

***Gould, C. N., Ohern, D. W., and Hutchison, L. L., Proposed groups of Pennsylvanian rocks of eastern Oklahoma, Research Bull. State Univ., No. 3, 1910.

Stratigraphy.— The equivalents of the following formations in Kansas, the combined thickness of which is approximately 800 feet, are included in the Ralston group as the latter is exposed in northern Oklahoma:

Lecompton limestone, Tecumseh shales, Deer Creek limestone, Calhoun shales, Topeka limestone, Severy shales, Howard limestone, Scranton shales, Burlingame limestone, Willard shales, Emporia limestone, Admire shales, Americus limestone, Elmdale formation, Neva limestone, Eskridge shales, Cottonwood limestone, Florena shales, and Neosho formation.

These formations are exposed along the Flint Hills in southern Kansas, but near the Oklahoma line most of the limestone members thin out and disappear, while sandstones come in and thicken to the south. No accurate section has been made across this group in Oklahoma, but it is probable that the group does not thicken to the south as rapidly as do the groups heretofore described. In fact there is some evidence that in Lincoln, Pottawatomie, and Cleveland counties the rocks representing the southern extension of the Ralston group are not so thick as they are farther north.

In southern Pawnee and northern Payne counties, the color of the rocks in the Ralston group changes and becomes a deep brick-red, and so continues to the southern limits. This area includes the greater part of the so-called Chandler beds mentioned above.

It will be seen that the horizon of the Neva limestone falls well below the top of the Ralston group as here defined.

This section was taken along the road on the south side of the creek until the upper part of the Fusulina horizon was reached. It was then carried along the north side (Winfield Automobile road) until the heavy limestone below the Neva was reached, when on account of lack of exposures the section was carried up the creek itself, to the cut with the thick, cherty Neva limestone in it, just above the big curve in the railroad. In reality, the section was run along the Winfield road all the way. Then it was discovered that the steep dip had set in on the prairie where it could not be detected and that the whole Neva section had been passed over with no exposure such as to make its true character apparent. Then the creek section was made from a point where there was no doubt as to the horizon. The section as compiled follows:

Section from near Cedarvale to Hooser, Kansas.

29. Limestone with large chert and silicious concretions, apparently not the whole thickness of the formation. The Wreford limestone, exposed in the top of the hill in and south of

	Ft.	In.
Hooser	15	0
28. Covered slope	30	0
27. Reddish brown, rather fine grained, massive sandstone	5	0
26. Covered	40	0
25. Massive limestone in two or more layers forming a rather prominent escarpment	10	0
24. Mostly covered slope including pink, maroon, and yellow shales	45	0
23. Rotten limestone forming small escarpment	6	0
22. Covered, including calcareous layers representing the Cottonwood Falls limestone and Florena shales. Dips not taken into account	49	0
21. Neva limestone. Total thickness about	20	0

The detailed section is as follows:

	Ft.	In.
Limestone, in 3 layers with shaly partings	3	9
Gray shales, coarse, with fragments of fossils	0	4
Limestone, in 4 layers, second and third layers cherty, top one darker than the rest	2	9
Calcareous shales 6 in. to	1	0
Limestone, in 5 ill-defined layers, much chert in large concretions	4	6
Shale, limestone in middle 1 foot to	1	10
Limestone in thin layers full of chert concretions and layers of chert	6	0

20. Drab shales with nodular limestone containing pelecypods, 6 feet	14	0
Limestone in 3 layers, 2 feet. Hard calcareous shales and shaly limestones, 6 feet.		
19. Largely covered on slope, about 60 feet, composed of shales and limestones. There are many thin limestones filled with pelecypods in this interval	60	0
18. Covered	15	0
17. Hard, thin-bedded fossiliferous limestone	9	0
16. Alternating shales and thin limestone, about	35	0
15. Covered, containing layer of calcareous tufa	17	0

14. Thin limestone and shales, nodular limestone in lower 5 feet	17	0
13. Fusulina horizon, thickness made up about as follows:	22	6

	Ft.	In.
Coarse soft limestone weathering *Fusulinae* and some other fossils	1	6
Ochery marl, literally filled with *Fusulinae* and some other fossils	1	0
Hard limestone, a mass of *Fusulinae*	1	0
Hard limestone, 2 layers, crinoid stems and *Myalinae*	2	0
Limestones poorly exposed, crinoid stems, chert with *Fusulinae, Schwagerina,* etc., weathering white	7	0
More limestones and cherts carrying *Fusulinae*	10	0

12. Drab shales with about 6 sheets of rather thin limestones literally filled with fossils, the top filled with *Fusulinae*	13	0
11. Fossiliferous limestones with very thin shale parting. *Fusulinae*	10	0
10. Blue to black shale weathering drab, fragments fossil plants, 3 inches limestone. Blue, fossiliferous limestone 8 inches. Brownish shale, slightly sandy, 9 inches. Hard, gray, fossiliferous limestone, 9 inches. Blue, nodular limestone, weathering yellow, 1 foot 4 inches	42	0
9. Impure, nodular, concretionary limestones 2 feet 6 inches	4	0

	Ft.	In.
Brown limestone weathering yellow, blocky	1	6

8. Drab and blue clay shales 5 feet. Thin streaks of shale with great masses *Myalina subquadrata* similar (2 ft. 6 in.) to those in cut near Foster, Okla.	7	6
7. Coal 5 inches, sandy shales with fossil plants 7 feet 8 inches	8	1

		Ft.	In.
6.	Covered	15	0
5.	Brownish limestone, weathering yellow, resting on blue clay shale	0	5
4.	Going west to first rise in ground, disregarding dip, barometer shows an interval of	75	0
3.	Sandstone, rather fine-grained and of a greenish shade and rather porous base not seen	8	0
2.	Probably a covered interval of a few feet.		
1.	A mile west of Cedarvale in the wagon road on the little hill, or terrace, about on the 1,000-foot contour line as shown on the Burden quadrangle, are 2 layers of calcareous sandstone containing many pelecypods, separated by some shale. Over this is a layer of fossiliferous shale followed by yellow limestone. The top member of the little section is a hard gray limestone. The section has about the the thickness of	15	0
	Total thickness of the section as given, about	607	0

Relatively little attention was paid to the relation of the strata at Cedarvale, since it was far below the horizons to be traced. The relative positions of numbers 1 and 3 are inferred rather than determined. Number 3 may be the same sandstone that is exposed in Cedarvale and probably represents the sand containing the Dexter-Elmdale gas.

Along the Winfield Automobile road, on the big hill west of Taussig, number 12 is well exposed and is quite fossiliferous.

Many of the limestones between the Fusulina horizon and the Neva may be observed along the Winfield Automobile road between Taussig and the railroad south of Hooser. However, the exposures are imperfect and great care is needed in approaching the Flint Hills escarpment and monocline not to miss a large part of the section. It is along here that the dip suddenly increases as the rocks pass under the escarpment.

The 7-foot layer in the Fusulina horizon is well shown near the creek east of the big curve in the railroad, as a solid ledge of thick-bedded limestone 8 feet 6 inches thick, while over it are more than 5 feet of calcareous material and soil filled with *Fusulinae*. About 4 feet of the middle of the thick ledge is practically without *Fusulinae*.

The total thickness of the section given above is approximately 600 feet. In working out the stratigraphy of the western Osage region south to Pawnee the Neva limestone and the Fusulina horizon, which must be near the horizon of the Americus limestone of the central part of the State of Kansas, are of greatest importance. The region just west of this is the southern continuation of the Kansas Permian. However, those formations which carry the flint in Kansas lose it in Oklahoma and the layers under consideration here which lie below them are the more cherty, while they are practically free from chert much of the way in Kansas.

Passing southward from the locality of the section given, several changes occur in the section and in the rocks of the two horizons here considered. Sections found along the outcrop of these rocks which may be of interest are given to show variation in appearance and composition of the formations.

The section at this place is poorly exposed. In part it duplicates the section in the road a half mile north of it.

Section 3 miles east of Big Beaver Creek and 2½ miles north of state line.

		Ft.	In.
5.	Neva limestone. The base of the formation is hard and very jagged. This rock has a somewhat similar appearance about Manhattan Kansas. Whole thickness not exposed	10	0
4.	Covered 5 feet; thin limestone; covered 10 feet; limestone breaking into fine hard pieces 3 or 4 feet. Unexposed 21 feet	50	0
3.	Limestone with rusty spots through rock, basal part thin-bedded and nodular, upper part more massive	10	0
2.	Limestone and shales as follows: Talus slope 10 feet; calcareous tufa 3 feet; covered 6 feet; about 4 feet of dense buff limestone weathering gray; covered 5 feet	36	0
1.	Fusulina horizon. The base of the section shown here is thin-bedded with rather long *Fusulinae* in abundance. The central part is thicker bedded and the *Fusulinae* are hardly noticeable on the surface, but show on fresh fracture. The upper part is marly and largely composed of *Fusulinae*. The exposure is 15 feet in thickness	15	0
	Total thickness	121	0

The above section is a poor one. The thickness of the rocks between the Fusulina horizon and the Neva limestone appears to

have thinned from 165 feet between Cedarvale and Hooser to 96 feet.

Where the upper layers of the Neva are exposed the chert has taken a peculiar porous, sublaminar appearance and occurs in large concretions, resembling to some extent the "sand rocks" of the Wreford limestone in the vicinity of Grand Summit, Kansas. Its outcrop is easily followed, even on level ground by these concretions. These concretions contain few fossils. *Fusulinae* are few and inconspicuous in the far south, *Schwagerinae* are still present.

The chert disappears rapidly also from the Fusulina horizon as it is followed southward. In Kansas the dip of the rocks probably carries the Neva limestone below the bed of Big Beaver Creek, though it was not looked for there. East of Big Beaver Creek, 2 miles north of the state line, the top of the high eastward facing escarpment is formed by the limestone in the middle of the Garrison formation. Around the heads of the ravines of Rock Creek the highest limestones and cherts represent the Neva limestone.

From this point south around the head waters of Rock Creek the higher flints all belong to the Neva. It crosses the state line in sec. 18, T. 29 N., R. 7 E. The outcrop extends almost due southwest to Grainola, making a westward turn around the head of Salt Creek. The exposure then runs nearly due south along the west side of Salt Creek clinging close to the creek until the mouth of Elm Creek is reached, 6 miles south of Grainola. In the southwest corner of sec. 27, T. 27, R. 6 it is nearly a mile and a half west of the creek and the Fusulina horizon is present well above the creek level at the southeast corner of the same section.

On the east side of Salt Creek only outliers are found. There is a large one on the east side of T. 29 N., R. 7 E., another small one east of Grainola and north of Antelope Creek. Between Antelope and Elm creeks is a large elongated outlier extending from the southwest part of section 12 to central 34. The Fusulina horizon is excellently exposed along Elm Creek west of Foraker and in the cuts at Foraker. The limestone at Foraker is not the Neva, which probably does not occur south of Dugout Creek.

In the region of Grainola the Neva limestone, while retaining its characteristic fauna, some of its chert, and general character, presents some interesting features, especially the weathering of the surface and the thickening of the base. The following section on the west side of Salt Creek 4½ miles south of Grainola is characteristic:

Section on west side Salt Creek 4½ miles south of Grainola.

	Ft.	In.
3. Massive bed of hard limestone weathering with extremely jagged surface through solution	6	0
2. Thin-bedded softer stone with frequently marly partings not exposed on hill slopes. *Schwagerinae*. Chert	15	0
1. Massive limestone bed not weathering quite so rough as number 3	4	8

In the vicinity of Grainola it will be seen that the Neva limestone has thickened to 25 feet or more, some of the upper part may not be exposed in the Salt Creek section, and it has a very strong westerly dip and the chert is somewhat reduced in quantity. However, it is sufficient to easily mark the outcrop on gentle slopes, and an occasional *Fusulina* is to be found in it while *Schwagerinae* still occurs. The Fusulina horizon is about 135 feet below it in this region. South of the latitude of the middle of township 27 the chert increases in abundance and the 2 marked layers are to be noted, the lower a flinty dense chert and the upper, which is porous and sandy-looking, on the outside, and occurs in large concretions which do not break up readily on weathering as does the lower chert. It is also well charged with *Fusulinae*. They are rather rare in the lower. *Schwagerinae* may be found on careful search in the limestone.

From the southwest corner of section 27, T. 27 N., R. 6 E., the outcrop swings west for 5 miles falling about a mile south in that distance along the north side of Salt Creek where it flows west, and the short tributaries to it come in from the north. From this point the outcrop extends directly south to the Arkansas river, bending westward up the creek south of Remington. There is 1 large and 3 small outliers on the east side of Salt Creek near Burbank. This is a small plateau about 5 miles by 4 lying south of the west flowing stretch of Salt Creek. It is highly dissected and the limestone forming its top is well filled with chert. Farther south the chert diminishes in quantity and the limestone in thickness. All the details of the outcrop were not mapped as time was lacking. South of this region the Neva limestone does not occur on the east side of Salt Creek or of the Arkansas River.

In the southeastern part of T. 27, N., R. 6 E., the Fusulina horizon reaches a thickness of 30 or 35 feet, with all its usual characteristics. A bed of minute *Fusulinae* occurs about 5 feet above the top of the ledge. Just south of Salt Creek in this region there is a sandstone appearing between the Fusulina horizon and the Neva limestone. The heavy ledge of limestone between these two horizons is only about 40 feet below the Neva and is considerably

thinner and composed of 2 layers, the upper one about 1 foot 4 inches to 1 foot 6 inches, weathering out in great slabs 1 foot 4 inches to 1 foot 6 inches thick, below which is a bed of shale and marl. The lower layer is 3 feet thick and the bottom of it is very fossiliferous.

Near the SW. corner sec. 1, T. 25 N., R. 5 E., the Fusulina horizon is represented by two strata of limestone 5 feet thick with some Fusulina marl between them. The associated layers not exposed would probably make the thickness of the beds over 15 feet. Fossil corals *(Axophyllum)* are abundant in one of these layers.

In the hills west of Fairfax, SE. cor. sec. 10, the following rough section of about 225 feet was taken.

All elevations were measured by barometer from an assumed level, and the elevations are wtihout significance except relatively.

Section west of Fairfax SE. cor. sec. 10.

		Ft.
10.	1115, Top of the cliff. Cherty layer eroded from the hill shows farther back from the escarpment. Many *Fusulinae*	20
9.	1095, base of Neva limestone	20
8.	1075, A foot or two of cross-bedded sandstone	45
7.	1030, Thin bed of pinkish buff sandstone	15
6	1015, Middle limestone, thinner, more fossiliferous	40
5.	975, Thin limestone, some *Fusulinae*	5
4.	970, Top of Fusulina horizon	20
3.	950, Main ledge of limestone near base of Fusulina horizon	20
2.	930, Yellow limestone, *Fusulinae* and other fossils	40
1.	890, Blocks of yellow, fossiliferous limestone in ravine	0
	Total	225

From these figures it is evident that the interval between the Fusulina horizon and the base of the Neva limestone is about 125 feet at this point. Both horizons are easily recognized in this section.

The one east on these hills is used as a reservoir for Fairfax. This hill has better exposures than the bluff west of it and the maroon and other colored shales are more apparent here.

In the butte west of the one where the section was taken the thin sandstone, number 8, suddenly thickens to 20 feet. It is local in its occurrence. Northwest of this place about a mile or two a heavy sandstone sets in at the top, or near the top, of the Neva

limestone and persists to the westward. It is rarely seen on the easternmost outcrops.

About 2 miles south of Remington a local lens of sandstone from 2 to 6 feet thick sets in just beneath the Fusulina horizon.

South of the river at the 35-27 section corner, northwest of Ralston, the sandstone lens occurs below the Fusulina horizon as it does north of Fairfax, and is about 6 inches in thickness. One-fourth mile west of the 22-26 corner, the top of the Fusulina horizon occurs in the low ground, Bar. 445 on the top of the bed. One mile farther west the base of the Neva occurs at 550 feet and there are 15 feet of it exposed. Disregarding the dip—which would add considerable to the interval—the thickness of the rocks between the Fusulina horizon and the Neva limestone would be 105 feet. The total thickness is probably 130 feet. The appearance of the Neva limestone and the underlying section is the same as on the north side of the river where the previous section was taken, except that the sandstone lens below it was very thin or wanting here and the lens below the Fusulina horizon is present as it is north of Fairfax. No *Schwagerinae* were seen here, and in fact, none have been observed south of Remington.

The Neva limestone forms the top of the high escarpment west of Ralston. Nearly due west of Ralston a decided shoulder in the escarpment is formed by the sandstone lens coming in just below the Neva. This is nearly wanting a mile or two farther north, but is present in the hills at Fairfax. As the Neva outcrop is followed, west and northwest of Ralston, toward the river the sandstone resting in it or in the upper part of it increases in thickness rapidly. On the west side of section 29, near the northwest corner, a section shows 28 feet of sandstone at the top with a partially exposed ledge of limestone inclosed. Beneath this was 11 feet of limestone. This layer has probably been materially reduced by solution at the base of the sandstone.

This ledge of sandstone and limestone represents the horizon of the Neva limestone farther north and is continuous with the "Standpipe" sandstone at Pawnee, and as shown in the NE. corner of sec. 18, T. 22 N., R. 5 E., where collections of fossil were made. Near the top of the formation at this place there is a thin limestone carrying *Spirifer cameratus*. No authentic account of the occurrence of this species is known above the Neva limestone where it is fairly abundant.

Section at Pawnee.

		Ft.	In.
18.	Brown, soft, fossiliferous sandstone about	7	0
17.	Covered	35	0

16.	Red arenaceous limestone grading into calcareous sandstone	3	0
15.	Mostly red shale, poorly exposed	32	0
14.	Layer of limestone with crinoid stems and foot of brown sandstone	2	3
13.	Yellowish shales	7	0
12.	Covered	15	0
11.	Purplish, irregular, crystalline limestone	1	0
10.	Olive shales	18	0
9.	Two limestones separated by shales; the upper in 2 layers. The lower, impure, nodular, buff. Whole formation very fossiliferous		
8.	Covered, apparently argillaceous, fossiliferous shales.		
7.	Red shales, apparently greenish below	20	0
6.	Hard, blue limestone, like No. 2 but coarser	0	11
5.	Covered, apparently blue shale above	5	0
4.	Bluish gray nodular limestone with *Fusulinae* minute crinoid stems, etc., looks rough buff-gray exposure.		
3.	Blue sandy shale	0	6
2.	Hard, blue fossiliferous limestone with fossils weathering irregularly, in 2 layers. Third layer nodular with large *Fusulinae* and other small fossils		6
1.	Covered	10	6
	Total	172	9

The section begins well down near the creek, and extends up the east side of the hill to the sandstone on which the standpipe rests.

Numbers 2 to 6 of the above section represent the Fusulina horizon which has an exposed thickness of 12 feet. Seven to 17 represents the interval between the Fusulina horizon and the sandstone of the Neva horizon, which has a thickness here of 142 feet 9 inches. It is not improbable that the limestone beneath the sandstone has been dissolved beneath the top of the sharp hill upon which the standpipe rests. Number 18 is the sandstone of the Neva horizon. It is quite fossiliferous and north of Pawnee contains limestone.

From Pawnee southward for some 10 miles the sandstone lenses thicken remarkably and in the divides the rocks are very poorly exposed. Positive correlations must be made around this region on the east side where the limestones are continuous. However, it appears that the fossiliferous limestone with abundant

Fusulinae along the top of the escarpment west of Cushing and south for a few miles probably belongs to the Fusulina horizon. A sample section of the southern region may be taken from the southwest side of sec. 30, T. 20 N., R. 5 E. Here the limestone facies is till present.

General section along SW. of sec. 30, T. 20, R. 5 E.

		Ft.
9.	Thin limestone, covering top of hill in thin blocks, weathering like number 7.	
8.	Covered about 10 feet to	15
7.	Limestone, very ferruginous below, blue on fresh fracture, weathering rusty brown. 2 beds.	
6.	Interval to base of limestone, upper 3 feet greenish to gray shale	6
5.	Blue shales end buff sandstone above, sandstone in 2 layers. Fossils in the upper.	
4.	Covered, probably shale	13
3	Blue clay shale, about	27
2.	Olive clay shales	5
1.	Red or brown shales	16

EASTERN OUTCROP OF THE PERMIAN IN OKLAHOMA.

So far as the evidence has been worked out it seems necessary to place the base of the lower Permian either at the base of the Elmdale formation, or, at the highest, at the top of the Neva limestone. It is in this part of the section that the greatest changes in the fauna take place, and the forms characteristic of the higher formations set in.* The changes may be very briefly stated in the following table which is expressive of the numerical relationship of Series IV to Series I-III:

	No. of Species.		No. of Species.	Species in Common.
Series I	131	Series IV	141	51
Series II	237	Series IV	141	73
Series III	264	Series IV	141	85

*Beede, J. W., and Rogers, Austin F., Kas. Univ. Geol. Survey, vol. IX, 1909, (1908 on title page), pp. 347-350; Jour. Geol., XVII., 1909, pp. 720-722.

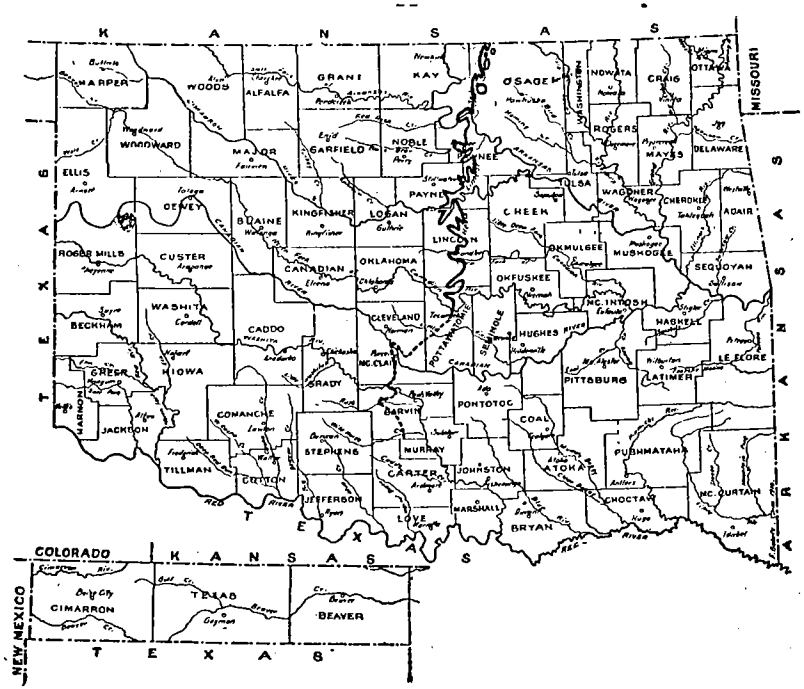


Fig. 1. Showing approximate eastern limit of Permian rocks.

It seems that the study of the Oklahoma material at hand will greatly increase the number of species from number IV without materially increasing the number of species common to number IV and the series below it. As it now stands, only a third of the fauna of number III gets through into number IV and 56 new species are added in number IV. However, what is more to the point is the fact that the complexion of the fauna has changed. The common types of series IV, are not the dominant types of series III, or of the rocks below. Any one familiar with the fauna of the lower rocks would realize in a moment that he was dealing with a different fauna and a different set of rocks as soon as he saw the faunal aggregates as they occur in these upper rocks.

The larger map shows the generalized outcrop of the Neva limestone, and the sandstones which replace it south of the Cimarron River. The base of Series IV is below this line, but the outcrops of the two formations are so close together most of the way that this map may be regarded as showing both the Neva limestone and the eastern edge of the Permian rocks of Oklahoma,

The following table shows all the rocks in each series:

Series	Stage			
PERMIAN	V	Well.	Wellington shales	200'
		Marion	Abilene conglomerate Pearl shales Herington limestone Enterprise shales Luta limestone	150'
	IV	Chase	Winfield limestone Doyle shales Fort Riley limestone Florence flint Matfield shales Wreford limesone	25' 60' 57-70' 60-70' 35-55'
		J	Florena shales Neosho member } Garrison formation Cottonwood limestone	
		I	Eskridge shales Neva limestone Elmdale formation	
PENNSYLVANIAN	III	H	Americus limestone Admire shales Emporia limestone Willard shales Burlingame limestone Scranton shales	700' —
		G	Howard limestone Severy shales Topeka limestone Calhoun shales Deer Creek limestone Tecumseh shales Lecompton limestone Kanwaka shales — Elgin sd in the fm.	
		F	Oread limesone 0-17' Lawrence shales Kickapoo limestone Leroy shales Stanton limestone Vilas shales Allen limestone Lane shales	728-1098' 150-600 280-400 23-23 75-75 728-1098
	II	E	Iola limestone Chanute shales	
		D	Drum limestone = Haskell 10'	
		C	Cherryvale shales Dennis limestone Galesburg shales Mound Valley limestone Ladore shales Bethany Falls limestone	180-490'
	I	B	Pleasanton shales Coffeyville limestone Walnut shales Altamount limestone 35' Bandera shales 120', N- 40' at Nowata Pawnee limestone 93' Labette shales 120' Fort Scott limestone 38'	
		A	Cherokee shales	450-500

Table from Journal of Geology.

north of the latitude of Shawnee. South of this place it has not been mapped.

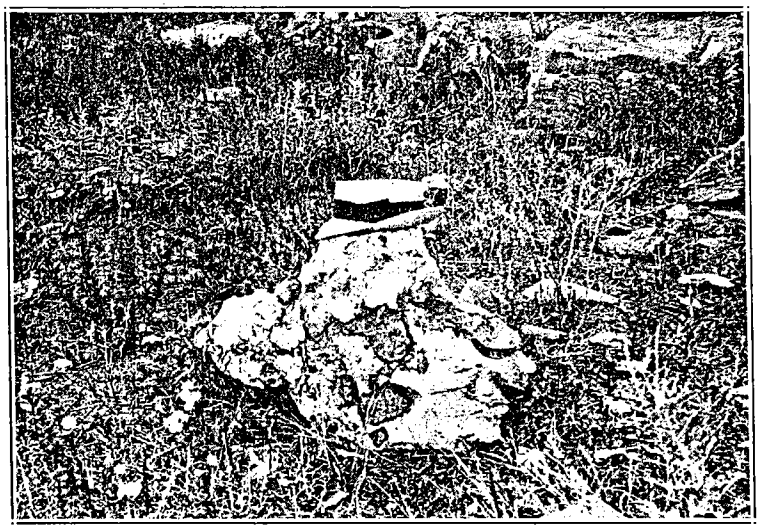
The map of the region north of Pawnee, shows the outcrop of the Neva limestone in a somewhat more detailed way. At the Kansas line the rocks below the Wellington shales are all light-colored sediments. By the time the formations are followed as far south as Pawnee they have all become red down to the Neva limestone. South of the Cimarron River the sandstones that have replaced the Neva limestone are red. In the Cushing oil field, east of Cushing, the drill is said to have penetrated about a 1,000 feet of red beds of Pennsylvanian age, though the rocks at Cushing are above them, and, are of normal light of color.

NATURE OF LITHOLOGIC AND COLOR CHANGES FROM LIGHT COLORED BEDS TO RED BEDS.

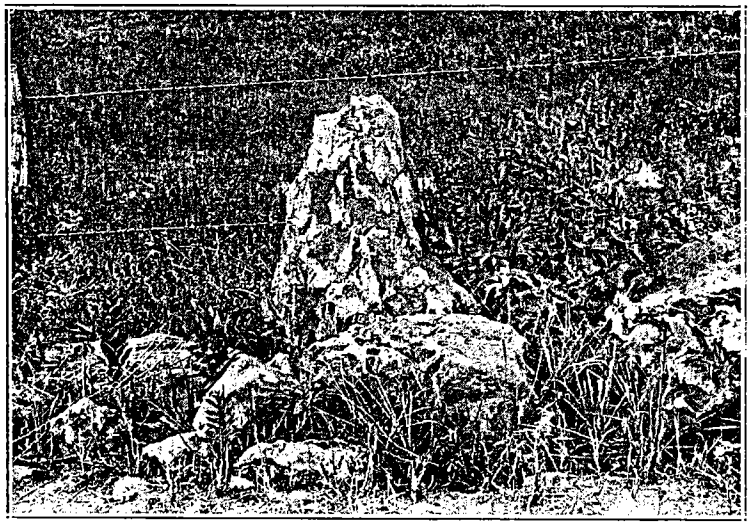
One of the most interesting features of this whole region is the nature of the changes from the light colored limestones and shales to the dark red sandstones and peculiar shales of the Redbeds.

The shales are red much farther north, as a rule, than are the limestones and sandstones. The change in color is frequently accompanied by some change in the character of the shale. The red shales are usually much less compact and durable and in the immediate region covered by this report seem to become more or less charged with very fine sand. On account of the fact that the shales are usually hidden from view, the nature of the transition has not been observed so carefully as has the transition from limestone to sandstone.

In the case of some of the higher limestones, Wreford, Fort Riley, etc., sand appears in the limestones, which have usually thinned appreciably. The sand may gradually increase for considerable distances, say from a few rods to a few miles, and become first a very sandy limestone, then a calcareous sandstone. Followed still farther, the traces of calcium carbonate disappear, sometimes to reappear as limestone in some areas. Again, as is shown along the Shawnee branch of the Santa Fe railroad from Kaw City to Skedee, or the upper Wreford limestone at Hardy, the first traces of the transition are seen in purple blotches scattered through the stone. These may enlarge and increase in number until the whole stratum is practically a purple or red limestone. In other regions the limestone may turn almost scarlet in a rod or two, as is the case with a limestone in the escarpment south of Cushing. The red limestones of the latter class usually dissipate quickly into sandstones. They are usually fossiliferous.



A. Showing a limestone with masses of sand in it. Note the ledge in background.



B. Showing similar condition with more sandstone present. The block in front and the one at right-hand side of picture show rocks composed chiefly of sandstone with irregular masses of limestone.

Sometimes a limestone layer will grade into a sandstone layer and then change back again into limestone in a few rods. Indeed, this is not infrequent in the region between Kaw City and Pawnee, and west and northwest of Pawnee. An instance of this as it oc-

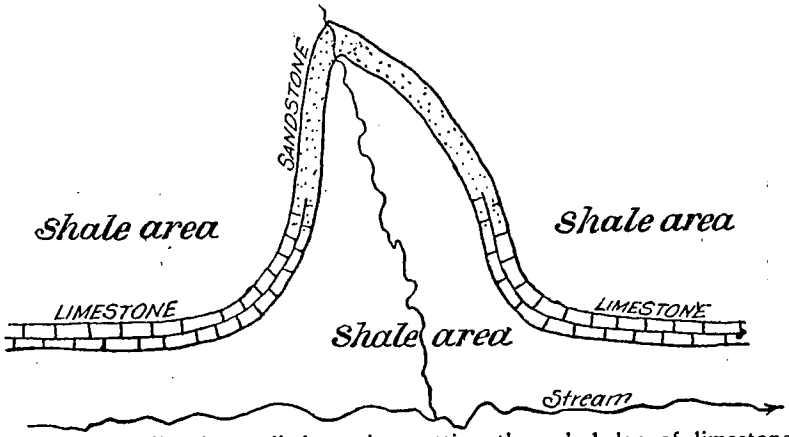


Fig. 2. Showing a little ravine cutting through ledge of limestone which is locally changed to sandstone. The sandstone outcrop is about 450 feet in length. The sandstone is less resistant than the limestone. Location north of Pawnee and west of Ralston.

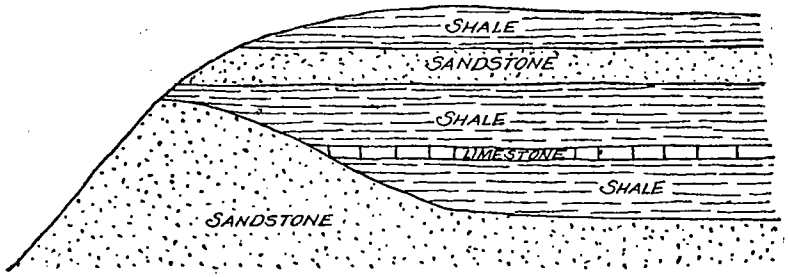
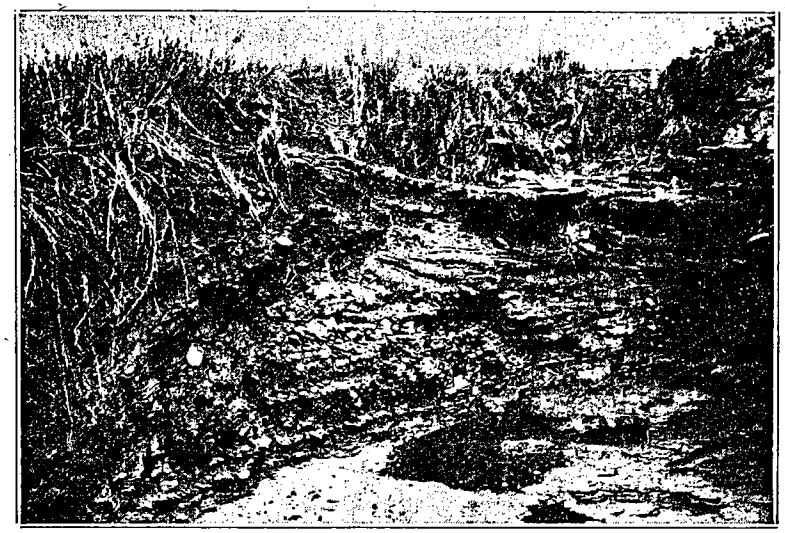
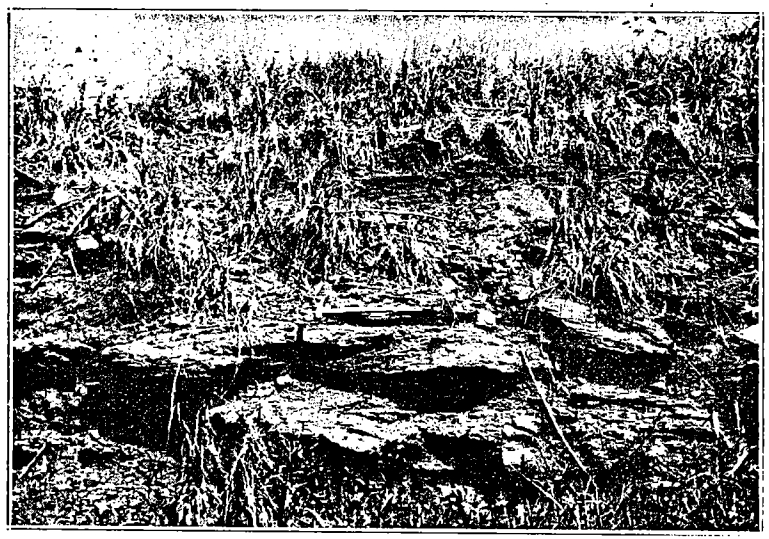


Fig. 3. Showing a bed of sandstone thickening and nearly uniting with the layer above. The limestone was deposited up to the sandstone elevation. Locality, west of Pawnee.

curs in the section north of Pawnee is shown in the accompanying photographs. Sometimes these sandstone replacements may not be more than 3 or 4 rods across. Several were seen in which, at a moderate distance, the whole transition from limestone into sandstone and back into limestone could be taken on an ordinary kodak negative. The sandstone in such cases is usually calcareous, but in some instances it is not.



A. View in a cut 5 miles southwest of Glencoe, Oklahoma. Showing base of bed of conglomerate, cross-bedded in three directions and resting on a horizontal bed of conglomerate.



B. Coarse sandstone at west end of cut, just above A.

At one point a ledge was made up of sandstone and limestone in indiscriminate masses, which were very irregular in form. The masses were all rather small, hardly ever over 2 feet in diameter and ranging from that to mere pockets. Sometimes there were pockets of sandstone in the limestone and sometimes pockets of limestone in the sandstone. That is, sometimes one or the other forms the predominating rock. On the whole the exposure was largely limestone. In most all cases the transition from the light colored sandstone to red sandstone takes place before going a great distance. The accompanying photographs illustrate the conditions. Opportunity to work out the history and significance of all these changes has not yet presented itself.

After passing some distance south or southwest of the region of transition just described, in which the sandstones maintain their usual thickness and relative positions, we pass into another zone where they thicken and thin, pinch out, end, and even cut out intervening beds of shale and limestone. An instance of the latter is shown in the accompanying diagram. In this region stratigraphic work becomes more uncertain, the fossils are wanting, and there seems to be no character of the rocks to tie to. At the bridge at Ripley is a sandstone about 40 feet in thickness which elsewhere is usually about 4 or 5 feet. All the sandstones of the section at Vinco are thicker than the average but appear to pinch out on the south side of the river between Vinco and Goodnight, so far as it is possible to determine by surface exposures. At Goodnight they have more than normal thickness. These belts of thickened sandstones extend nearly north and south, with the region of very thin sandstones or mere traces of white sand and iron concretions marking their horizons, between them.

These long stretches of sandstone extend from just west of Pawnee, nearly straight south to the vicinity of Shawnee, a distance of 60 miles on an air line. Wherever the region of shales west of this belt was crossed as near Lela, west of Stillwater, Goodnight, etc., another belt of thickened sandstones was found. Another feature of this region that must not be lost sight of is the fact that the lower horizons traced eastward grade out into normal light colored beds of marine origin, at least nearly as far south as Shawnee. Whether these great masses of sand were thrown up as barriers along the southern tongue of the sea to the north and northeast, or whether they represent river debouchures from the mountains to the southward has not yet been determined. For a number of reasons, some of which will follow, the writer is at present inclined to the opinion that they are connected with rivers. With further work it appears now that the question can be settled quite definitely and the origin of the sediments determined. If

PLATE IV.

A. Finer grained sandstone on south side of cuts, just above and to the east of B, Plate III.

B. North side of cut, just east of above view. Sandstone ends abruptly against shale, but the top layer continues to the right-hand edge of the picture over the shale.

they were barriers, it would seem peculiar that the different layers should thicken and thin so nearly simultaneously, while this is what would be expected if the sand were brought down to mouths of rivers whose channels at times extended well out across low fans, coastal plains, and shallow waters.

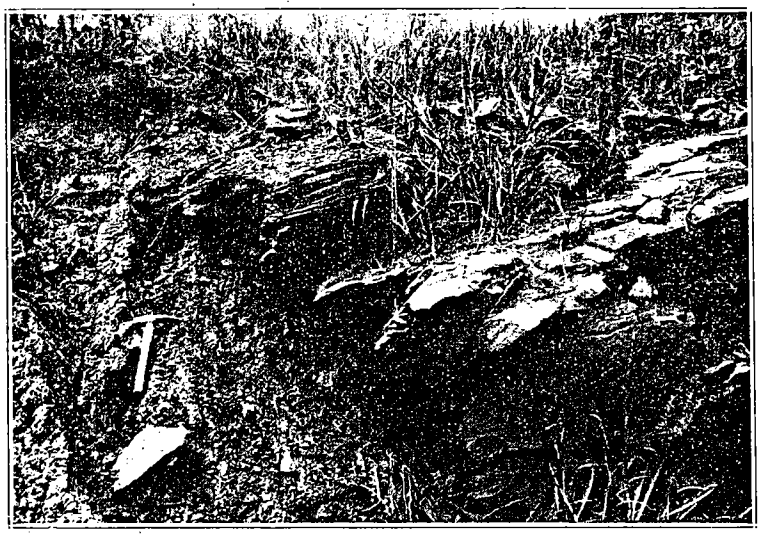
In some places the deposition of sandstone is very irregular. Over some areas a sandstone may be wanting and its place apparently filled with soft shales that weather and slump very rapidly, forming great amphitheaters. In some instances, the sandstones occupy beds cut in the soft shales by currents of some kind. Thus, at a place 5 miles southwest of Glencoe a cut in the railroad reveals such a case, which is shown in the series of photographs here reproduced. In the ditch where the wagon road crosses the railroad is a conglomerate bed over which are conglomeratic sandstones cross-bedded in three directions, in a cross-section of about 15 square feet. On top of this, and appearing in the west end of the cut is a coarse sandstone. A little higher and farther east the sandstone is fine-grained and abutts a nearly vertical bank of soft shale. On the south side of the cut the appearance is that of a fault, though there are no indications of it in the contact and on the opposite side of the cut the top layer of sandstone extends far over the shale bed which would be impossible were it a fault. A sandstone appears in the cut a few rods farther east, which may or may not represent the same sandstone. It is fairly thick at the west end of the cut, and coarse in the lower part but thins to a few inches in the central part, and again thickens and then disappears near the east end. Where the sandstone in the first cut came against the shale there was pronounced fan-shaped cross-bedding radiating from the shale. From the assortment of materials it looks as though this were a stream deposit.

At another place two sandstones occurred about 30 feet apart with a thin limestone near the top of the intervening shales. Following the outcrop of this limestone south on the east side of the hill for less than a quarter of a mile the lower sandstone was found to thicken and approach the limestone and at the south end of the hill it actually rose above the limestone, appearing to cut it off, and nearly joined the sandstone above. A half mile farther west the entire section presented its normal thickness with all the strata in place as usual.

Many of the peculiarities which have been described occur in the northern part of the State. Farther south and especially farther west they appear to be more complicated. Another feature that was noted was that some of the beds became quite coarse by the time the latitude of Shawnee was reached. Our studies did not extend south of Shawnee.

The fact that the stratigraphy is more regular in the same horizons in the eastern part of the region studied than in their

PLATE V.



A. On the south side of cut, opposite view in B, Plate IV. Note abrupt termination of sandstone against shale, and the fan-shaped cross-bedding radiating from bank.

B. Red limestone, east of Chandler.

western extensions as well as the fact that the same formations contained limestones with marine fossils at their eastern outcrop for some distance south of Pawnee, would seem to indicate that an arm of the sea at Neva time extended south from the great northern area as far as the Cimarron River, or a little beyond, but that its water were extremely shallow, if present, on the flats west of the 96° 45 ' meridian. The disappearance of the fossils, and the irregular and interrupted character of the stratification seems to indicate the passing from marine conditions on the northeast to shallow water or even subaerial conditions to the south and west. This would appear to be the direct result of the influence of the Arbuckle Mountain region upon the sedimentation of the time. Subaerial conditions continued near the mountains and marine conditions beyond the influence of its fans.

In the light of these changing sediments the relative horizons of the Kansas, Oklahoma, Texas, Illinois, and Pennsylvania vertebrate fossil beds has been called into question, and a few paragraphs may be profitably contributed to the subject.

CORRELATION OF THE FOSSIL VERTEBRATE HORIZONS.

It is not possible to go into all the details of the correlation of the vertebrate-bearing beds in this paper. This will be done later, so far as the stratigraphy and invertebrate paleontology bear upon the subject; with pretty full data both as to the stratigraphy and the fossils.

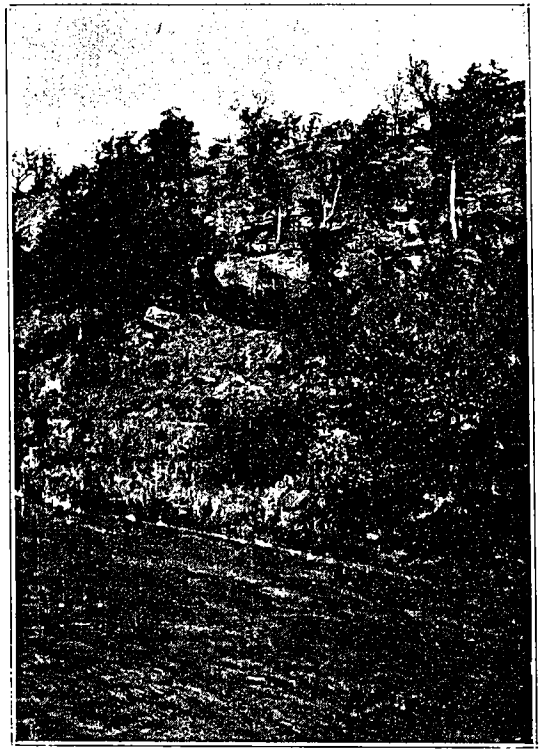
The larger formations of the Mississippi Valley are pretty well marked off by their invertebrate faunas and their fossil floras, and are not beyond correlation.

Kansas and Oklahoma.—The horizon of the Cowley County, Kans., vertebrates is some 50 feet below the Wreford limestone, in the Neosho member of the Garrison formation. After working out the geology of eastern Kay County, Okla., a trip was made into the western part of the county, to the Eddy locality. There is some structure (low folds) in this region, but the sandstone from which the fossils come, and from which David White collected fossil plants, seems to be as high as the base of the Wellington shales, and is probably near the horizon of the fossil plants from the basal Wellington in Dickinson County, Kansas. In terms of Kansas stratigraphy this makes the horizon of the Oklahoma beds near Eddy, 460 feet above the Kansas bone beds. The *(Labyrinthodont)* from Pottawatomie County, Kans., came from a horizon probably 220 feet below the bone beds of Cowley County, Kansas.

Pennsylvania.—The bones found by Raymond in the Conemaugh of Pennsylvania, in the vicinity of Pittsburg, came from

a horizon below that of the Ames limestone. The horizon of the Ames limestone, as has been pointed out in the West Virginia reports and Bulletin 17 of the Ohio Survey* may be about that of the Oread limestone. Certainly it cannot be very high above it and it may be below it. The Oread limestone is about 1,000 feet below the Cowley County bone bed and about 1,400 feet below the Eddy, Oklahoma, bone bed, or McCann sandstone.

PLATE VI.



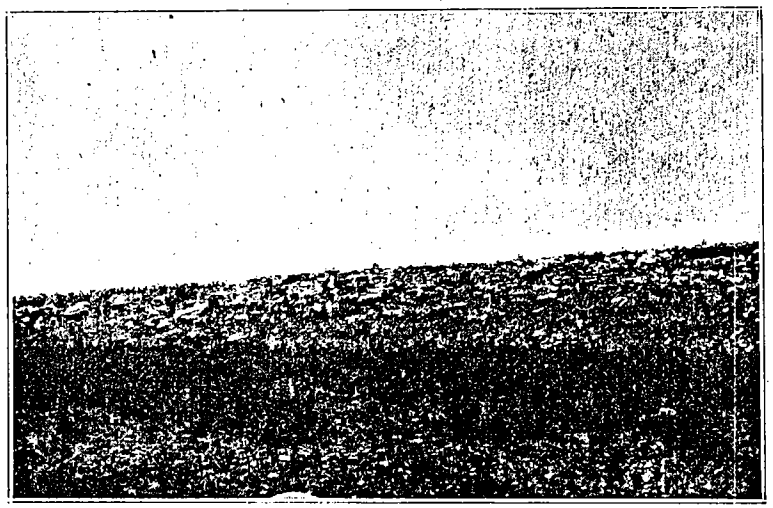
Thick bed of sandstone north of bridge at Ripley. This bed is normally about 6 feet thick.

Illinois.—The position of the bone beds of Illinois is, as yet, unknown. If, as supposed by Cope, the bones came from an old river bed of Permian age, excavated in Pennsylvanian shales, they

*Mark, Miss Clara G., Fossils of the Conemaugh formation of Ohio, Bull. Ohio Geol. Survey, No. 17, 1912, pp. 293-294.

PLATE VII.

A. Red limestone and sandstone near negro school, northwest of Davenport.



B. Limestone changing into sandstone. Limestone on right edge of picture, while the same ledge at the left side is sandstone. Locality west of Pawnee.

PLATE VIII.

A. Limestone ledge one mile south and one and a half miles east of West Point, Payne County. At the locality of the trees to the right the limestone is replaced by sandstone.

B. View about 300 feet east of above. Note peculiar bedding of sandstone which has replaced the limestone.

may be of about the age of the Kansas beds, or as suggested by Williston, the Oklahoma or Texas beds. However, the section was not carefully described by Cope and as a result there is some doubt as to the accuracy of his observation. The worst feature of it all is that there has been so much slumping at the old locality that it is impossible to get any true idea of the real condition of things. A careful survey of the immediate region fails to throw much light on the question. It will require a long and patient investigation to determine the matter. Certain it is that there is no reason for supposing that the surrounding shales are as high stratigraphically as the basal Permian of Kansas. Such "river beds" are known to occur in Oklahoma, but are of a much later date.

Texas.—The horizon of the bone beds of Texas is an extended one, and probably does not correspond to any one horizon in Kansas or Oklahoma, but to several of them. Cummin's correlation of the *Phacoceras dumbeli* zone of the Wichita formation with the Fort Riley limestone is probably about as near correct as we can state it at the present time. While this fossil is confined to a single horizon in northern Texas, and while it is only from the Fort Riley limestone of northern Kansas, where it is not rare, yet in southern Texas it occupies a considerable thickness of beds. From material in hand it seems that at least the northwest half or two-thirds of Archer County, Texas, is of lower Permian age.

REVIEW.

An extensive review of the literature bearing on the age and correlation of the Kansas and Texas sections will not be entered into at the present time. However, there are some recent papers that deserve mention here. Much of the important literature down to 1907 was reviewed by the writer in an article on the Invertebrate Paleontology of the Upper Permian Redbeds of Oklahoma and the Panhandle of Texas.* The literature up to 1912 has been discussed by Bailey Willis in the Index to the Stratigraphy of North America.** There is one reference in the latter that should be mentioned in this connection. In the footnote on page 468 the statement occurs that "Beede recently traced the Wreford limestone into the McCann sandstone of Gould, yielding typical Texas Permian vertebrate. Note by S. W. Williston, June, 1909." There evidently was a slip of the pen somewhere since the Wreford limestone was traced into the "Payne sandstone" by Kirk and reported in the Third Biennial Report of the Territorial Geologist of Oklahoma.*** This paper was reviewed by me in the

*Beede, J. W., Kans. Univ. Sci. Bull., vol. IV, No. 3, 1907, pp. 115-171.

**Willis, Bailey, Prof. Paper U. S. Geol. Survey No. 71, 1912.

***Kirk, Chas. T., Third Biennial Report of the Territorial Geologist of Oklahoma, 1904, pp. 5 14.

American Geologist in June, 1905. The McCann sandstone is some 410 feet above the Wreford limestone, in Kansas.

Since the appearance of the "Index" by Willis, just mentioned, three papers have appeared which deal with the subject. One of these was by S. W. Williston and E. C. Case, on The Permo-Carboniferous of Northern New Mexico.† There seems to be some doubt in their minds as to the age of the beds in the Mississippi Valley in which the bones are found. They state that "It has been questioned by us elsewhere whether the vertebrate fossils found in Texas, Kansas, Illinois, and Pennsylvania are really of Permian age." Aside from the literature referred to, the question of the age of the Kansas and Texas beds has been discussed by Gordon, Girty, and White the year before,†† and the Permian age of the beds pretty well confirmed, especially by White, based on the fossil plants found in the strata. The subject was also covered by Sellards for the Kansas deposits in his papers on the Fossil Plants and Insects of the Kansas Permian, printed in volume IX. of the Kansas Survey.*

A paper by David White appeared at about the same time as the paper by Williston and Case on the Character of the Fossil plant Gigantopteris Schenk and its Occurrence in North America. In this paper White shows additional evidence of the Permian age of the Texas and Oklahoma beds and that Kansas beds are of Permian age down to the base of the Wreford limestone.**

Case, however, in his paper on the Redbeds between Wichita Falls, Texas, and Las Vegas, New Mexico, in relation to their vertebrate fauna refers to the Texas beds as being of "Permian or Permo-Carboniferous age."

From the above brief statements it would appear that the following table of the stratigraphic relationships of the strata in which the vertebrates have been found might be made:

PERMIAN.

Texas.	Oklahoma.
Texas.	Illinois?
Kansas.	

PENNSYLVANIAN.

Kansas (Labyrinthodont).	
Pennsylvania,	Illinois.

The lowest of these formations would be some 1,500 to 2,000 feet below the highest, in the terms of Kansas stratigraphy.

†Williston, S. W., and Case, E. C., Jour. Geol. vol. XX, 1912, pp. 1-12.

††Gordon, C. H., Girty, G. I., and White, David, The Wichita formation of northern Texas, Jour. Geol. vol. XIX, 1911, pp. 110-134.

*Sellards, E. H., Kans. Geol. Survey, vol. IX, 1909, pp. 434-541.

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