OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Bulletin 40-QQ

OIL AND GAS IN OKLAHOMA

CHEROKEE AND ADAIR COUNTIES

By
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NORMAN
MAY, 1930

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FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19, Part II, entitled "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted and for several years copies have not been obtainable.

The present Director has seen the need of a revision of this bulletin. On account of the lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the State to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Geological Survey has every confidence in the judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind, are at best, progress reports, representing the best information obtainable as of the date issued, and doubtless new data will cause many changes in our present ideas.

The author of this report on Cherokee and Adair counties, Mr. Ira H. Cram, has made a special study of the stratigraphy of northeastern Oklahoma, especially of the pre-Mississippian formations. Mr. Cram, with the assistance of E. O. Ulrich, of the U. S. Geological Survey, has correlated these formations with outside areas. The correlation chart accompanying this report will be found most useful since it embodies a much larger area than these two counties.

Norman, Oklahoma
May 1930

CHAS. N. GOULD,
Director

CHEROKEE AND ADAIR COUNTIES

By

Ira H. Cram*

INTRODUCTION

Although drilling for oil or gas has met with little success in Cherokee and Adair counties, Oklahoma, these counties are of particular interest to the oil fraternity for it is in these counties that one may study at the surface the character and structure of many of the formations that are penetrated by the drill in the oil pools to the west. It is, therefore, the plan of this paper to compile briefly the important information on the geology of these counties contained in the published accounts, and to add what little information the writer has been able to gather by field studies.

The following published reports deal with the general geology of Cherokee and Adair counties:

Drake, N. F., A geological reconnaissance of the coal fields of Indian Territory. Contributions to Biology from the Hopkins Seaside Laboratory (Leland Stanford Jr. University) no. 14, also in the Proc. Am. Phil. Soc., vol. 36, no. 156, 1898.

Taff J. A., U. S. Geol. Survey, Geol. Atlas, Muskogee folio (No. 132), 1906.

Siebenthal, C. E., Mineral resources of northeastern Oklahoma: U. S. Geol. Survey Bull. 340, pp. 187-228, 1908.

Snider, L. C., The geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, 1915.

Shannon, C. W., and Trout, L. E., Petroleum and natural gas in Oklahoma; Part I. General information concerning oil and gas geology of Oklahoma: Oklahoma Geol. Survey Bull. 19, 1915.

Gould, Chas. N., Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey Bull. 35, 1925.

Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (No. 154), 1907.

Following are important papers dealing with the oil and gas resources or stratigraphy of these counties:

Shannon, C. W. (and others), Petroleum and natural gas in Oklahoma. Part II. A discussion of the oil and gas fields, and undeveloped areas of the State, by counties: Oklahoma Geol. Survey Bull. 19, 1917.

Aurin, F. L., Clark, G. C., Trager, E. A., Notes on the subsurface pre-Pennsylvanian stratigraphy of the north Mid-Continent fields: Am. Assoc. Pet. Geol. vol. 5, pp. 117-153, 1921.

White, Luther H., Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 40-B, 1926.

Edson, Fanny Carter, Ordovician correlations in Oklahoma: Am. Assoc. Pet. Geol. vol. XI, pp. 967-975, 1927.

Roth, Robert, A comparative faunal chart of the Mississippian and Morrow formations of Oklahoma and Arkansas: Oklahoma Geol. Surv. Circ. 18, 1929.

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In 1926 the geologic map of Oklahoma compiled by Hugh D. Miser of the United States Geological Survey was published. The geologic map accompanying this report is a compilation of the works of Taff, Snider, and Miser to which has been added the writer's reconnaissance map of the Illinois River area of the Siloam Springs quadrangle. In the text the Canadian, Mississippian and Pennsylvanian are treated as systems; but on the geologic map the practice of the United States Geological Survey of including the Canadian within the Ordovician and including the Mississippian and Pennsylvanian as series within the Carboniferous system is followed. The correlation chart is for the most part a compilation.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to E. O. Ulrich, Hugh D. Miser, George H. Girty, Raymond C. Moore, A. A. Langworthy, Sidney Powers, A. I. Levorsen, S. W. Lowman, and Robert H. Dott, for valuable suggestions, information and criticism; and to Theron Wasson, Chief Geologist of the Pure Oil Company, for permission to publish the report.

LOCATION AND PHYSIOGRAPHY

Cherokee and Adair counties (fig. 1.) cover an area of 1,327 square miles in northeastern Oklahoma. Adair County is bordered on the east by Arkansas and on the west by Cherokee County. The area includes parts of the Winslow, Tahlequah, Muskogee, Pryor and Siloam Springs quadrangles.

Figure 1. Index map of Oklahoma showing location of Cherokee and Adair counties.

The physiography of the area has been well described by Taff[1] and Snider.[2] The southern part of the area is in the Boston Mountain plateau; the northern part is in the Springfield plain. Briefly, the area is a rather deeply dissected plateau. Elevations range from 1.500 feet in eastern Adair County to 500 feet along the Grand and Illinois Rivers. The entire area lies in the drainage basin of the Arkansas River. The western part of Cherokee County is drained by the Grand (Neosho) River. The Illinois River and its main tributary, Barren Fork, drain the remainder of the area except for the southeastern portion which is drained by Sallisaw and Little Lee Creeks.

STRATIGRAPHY

SURFACE FORMATIONS

CANADIAN (?)

DOLOMITIC LIMESTONE

Character and distribution. Along the lower course of Rock Branch in sec. 7, T. 19 N., R. 25 E. dolomitic limestone underlying the Burgen sandstone is excellently exposed. So far as known this is the only exposure of the base of the Burgen in the area under consideration. The rock is a very finely crystalline, hard, massive dolomitic limestone. The upper part appears finely laminated as a result of weathering, and contains some edgewise conglomerate. Some layers appear cherty, but no chert was observed. Occasional sandy spots were noted. The top of the formation is some 25 feet above the Illinois River, but only the upper 15 feet of the formation are exposed.

Age and correlation. The dolomitic limestone just described is entirely unlike any of the Tyner or Burgen dolomitic limestones, but resembles very closely the upper Arbuckle limestone of the Arbuckle Mountain area, Oklahoma. Unfortunately no fossils were observed, and correlations must, therefore, be made on the position and lithology of the formation. On these two criteria this limestone is tentatively correlated with part of the upper Arbuckle limestone of Canadian age.

North at Spavinaw, Oklahoma, cherty dolomite the age of the "Swan Creek zone" of the Cotter formation in Missouri of Canadian age is exposed[3], and just west of Flint, Oklahoma, about 2 miles north of the north line of Adair County, in a small tributary of Flint Creek, about 25 feet of fine grained dolomite resembling somewhat the Spavinaw occurrence underlie white sand of the Burgen type. In the absence of fossils the exact correlation of these eastern Oklahoma occurrences of pre-Burgen rocks cannot be told. It is probable that they

1. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah Folio (No. 122), 1905; U. S. Geol. Survey Geol. Atlas, Muskogee Folio (No. 132), 1906.
2. Snider, L. C., The geology of a portion of northeastern Oklahoma. Okla. Geol. Survey Bull. 24, pp. 10-14, 1915.
3. White, Luther H., Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 40 B, p. 11, 1926.

are of Canadian age, but they need not be strictly contemporaneous in spite of their occurrence at the top of the Canadian, for Canadian time was followed by a period of warping and peneplanation which in places removed considerable thicknesses of the Canadian before the advent of Ordovician seas. Furthermore, the various formations of Canadian age are themselves separated by unconformities. Thus, in northern Arkansas the Canadian section is, in descending order, Black Rock limestone, 200 feet; Smithville limestone, 200 feet; Powell limestone, 200 feet; Cotter dolomite, 500 feet; and Jefferson City dolomite, 400 feet; but the Black Rock and Smithville are only developed locally, and the Powell is locally absent.[4] It is probable that similar conditions exist in eastern Oklahoma making each exposure of Canadian rock a difficult problem in correlation.

Stratigraphic relations. The contact of the Canadian(?) limestone with the overlying Burgen sandstone is very sharp, and only slightly undulating. Strata above and below the contact are perfectly parallel. There can be no doubt that the relation is one of unconformity.

ORDOVICIAN

BURGEN SANDSTONE

Character and distribution. The Burgen sandstone is exposed in four anticlinal folds along Illinois River. The type locality of the formation as described by Taff[5] is Burgen Hollow about 6 miles northeast of Tahlequah. He described the formation as being composed entirely of sandstone, and attaining a thickness of over 100 feet. Apparently the base is not exposed in this area. The writer has not seen the Burgen in its type locality, but along the eastward flowing stream in sec. 1, T. 17 N., R. 22 E. he measured the following partial section:

Section of Burgen sandstone, sec. 1, T. 17 N., R. 22 E.

	Ft.	In.
BURGEN SANDSTONE (contact with Tyner indefinite)		
16. Sandstone; white to ferruginous, hard, massive fine and even grained, mostly angular, makes ledge and water falls	15	0
15. Sandstone; white, somewhat ferruginous, even bedded in 5" layers, fine, angular, somewhat friable	6	0
14. Sandstone; thin and unevenly bedded, somewhat shaly, merges with above	1	6
13. Sandy shale; green, heterogeneous, full of rounded quartz grains	1	0
12. Covered; probably sandstone or shaly sandstone	2	6
11. Sandstone; white, fine grained, massive, somewhat ferruginous	8	6
10. Sandstone; white to green, interbedded with sandy green shale	3	6

(Continued on page 9)

4. Purdue, A. H. and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Harrison and Eureka Springs Folio (No. 202), p. 16, 1916.
5. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah Folio (No. 122), p. 2, 1905.

Section of Burgen sandstone, cont'd.

	Ft.	in.
9. Sandy shale; alternating thin laminae of green shale and sand		5
8. Shaly, sandy dolomitic limestone; looks conglomeratic		4
7. Calcareous sand; white, hard, thin bedded; thin shale bed at base; few pelecypods		9
6. Calcareous sand; white, very hard; many pelecypods		6
5. Shale; green, hard, slaty; rare streaks of sand		6
4. Interbedded green shale, sandy shale, shaly sand, thin hard sandstone and hard sandy dolomitic limestone; more shaly near top	1	3
3. Sand; white, hard, very fine grained	1	2
2. Sandy dolomitic limestone; buff, very hard, numerous cephalopods		4
1. Sand; white, very fine grained		6
Covered to river	6	0

Across the river in sec. 31, T. 18 N., R. 23 E., the top of the Burgen is 100 feet above the river. Here the upper half resembles the section just described, but the lower half is so obscured by slump from the upper beds that its character can scarcely be detected. It is probably sandstone. From this locality the Burgen plunges northward, but soon rises to the surface again in the vicinity of sec. 2, T. 18 N., R. 23 E. Here the writer measured the following partial section:

Section of Burgen sandstone, sec. 2, T. 18 N., R. 23 E.

	Ft.	in.
TYNER FORMATION		
BURGEN SANDSTONE		
6. Sandstone; thin bedded, possibly somewhat shaly	10	0
5. Covered	3	0
4. Sandstone; brown, massive	5	0
3. Dolomitic limestone; buff, very fine grained, hard, massive	1	6
2. Sandy dolomitic limestone; buff, very sandy	1	6
1. Sandstone; massive, exposed to creek	12	0

Time was not available to map in detail the Burgen along Illinois River in the Siloam Springs quadrangle; hence, the area of undifferentiated Burgen and Tyner on the geologic map. Along Illinois River at the base of the road cut in sec. 16, T. 19 N., R. 24 E. the following section was measured.

Section of Burgen sandstone, sec. 16, T. 19 N., R. 24 E.

	Ft.	in.
CHATTANOOGA SHALE		
BURGEN SANDSTONE		
13. Sandstone; more thin bedded, possibly somewhat shaly; contact with Chattanooga not seen, but Chattanooga is exposed not over 5 feet above	10	0

(Continued on p. 10)

Section of Burgen sandstone, Cont'd.

		Ft.	in.
12.	Sandstone; massive well bedded	17	6
11.	Covered	3	0
10.	Sandstone; soft, friable	2	0
9.	Covered	4	0
8.	Sandstone; white, soft	1	6
7.	Sandy dolomitic limestone, brown, quite sandy; contains many cephalopods	1	6
6.	Dolomitic limestone; brown, finely crystalline with blotches of more crystalline dolomite	3	6
5.	Dolomitic limestone; brown, very finely crystalline; thin bedded		6
4.	Sandy dolomitic limestone; buff to brown, massive, like bed 2 but upper few feet are harder and less sandy	10	0
3.	Sandstone; soft, coarse, made up of rounded frosted quartz grains		3
2.	Sandy dolomitic limestone; buff, very fine grained, with many disseminated rounded sand grains	2	0
1.	Sandstone; white, soft, massive, top few inches very hard; exposed to river	9	0

From this locality the Burgen plunges northward and eastward, but soon rises to the surface in the northwestern part of T. 19 N., R. 25 E. Along Rock Branch, in sec. 7, T. 19 N., R. 25 E., the writer measured the following excellently exposed section:

Section of Burgen sandstone in sec. 7, T. 19 N., R. 25 E.

		Ft.	in.
CHATTANOOGA SHALE			
SYLAMORE SANDSTONE			
8.	Sandstone; conglomeratic, pebbles of green shale	2	6
BURGEN SANDSTONE			
7.	Sandstone; alternating soft and hard in thin beds; some of the softer layers are greenish and somewhat shaly; near the middle a zone of cephalopods	7	0
6.	Sandstone; brown, in part black, soft, friable	3	0
5.	Sandstone; hard	1	0
4.	Sandstone; soft	2	0
3.	Sandstone; hard, massive	1	0
2.	Sandstone; thin bedded	2	0
1.	Sandstone; hard, massive; makes cliff overlooking Illinois River	44	0
CANADIAN (?) DOLOMITIC LIMESTONE			
	Dolomitic limestone; very finely crystalline, hard, massive; the upper part appears thin bedded as a result of weathering and contains some edgewise conglomerate; some layers appear cherty but no chert was observed; occasional sandy spots; exposed	15	0
	Covered to river	10	0

A small patch of Burgen is brought to the surface by folding in secs. 9 and 16, T. 19 N., R. 25 E.

The cephalopods found in bed 7 of the above section appear to be identical with those found in bed 7 of the section exposed in sec. 16, T. 19 N., R. 24 E., and identical with those found in bed 2 of the section exposed in sec. 1, T. 17 N., R. 22 E. On the basis of this zone of cephalopods one may reconstruct a complete section of the Burgen by adding to the base of the first measured section described beds 1 to 6, inclusive, of the last section described. This gives a thickness of 96 feet 3 inches for the total thickness measured by the writer.

The presence of a zone of dolomitic limestone, sandy dolomitic limestone, green shale and shaly sandstone near the middle of the Burgen changes the prevalent conception that the Burgen is pure saccharoidal sandstone. This zone is rather widespread. The writer has noted it in several wells drilled west of Cherokee County (see figures 2 and 3, pp. 17 and 27.)

Age and correlation. The following fossils collected by the writer from bed 6 of the Burgen exposed in sec. 1, T. 17 N., R. 22 E., have been identified by Ulrich.

Matheria n. sp. (a Black River genus).
Psiloconcha sp. (very much like a Cincinnatian species but not good enough to identify with certainty).
Raphistomina sp. (scarcely distinguishable from R. denticulata a Black River species).
Fragment of last whorl of a large shell that suggests a Lophospira like L. ampla and L. tropidophora, both Richmond species.
Patelloid shell not very different from the Black River species Palaeacmae humilis.
Primitia sp. like P. sanctipauli (abundant)
Aparchites (?) sp.

The cephalopods collected by the writer (see measured sections) according to Ulrich probably belong to a new genus with peculiarities that require more study.

> Apparently it combines some old characters with other features that appear mainly in Trenton and younger deposits.
>
> In view of the prevailing opinion that the Burgen corresponds to the St. Peter, it is disappointing to find that none of the pelecypods is specifically the same as any of the St. Peter shells from Minnesota, and only one belongs to a St. Peter genus. Besides these pelecypods the rock yielded one specimen each of three gastropods which again have no representatives in the St. Peter of Minnesota.
>
> As you doubtless know, I have long insisted that the Burgen does not fall into the place to which it is usually assigned by Oklahoma geologists—that is about the middle of the Simpson. It is either older than the base of the Simpson and of the age of some part of the Buffalo River series, or it is much younger—probably Black River. The fossil evidence is lamentably indecisive and really goes little farther than to prove the Ordovician age of the Burgen. Nor do we get any quite satisfactory help from the paleogeographic aspects of the problem. The St. Peter

waters doubtless came in from the south, the Decorah from the north; and as there is no satisfactory evidence to show that the Burgen connects laterally with any member of the Buffalo River series, and as no species of fossils is known to be common to them, there remains no compelling reason for placing the Burgen beneath the Black River. Moreover, the ostracods, and in fact the preponderance of the faunal evidence as a whole, favor Black River. On the other hand, the Burgen cephalopods suggest primitive stock; but that may mean only that they are modified descendants of their northern ancesters whose early Ordovician history is unknown. No faunas of northern origin of that date have yet been discovered. Besides, the Burgen cephalopods are not closely related—even generically—either to the St. Peter species figured by Sardeson or to the three new genera that I am describing from a limestone in northwest Arkansas that must be very nearly of the age of the St. Peter.

In view of these facts I am, somewhat reluctantly, I confess, forced to the conviction that the Burgen is a much younger deposit than the St. Peter and probably that it is represented in the Arbuckle region by the sandstone that is locally developed, especially on the northeast flank of that uplift, at the base of the Bromide and above the Criner. The sand probably was blown in from eroding surfaces of Buffalo River sandstones on the west side of the Ozark uplift, which we have every reason to believe was emerged at that time.[6]

In view of the indefiniteness of the correlation of the Burgen sandstone the name Burgen should be applied to the eastern Oklahoma beds rather than St. Peter. Ulrich's suggestion that the Burgen is the basal sandstone of the Bromide formation of the Simpson group is not entirely out of line with subsurface evidence, but if the writer's suggestion that the lower Tyner is lower Simpson in age proves to be correct, the Burgen must be older than Ulrich suggests it to be. Possibly it is the basal sandstone of the Oil Creek formation of the Simpson group.[7] (See pages 19, 20 and Plate III.)

Stratigraphic relations. The Burgen overlies unconformably the Canadian(?) dolomite. The upper contact of the Burgen is seldom exposed, and its stratigraphic relations to the Tyner formation are thus uncertain.

TYNER FORMATION

Character and distribution. The Tyner formation is exposed in four anticlinal areas. It receives its name from Tyner Creek which empties into Barren Fork in the vicinity of Proctor. The Tyner Creek section is poor. Here at the top of the formation just below the Sylamore sandstone are approximately 6 feet of brown to gray, finely crystalline, dolomitic limestone underlain by two feet of buff, very finely crystalline, dolomitic limestone, the top 3 inches of which are cherty and sandy. The interval from the base of this bed to the creek bed is approximately 30 feet, but the exposures are poor. This interval appears to be mainly shale, with a few sandstone beds. A one-foot bed of sandstone was noted at one locality 4 feet below the upper limestones. A much better section was measured by the writer in the railroad cut on the north bank of Barren Fork in sec. 9, T. 17 N., R. 24 E.

6. Ulrich, E. O., personal communication.
7. Decker, C. E., and Merritt, C. A., The Simpson formation: Oklahoma Geol. Survey manuscript.

Partial section of Tyner formation in sec. 9, T. 17 N., R. 24 E.

		Ft.	in.
SYLAMORE SANDSTONE MEMBER OF CHATTANOOGA FORMATION			
16.	Sand; hard, tight, conglomeratic, impure		2
15.	Clay; soft, ferruginous; an ancient soil		1
TYNER FORMATION			
14.	Dolomitic limestone; brownish gray, finely crystalline, massive; about 3 feet from top is small lens of sublithographic brownish gray limestone; basal 5 inches are harder and weather as part of bed 13; the base is cherty	8	0
13.	Sandstone; top 2 inches very hard, cemented with silica and carbonate; the middle is softer, white, honeycombed; the basal 1½ inch is harder but not so hard as the top	1	10
12.	Dolomitic limestone; brown, very finely crystalline	1	8
11.	Shale; dark gray, hard, somewhat dolomitic		2
10.	Sand; white, hard, porous, fine grained with imbedded large round quartz grains; becomes shaly toward base; massive	2	0
9.	Argillaceous dolomite; greenish gray, very finely crystalline; grades downward into hard dolomitic shale which breaks with a conchoidal fracture; basal ½ inch sandy and shaly	2	0
8.	Shale; green, weathers variegated, slaty		2
7.	Sandy shale; green, hard, very sandy		6
6.	Sandy dolomitic limestone; brown, very finely crystalline		5
5.	Shale; green, fissile, containing a few sand beds especially toward base	1	6
4.	Magnesian limestone; brown, hard, very finely crystalline, slightly sandy, thinly laminated; fragments of pelecypods		10
3.	Shale; green fissile, weathers variegated; occasional sandy streaks	1	11
2.	Magnesian shale; green, conchoidal fracture, hard; much like basal part of bed 9		11
1.	Sandy dolomitic limestone; brown, massive, becomes very sandy toward base grading into white sand; exposed	4	0
Covered to water level		15	0

The writer has not seen the Tyner exposed in Baumgarner Hollow. According to Taff, some 20 feet of interbedded brown sandstone, calcareous sandstone, and bluish or greenish shale are exposed.[8]

The complete section of the Tyner formation is exposed along Illinois River just northeast of Tahlequah. The section given below is

8. Taff, J. A., U. S. Geol. Survey Tahlequah folio (No. 122), p. 2, 1905.

a composite section containing the data on several measured sections. Beds 1 to 19, inclusive, were measured at the Eagle Nest in the SW.¼ sec. 13, T. 18 N., R. 22 E.; beds 20 to 35, inclusive, were measured along the road ½ mile south, and the information contained under beds 36 and 37 is a summary of the data gathered on the upper Tyner beds.

Composite section of the Tyner formation exposed in the anticlinal area along Illinois River northeast of Tahlequah.

	Ft.	in.
FERNVALE LIMESTONE		
39. Limestone; white to gray, coarsely crystalline, highly fossiliferous; absent along Eagle Bluff in secs. 24 and 13, T. 18 N., R. 22 E. maximum thickness noted	10	0
FITE LIMESTONE		
38. Limestone; light gray, sublithographic, hard, with blotches of crystalline calcite; often near the middle contains a lens of brownish fine grained dolomitic limestone; sparingly fossiliferous; thickness rather constant where protected from pre-Chattanoogan erosion by Fernvale limestone; maximum noted	8	0
TYNER FORMATION		
37. Dolomitic limestone; gray to brown, finely crystalline, very hard, massive; often near middle contains a lens of brownish gray dense textured limestone, varies in thickness from 6 to 12 feet		
36. Chert and cherty dolomite; varies from a chert bed 6 inches thick to a cherty dolomite; marks a distinct change in sedimentation; always present at base of bed 37; maximum thickness noted	1	6
35. Dolomitic limestone; brownish, very finely crystalline, massive, may be absent locally if the thin black sandstones and black sandy dolomitic limestones noted in many localities prove to be the same as bed 34; maximum thickness	2	0
34. Sandy dolomitic limestone; brown to black, very hard, slightly sandy		6
33. Sandstone; white to gray, heterogeneous, unassorted, a little calcareous cement, massive	2	0
32. Dolomitic limestone; buff, very finely crystalline, earthy, much less hard than above dolomites, massive	2	0
31. Shale; green, hard, fissile, very slightly sandy	1	0
30. Dolomitic shale; greenish, very hard, breaks with conchoidal fracture, approaches argillaceous dolomite	6	0
29. Dolomitic limestone; buff, very finely crystalline, earthy, massive	2	0
28. Shale; green, slightly magnesian, conchoidal fracture	1	0
27. Sandy shale; green, quite sandy		8

(Continued on p. 15)

Composite section of Tyner formation, Cont'd.

	Ft.	in.
26. Shale; green, hard, fissile	3	0
25. Sandstone; white to gray, fine grained, slightly shaly thin bedded; contains pelecypods	1	6
24. Sandy shale; green, thin bedded, very sandy		6
23. Sandstone; impure, very fine grained, very hard		3
22. Sandy shale; green thin bedded		3
21. Shale; dark green, fissile, slightly magnesian	3	0
20. Sandstone; impure, somewhat calcareous and shaly		6
19. Sandy marly dolomite; yellow, soft, earthy, very sandy, weathers to a soft ochery mass	1	0
18. Sandy dolomitic limestone; yellowish brown, very sandy, harder and more massive toward base	3	0
17. Shale; green, mostly covered	4	0
16. Dolomite; brown, finely crystalline, massive	1	0
15. Sandy shale; green, soft, very sandy, with small rounded quartz grains	5	0
14. Sandy dolomite; brown, finely crystalline, with streaks and blotches of hard sand, hard, massive; resembles somewhat bed 37 in texture and hardness	1	6
13. Shale; green, slaty	1	0
12. Shale; dark greenish, slaty	1	6
11. Shale; green, soft, magnesian	2	0
10. Shale; dark greenish	1	0
9. Shale; green, rotten, magnesian	3	0
8. Shale; dark and green in alternating thin beds; contains streaks of hard fine sandstone near top	4	0
7. Greenish shale and brown earthy dolomite; in alternating thin (½ inch) laminations near top; dolomite beds become thicker (2 inches) and harder toward base grading into bed 6	5	5
6. Dolomite; gray, finely crystalline, massive	1	6
5. Shale; green, with streaks of hard fine grained sandstone; rare fragments of fish teeth		6
4. Dolomite; buff finely crystalline, massive, contains a 2 inch shale streak 6 inches below top	2	0
3. Shale; green, slaty; occasional thin streaks of hard fine grained sandstone		9
2. Dolomite; gray, finely crystalline, somewhat argillaceous massive; contains a 2 inch shale streak 1 foot below top	2	6
1. Shale; green slightly sandy, imbedded rounded sand grains; exposed		6
Covered to river	30	0

The upper part of this section resembles to a marked degree the Barren Fork section. The writer has not seen the actual contact of the Tyner and Burgen. At a locality in sec. 2, T. 17 N., R. 22 E., the same sequence of beds near the base of the Tyner as beds 2 to 7 inclusive of the above section was observed, and there the interval between this lower Tyner sequence and the Burgen could scarcely be more than 10 feet. Adding 10 feet to the total thickness of the above section gives a thickness just 2 inches less than 91 feet for the total Tyner section known to the writer.

The Tyner formation dips northward from the Eagle Nest, and is below the surface at a point about 1½ miles to the northeast. It soon rises again in the vicinity of the NE.¼ sec. 5, T. 18 N., R. 23 E. The Tyner gradually disappears to the northeast due to pre-Chattanoogan folding and peneplanation. The upper Tyner dolomitic limestones have not been seen north of the Eagle Nest. In sec. 2, T. 18 N., R. 23 E. the Tyner is only about 40 feet thick, and is composed mainly of shale. There is Tyner along the west bank of Illinois River in T. 19 N., R. 23 E., and some in sec. 18, T. 19 N., R. 24 E., but in sec. 16, T. 19 N., R. 24 E., the Tyner is completely absent, unless a covered zone 5 feet thick between the Burgen and Chattanooga happens to be Tyner. This seems improbable. In the Ordovician exposure along Rock Branch the Chattanooga formation rests upon middle Burgen, and there is no evidence of Tyner in the exposure of pre-Chattanoogan rocks just west of Flint.

A significant fact concerning the stratigraphy of the Tyner formation is the existence of a distinct break in sedimentation at the base of bed 14 of the Barren Fork section and its equivalent, bed 36 of the Illinois River section. This break is marked by the distinctly cherty character of the basal portion of the upper dolomitic limestones, and by a distinct change in sedimentation. The beds just above the break are hard, massive, finely crystalline dolomitic limestones; those below are shales, sandstones, and dolomitic limestones that are softer and more fine grained than the upper beds. Apparently the upper dolomitic limestones do not rest upon the same bed in all cases. In many exposures along Illinois River a thin bed of black sandstone or black sandy dolomite underlies the cherty bed, but in several places a bed of very finely crystalline dolomitic limestone intervenes.

Another possible break in sedimentation in the Tyner is at the top of bed 7 of the Illinois River section. The earthy dolomites below the top of bed 7 are quite unlike any of the superjacent beds in that they are softer and oftener more coarsely crystalline. Occasionally the upper beds of this series, both in wells and at the outcrop, are glauconitic, and the shales overlying these beds in wells are usually in part red. So many beds of the Tyner shales weather into variegated colors that it is impossible to tell at the outcrop which bed, if any, would be red if unweathered. The different lithology of these lower Tyner dolomites, the glauconitic nature of some of them, and the presence of a zone of red shales immediately above them in wells suggest a break in sedimentation.

For the sake of convenience the Tyner may be divided into upper, middle, and lower parts. The upper Tyner is composed of beds 36 and 37 of the Illinois River section, the middle Tyner is composed of beds 8 to 35, inclusive, and the lower Tyner is composed of all beds between the base of bed 8 and the top of the Burgen sandstone.

The Tyner formation is widespread underground in Oklahoma. The section penetrated in the Shell Petroleum Corporation's No. 1 Owens, in the NW.¼, NE.¼, sec. 25, T. 16 N., R. 19 E., is remarkably similar to the section exposed along Illinois River, except that the beds are thicker than at the outcrop. This is well shown in figure 2. Plate 3 gives the writer's conception of the changes which the Tyner undergoes when traced southward and westward underground in Oklahoma. The broader relations of the Tyner will be discussed in subsequent paragraphs.

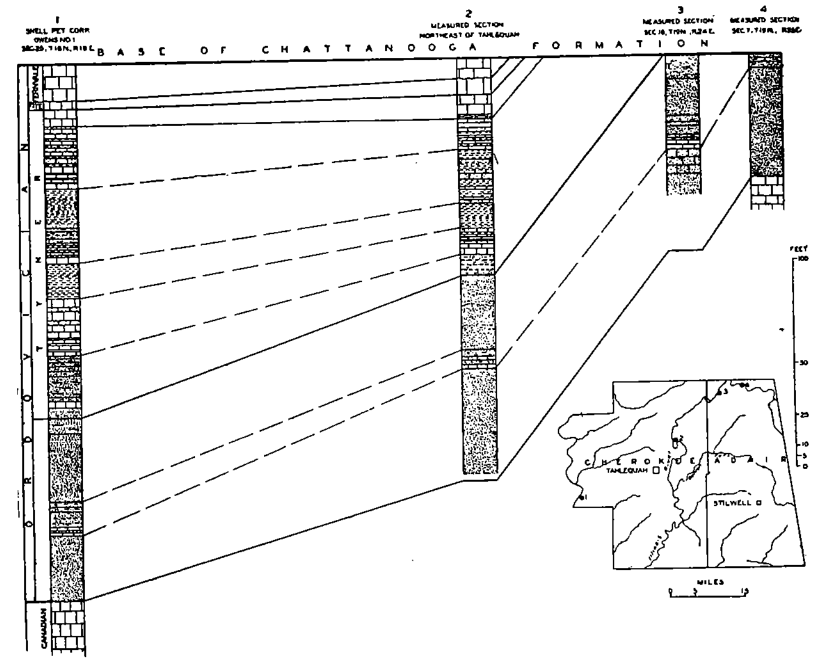

Figure 2. Northeast-southwest section of pre-Chattanooga formations through Cherokee and Adair counties, Oklahoma.

Age and correlation. The Tyner formation is sparingly fossiliferous. Near the center of sec. 2, T. 17 N., R. 22 E., Ulrich collected from "dolomitic sandstone" (bed 37 of the writer's Illinois River section), *Camarocladia rugosa.* From the underlying cherty dolomite (bed 36 of the Illinois River section) Ulrich collected the following fauna:

Streptelasma? sp. (with strongly trabeculate septa)
Eurydictya sp.
Rafinesquina sp. (small)
Ctenodonta sp. (small)
Hormatoma cf. salteri
Pterygometopus sp.
Ceraurus sp.
Leperditia cf. fabulites
Leperditella sp.

Ulrich regards *Camarocladia rugosa* as a dependable guide fossil of the upper Decorah (upper Ion member), and states that the fauna of the cherty dolomite indicates Black River.[9] Thus the evidence collected to date indicates that the upper Tyner is Black River in age. Subsurface evidence is entirely in accord with this conclusion.

The main part of the Tyner formation (beds 1 to 35, inclusive, of the Illinois River section) has to date proved to be practically unfossiliferous. Fragments of pelecypods from bed 25 of the Illinois River section and from bed 4 of the Barren Fork section were observed. Samples were collected from every bed of the Tyner and examined for microfossils in the laboratory, but none was observed. In Baumgarner Hollow (south side sec. 32, T. 18 N., R. 23 E.) Ulrich[10] found a ledge of sandstone containing;—

> " a few imprints of undeterminable species of pelecypods and better moulds of an orthoid with simple plications that suggests **Dinorthis sweeneyi**, a high Decorah fossil, but may be a **Pletorthis**. Its only value is that it tends further to establish the presence of late Decorah beds in the Tyner.

On the bank of Barren Fork in the southwest corner of sec. 10, T. 17 N., R. 24 E. Taff found a layer of roughly laminated sandstone crowded with fairly good casts of shells. Taff was not more specific than to state that the "layer lies under the Chattanooga shale." Concerning these fossils Ulrich says[11];

> There are three species of **Psiloconcha** closely allied to and, with such material, practically indistinquishable from **P. subovalis**, **P. inornata**, and **P. sinuata**. Then there is a species of **Modiolopsis** related to **M. mytiloides**, a Trenton fossil; a **Whiteavesia** that is not very near any described species; and a **Rhytimya** that is not well enough preserved for exact determination. With nothing more to go on I can think of no other horizon than late Cincinnatian or early Richmond.

In the light of the writer's studies of the Barren Fork section the presence of Cincinnatian rocks seems improbable. The writer did not do detailed work in sec. 10, but in sec. 9, T. 17 N., R. 24 E., studied a section of Tyner underlying Chattanooga shale, the upper bed of which is undoubtedly the equivalent of beds 36 and 37 of the Illinois River section which on paleontologic and subsurface evidence are known to be of Black River age. If Cincinnatian beds are present in the writer's section (page 13) they must be the beds diagnosed as Sylamore.

9. Ulrich, E. O., personal communication.
10. Ulrich, E. O., personal communication.
11. Ulrich, E. O., personal communication.

However, the lithology of the Sylamore in this section is quite unlike that of the fossiliferous sandstone collected by Taff, and furthermore, it is difficult to believe that a thin deposit of Cincinnatian sandstone could have withstood pre-Chattanoogan erosion. It would seem that either beds of Cincinnatian age come into the section in sec. 10, T. 17 N., R. 24 E., or that the fossils do not faithfully portray the age of the rock. In view of the Cincinnatian aspect of some of the St. Peter pelecypods it is possible that Black River or Chazyan species may partake of these characteristics when environmental conditions are right. It is unfortunate that Taff did not include a measured section with his collection. Until the exact stratigraphic position of his collection is determined it is believed that based on the writer's studies in sec. 9, T. 17 N., R. 24 E. and regional stratigraphic and structural considerations it is most logical to assume that Taff's collection came from beds below bed 14 of the Barren Fork section, and that the Cincinnatian aspect of the fossils is due to the poor preservation and to the tendency of certain early Ordovician species to partake of Cincinnatian characteristics.

A great deal of subsurface data is available on the correlation of the Tyner formation and its relation to the Simpson group of beds of the Arbuckle Mountain sequence. This data is summarized in plate III. The Tyner formation is the northeastern fringe of the Simpson. The upper Tyner is readily traced into the Bromide formation of the Simpson group. According to the writer's interpretation of underground conditions the middle Tyner shales are gradually replaced by sandstone ("Wilcox" sand) to the west of the outcrop. Accompanying this lateral gradation sandstone beds not strictly contemporaneous with the middle Tyner probably come into the section above and below the equivalent of the middle Tyner. Thus the middle Tyner loses its identity in a thick body of sand as it is traced toward the Arbuckle Mountains, but it is probable that it is Black River in age. If this is true the stratigraphic break at the top of the middle Tyner is not of great time value and is represented in the Arbuckle Mountains by Black River sediments.

The possible stratigraphic break at the base of the middle Tyner (page 16) is herein considered to be the boundary between Black River and Chazyan deposits in eastern Oklahoma. The evidence for the Chazyan age of the lower Tyner is not conclusive but decidedly suggestive. Microfossils found in wells below the red shale in the lower Tyner dolomitic limestone are decidedly suggestive of lower Simpson, hence Chazyan, rather than Black River. A red shale found below the thick "Wilcox" sand section of the Seminole-Wewoka area is interpreted to be the same bed as the red shale so widespread in the basal part of the middle Tyner in northeastern Oklahoma. Granting that this correlation is correct, the lower Tyner belongs far down in the Simpson, and is Chazyan in age. The red shale has not been noted south of

Wewoka in the immediate vicinity of the Arbuckle Mountains. If it represents a break in sedimentation, its absence in the Arbuckle area can be logically interpreted to mean that the Arbuckle section is complete and without breaks of the magnitude represented by the red shale farther north.

To summarize; the upper Tyner formation is of Black River age as proved by fossils collected at the outcrop and by underground tracing of beds. The middle Tyner is probably Black River in age as suggested by subsurface studies. The lower Tyner is possibly Chazy in age. This correlation is based upon the presence of a probable stratigraphic break at top of the lower Tyner, upon the different lithology of the lower Tyner, upon the meager microfaunas found to date in wells in the lower Tyner, and upon the tracing of the red shale of the middle Tyner and underlying beds toward the Arbuckle Mountains.

Stratigraphic relations. The Tyner formation is overlain by the Fite limestone in the vicinity of the great bend in the Illinois River just northeast of Tahlequah, but the Fite is absent because of pre-Chattanoogan erosion at the Eagle Nest, and the Chattanooga rests upon the Tyner from this point northward and eastward. Farther eastward the entire Tyner is cut out. See figures 2 and 3. In the Barren Fork area the Chattanooga rests upon the upper Tyner dolomitic limestones. The contact of the Tyner with superjacent beds is in all cases one of unconformity.

The basal contact of the Tyner is seldom, if ever, accurately located, and, therefore, the stratigraphic relations of the Tyner formation to the underlying Burgen sandstone are uncertain.

FITE LIMESTONE

Name. Taff included in the upper part of his Tyner formation of the Illinois River area a group of limestones the upper bed of which is distinct both in lithology and fauna from the underlying beds.[12] Because this bed is so distinct and because it is absent in the type locality of the Tyner it is herein termed the Fite limestone from excellent exposures on the estate of Dr. Fite in sec. 11, T. 17 N., R. 22 E.

Character and distribution. The Fite limestone is a hard, light gray sublithographic limestone attaining a thickness of 8 feet where protected from pre-Chattanoogan erosion by the Fernvale limestone. Blotches of crystalline calcite within the sublithographic matrix are almost invariably present, and often near the middle of the bed there is a lens of brownish fine grained dolomitic limestone. Fossils are rare and fragmentary. The Fite limestone occurs only in the anticlinal area just northeast of Tahlequah. It is not present in the Barren Fork area

12. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 2, 1905.

of Tyner exposures, and has been removed by pre-Chattanoogan erosion from all Ordovician exposures along Illinois River northeast of Eagle Bluff (center SE.¼ SE.¼ SW.¼ sec. 13, T. 18 N., R. 22 E.)

Age and correlation. The following fossils collected by the writer and Ulrich have been identified by Ulrich.

Tetradium n. sp. (much like T. cellulosum but with much larger tubes and correspondingly larger stems).
Colpomya cf. faba.
Cyrtodonta aff. C. billingsi (has thinner shell).
Lophospira perangulata (the Richmond variety).
Liospira cf. micula.
Dalmanella jugosa (Minnesota variety).
Plectambonites (Sowerbyella) sp.
Leperditia caecigena (Bighorn variety).
Isochilina n. sp.

According to Ulrich;

> The **Dalmanella** and **Sowerbyella** are of specific types that are unknown beneath the Trenton, and both are most like early Richmond species; and the **Cyrtodonta** is of the section of the genus that ranges upward to late Silurian. The specimens are too poor for positive specific identification but what they do show in no wise contradicts their interpretations as lower Richmond fossils. In other words, I still correlate the Fite limestone with the Wykoff limestone of southern Minnesota and the lower, pure limestone part of the Bighorn limestone of Wyoming. If this correlation is correct then it gives us our first positive clue to the relations of the Wykoff and Fernvale limestones, because the latter clearly overlies the supposed equivalent of the former in northeastern Oklahoma.[13]

The Fite limestone was originally correlated by Ulrich as Black River, and has been considered as Black River by the majority of Oklahoma stratigraphers including the writer. A limestone with identical lithologic characteristics and occurring in the same stratigraphic position is wide spread underground in Oklahoma, and is known as the "dense lime." It seems likely that at least the upper part of this "dense lime" is the Fite limestone. It can easily be traced into the Greater Seminole District, but south in the vicinity of Ada it either pinches out or changes in character. In the light of Ulrich's identification of the Fite limestone as pre-Fernvale Richmond it seems best to assume that the "dense lime" pinches out, for rocks of pre-Fernvale Richmond age have not been identified in the Arbuckle sequence. Certain dense textured limestones found in wells in the vicinity of Ada have been correlated with the "dense lime," but these dense beds contain an entirely different microfauna and are readily correlated with beds which lie below the horizon of the "Seminole" sand and just above the "Wilcox" sand in the St. Louis area. Thus the subsurface evidence, so far as it goes, tends to corroborate Ulrich's diagnosis of the Fite limestone as

13. Ulrich, E. O., personal communication.

early Richmond rather than Black River, but the possibility still remains that the "dense lime" found in wells is Black River or early Trenton in age.

Stratigraphic relations. The Fite limestone overlies the Tyner formation unconformably, and is unconformably overlain by the Fernvale limestone or Chattanooga formation. In all cases the contacts are extremely sharp and marked by most abrupt breaks in sedimentation, yet no discordance in dip is discernible. Underground in Oklahoma an occasional bed of sandstone is present between the Fite and Fernvale limestones.

FERNVALE LIMESTONE

Character and distribution. This limestone is exposed in the Ordovician inlier along Illinois River just northeast of Tahlequah. It is not present in the section exposed along Barren Fork, nor in the excellent exposure of Tyner along the Illinois River in secs. 13 and 24, T. 18 N., R. 22 E., and has not been noted north of the latter locality. The Fernvale is excellently exposed in the road cut in sec. 12, T. 17 N., R. 22 E. It is mapped with the Tyner on the geologic map. Throughout the area of its outcrop this formation is a light gray, coarsely crystalline limestone, in places replete with well preserved fossils, and attaining a thickness of 10 feet.

Age and correlation. On the basis of its fauna and lithologic character the limestone just described is correlated with the Fernvale limestone of lower Richmond age, of western Tennessee.[14] The Fernvale is a very widespread and overlapping formation.[15] It occurs in the Arbuckle Mountains as the uppermost bed of the Viola limestone. The Fernvale is the "Viola" limestone of the oil fields.

Because this limestone is so distinct lithologically and faunally from the underlying Fite limestone with which it was formerly mapped, it is here distinguished as a separate formation, Fernvale limestone.

Stratigraphic relations. The contact of the Fernvale with the underlying Fite limestone is easily determined, and is not marked by discordance in dip. At this contact in wells there is often a thin bed of sandstone which in rare instances reaches a thickness of 5 feet. The contact of the Fernvale with subjacent formations throughout Oklahoma and the Mississippi Valley is one of unconformity.[16]

SILURIAN

ST. CLAIR LIMESTONE

Character and distribution. This formation is exposed in four

14. Ulrich, E. O., personal communication.
15. Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull. 22, p. 305, 1911.
16. Ulrich, E. O., op. cit.
Weller, Stuart, The pre-Richmond unconformity in the Mississippi Valley: Jour. Geol. vol. 15, pp. 519-525, 1907.

localities in the southern part of the area under consideration. South of the southeast corner of Cherokee County near Marble in T. 13 N., R. 23 E. it is more fully exposed and consists of thick, massive beds of pinkish white, coarsely crystalline limestone often containing small cavities about which the rock is more coarsely crystalline. The base of the formation is not exposed at any locality in eastern Oklahoma; thicknesses up to 100 feet have been recorded. At the top of the formation and separated from the main body of limestone by an unconformity in the vicinity of Marble are 5 to 8 feet of white coquina-like limestone which, although mapped as St. Clair in previous publications, is here distinguished as a separate formation, the Frisco limestone of the Arbuckle Mountains section.

Age and correlation. The fauna collected by Taff from the upper portion of the St. Clair near Marble according to Ulrich "reminds in some respects of the Osgood, in others of presumably later Niagaran faunas at Chicago and in Sweden."[17] This is Ulrich's upper St. Clair, which he believed to be younger than the typical St. Clair of Arkansas, and which he correlated as Osgood (Rochester). In view of the great thickness of the St. Clair in eastern Oklahoma, and in view of the presence of the typical St. Clair fauna in the pink-crinoidal bed of the Chimneyhill limestone in the Arbuckle Mountains it is believed that the typical St. Clair is present in eastern Oklahoma below the beds containing the fauna found by Taff. The fauna of the typical St. Clair, some 200 species in all, is unlike any other fauna found to date on the North American continent. Its "nearest correlative is found in southern Indiana where a locally developed bed with a similar fauna lies apparently just beneath the horizon of the Osgood limestone. The St. Clair, therefore, must fall somewhere in the upper part of the Clinton group of the Niagaran series."[18]

Stratigraphic relations. The base of the St. Clair is not exposed in eastern Oklahoma. (See page 48.) The unconformity between the St. Clair proper and the overlying Frisco limestone[19] is reported to be readily recognizable. It represents all of the upper Niagaran and all of the Cayugan of Silurian time, and the greater part of the lower Devonian. The Henryhouse and Haragan marls of the Hunton group were deposited at that time, and since the correlatives of these formations are present in western Tennessee in the Brownsport, Rockhouse and Birdsong formations, they may have also been deposited in eastern Oklahoma, and removed by subsequent erosion. In the exposure north of Bunch, and in the exposure in the northeast portion of T. 14 N., R. 23 E., the St. Clair is overlain by the Boone formation. Near Cookson it underlies the Chattanooga shale.

17. Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull. 22, p. 559, 1911.
18. Ulrich, E. O., personal communication.
19. Schuchert, Charles, Devonian of Oklahoma, with special reference to Oriskany and Camden formations: Geol. Soc. America Bull. vol. 33, 1922.

DEVONIAN

FRISCO LIMESTONE

Character and distribution. The Frisco limestone is exposed south of Cherokee County in the vicinity of Marble where it is a 5 to 8 foot bed of coquina-like limestone overlying unconformably the St. Clair limestone. (See page 33.) It may or may not be present in the exposures mapped as St. Clair limestone in Cherokee and Adair counties. The tendency of pre-Chattanoogan erosion to cut more deeply into the section as the unconformity is traced northward may favor the assumption that the Frisco limestone is probably absent from the more northerly exposures of the St. Clair.

Age and correlation. The limestone bed under discussion contains an upper Oriskany fauna, upper-lower Devonian.[20] It is the equivalent of the Frisco limestone[21] of the Hunton group and of the Little Saline limestone of southeastern Missouri.[22] This Devonian limestone was mapped as St. Clair by Taff, but obviously it cannot be called St. Clair because the latter is of middle Silurian age. The writer proposes the name Frisco limestone for this bed because the fauna and lithology prove it to be the direct equivalent of the Frisco limestone of the Arbuckle Mountain region.

Stratigraphic relations. The unconformity at the base of the Frisco limestone has been discussed. (See page 23.) It is separated from the overlying beds by an unconformity. Where overlain by the middle Devonian sandstone the time break is shortest. Taff[23] reports that the calacareous beds at the base of the "Sylamore" seem to blend with the top of the St. Clair.

SALLISAW SANDSTONE

Character and distribution. This formation is a calcareous sandstone of earliest middle Devonian age which occurs in the vicinity of Marble where it has been mapped with the Sylamore sandstone. Inasmuch as the true Sylamore sandstone is herein considered to be of Mississippian age, the beds containing the middle Devonian fossils are separated from the Sylamore, and given the name Sallisaw sandstone from exposures along Sallisaw Creek. The distribution of this sandstone is unknown. The middle Devonian fossils were found in one place only. It is probable that this sandstone is present only as remnants beneath the true Sylamore sandstone. It may or may not be present in the two exposures mapped as Sylamore in T. 14 N., R. 23 E. Taff mentions that the Sylamore sandstone of the Marble area is calcareous near the base. Inasmuch as the middle Devonian fossils were collected from calcareous sandstone, further collecting may prove the entire calcareous basal Sylamore to be Sallisaw sandstone.

20. Schuchert, Charles, op. cit.
21. Reeds, Chester A., The Arbuckle Mountains, Oklahoma: Nat. Hist. vol. 26, no. 5, 1926.
22. Stewart, Grace Anne, (In Branson, E. B.) The Devonian of Missouri. Missouri Bur. Geol. and Mines. vol. 17, 2nd Ser. pp. 213-269, 1923.
23. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 3, 1905.

Age and correlation. The Sallisaw sandstone is the age of the Camden chert of western Tennessee, earliest middle Devonian.[24] It is thus the age of the lower division of the Arkansas novaculite of the Ouachita Mountain region of Oklahoma and Arkansas[25], and possibly the age of the Penters chert of northern Arkansas.[26]

Stratigraphic relations. The Sallisaw sandstone overlies the Frisco limestone unconformably, but at the locality where the Devonian fossils were found its contact with overlying beds was obscured by a covered zone a few feet thick between it and the Chattanooga.[27] Its contact with the Sylamore sandstone is undoubtedly one of unconformity for the entire upper part of the middle Devonian and the upper Devonian are apparently not represented. Taff noted no unconformity within his Sylamore, but did note an unconformity at the top.

> In Walkingstick Hollow, near the southwest corner of sec. 36, T. 14 N., R. 23 E. there are excellent exposures of the shale and underlying sandstone member. The surface of the sandstone here is uneven, appearing as if worn in shallow, oval, pothole-like depressions and irregular elevations, in and over which black shale has been deposited. A peculiar feature of the contact phenomena here is that no detrital sandstone material related to the underlying beds is found in the base of the black shale.[28]

The presence of middle Devonian fossils and this unconformity immediately suggest that the entire sandstone mapped as Sylamore in the southern part of the Tahlequah quadrangle is middle Devonian in age. Future detailed work may prove this to be the case, but at present it is regarded more logical to assume that the unconformity described is a local feature, and that the Sallisaw sandstone probably occurs in patches beneath the Sylamore sandstone. A similar instance is found in the Eureka Springs quadrangle of Arkansas, where the Clifty limestone, a local limy zone at the base of the Sylamore sandstone, contains a Hamilton fauna, upper-middle Devonian.[29] A reasonable interpretation of these isolated occurrences of middle Devonian beds beneath the true Sylamore sandstone is that sandstone was deposited locally during the interval between the deposition of the Frisco limestone and the Mississippian, and that these local sandstones may, therefore, contain the fossils of any sea that was of such a widespread nature as to submerge the area. Sandstones separating strata of widely different ages usually vary in age from place to place.

24. Schuchert, Charles, op. cit.
25. Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geol. Surv. Bull. 45, pp. 27 and 33, 1927.
26. Miser, H. D., Deposits of managanese ore in Batesville district, Arkansas; U. S. Geol. Survey Bull. 743, 1922.
27. Dunbar, Carl O., personal communication.
28. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 3, 1905.
29. Purdue, A. H., and Miser, H. D., op. cit., p. 9.

MISSISSIPPIAN

CHATTANOOGA FORMATION

Character and distribution. The Chattanooga formation is well exposed in Cherokee and Adair counties along streams that have cut their courses through the Boone formation. The formation consists of hard, fissile, well-jointed black shale 20 to 60 feet in thickness with a local sandstone member, the Sylamore, at its base. The Sylamore sandstone member varies greatly in thickness and character. In northern Cherokee and Adair counties a zone of impure sandstone and sandy shale varying in thickness up to 1 foot, and grading upward into the Chattanooga shale can usually be detected. In this same area the Sylamore may be a rather coarse grained, ferruginous sandstone containing pebbles of phosphatic material and shale. In a few localities in this northern area the Sylamore is massive sandstone resembling the Burgen and attaining a thickness of 10 feet. Just south of Cherokee County, in T. 13, N., R. 23 E., the Sylamore attains its best development. Here it attains a thickness of 30 feet according to Taff, and is composed of massive, generally even textured sandstone with a few small phosphatic pebbles and fragments of fish bones.

Age and correlation. The middle Devonian age of certain beds mapped as Sylamore in the Marble area has been discussed. (pages 24, 25). In the northern part of the area under discussion the Sylamore can scarcely be anything but the introductory phase of the Chattanooga shale. Every exposure examined by the writer shows a gradual gradation from sandstone through impure sandstone and sandy shale into the non-sandy shale of the Chattanooga. The Chattanooga shale is herein considered to be of Mississippian age and, therefore, the Sylamore is classed as Mississippian. In central Missouri the Sylamore is almost certainly of Mississippian age for it rests upon the highly eroded edges of the Snyder Creek shale of uppermost Devonian age.[30] The black shale of the Chattanooga contains conodonts and the ubiquitous *Protosalvinia (Sporangites) huronense.* It is the western continuation of the Chattanooga shale of northwestern Arkansas which contains conodonts that prove it to be the equivalent of the true Chattanooga of Tennessee.[31] The Chattanooga and its equivalents, the Ohio shale, the New Albany shale, the Woodford chert, and the middle Arkansas novaculite have long been assigned to the lower Mississippian by Ulrich although most geologists have assigned them to the upper Devonian. As additional evidence is gathered, Ulrich's diagnosis seems to be correct. Ulrich and Bassler failed to find a single species of conodonts from the upper Devonian Portage shales of New York in the Chattanooga or Ohio shales except locally at the base of the Ohio in Kentucky

30. Branson, E. B., The Devonian of Missouri; Missouri Bur. Geol. and Mines, 2nd series, vol. XVII, p. 7, 1923.
Branson, E. B., and Williams, J. S. Relationship of upper Devonian and lower Mississippian faunas in Missouri: Geol. Soc. America Bull. vol. 36 (Abst.) 1925.
31. Purdue, A. H., and Miser, H. D., op. cit., p. 9.

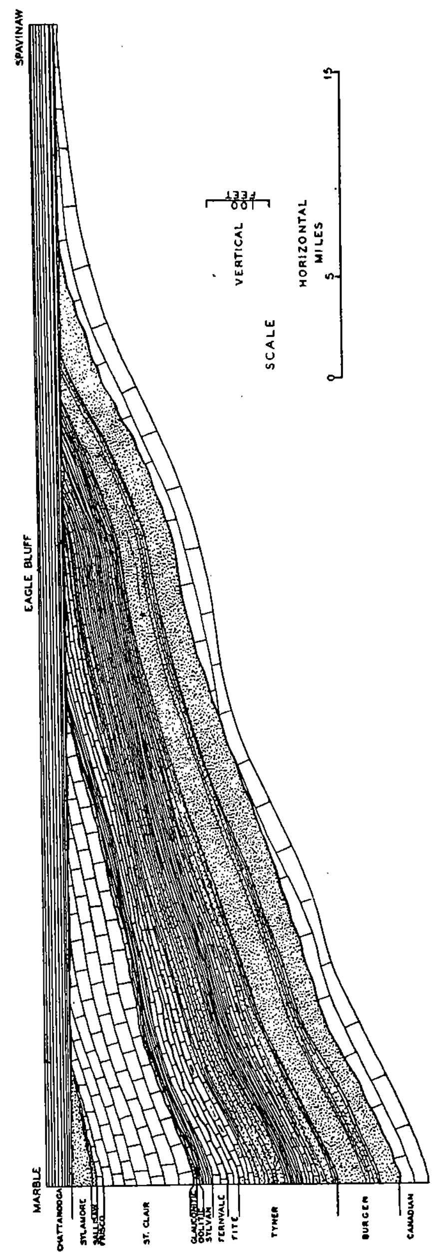

Figure 3. Generalized north-south cross-section from Marble to Spavinaw through Cherokee County, Oklahoma.

where Devonian conodonts associated with *Schizobolus truncatus* Hall are found.[32] They, therefore, correlate the greater part of the Ohio and all the Chattanooga shale as Mississippian. In Missouri the Grassy Creek shale, the northward extension of the Chattanooga, "rests with marked unconformity on strata of Ordovician, Silurian and Devonian age and appears to be closely related to the overlying largely clastic Kinderhook beds."[33] Moore includes the Chattanooga shale as the basal member of the Kinderhookian. Butts[34] presents a good review of the problem, and Swartz[35] has recently presented additional evidence toward the correlation of the typical Chattanooga as Mississippian. Briefly, the faunal character of the Chattanooga, its close relationship with the Kinderhook, and its overlapping nature are strong points in favor of its correlation as basal Mississippian.

Stratigraphic relations. The Chattanooga formation overlaps all older formations. The accompanying figure 3 brings this out clearly. Near Marble the formation is seen to rest upon the Sallisaw Creek sandstone, or Frisco limestone; just northeast of Tahlequah it rests upon the Fernvale limestone; along Eagle Bluff it lies upon the upper Tyner limestones; in sec. 2, T. 18 N., R. 23 E., it rests upon middle Tyner shales, and at Spavinaw it rests upon the Canadian dolomite. (See also fig. 2). As the basal contact of the Chattanooga is traced eastward the formation is found to lie upon progressively older strata resting upon Tyner dolomite in the Barren Fork exposures, and upon middle Burgen in sec. 7, T. 19 N., R. 25 E. White shows the same overlapping nature of the formation in the subsurface of northeastern Oklahoma.[36] This unconformity at the base of the Chattanooga is not accompanied by any discordance in the dip of the beds except if considered regionally. No beds of post-Camden Devonian age have been recognized in eastern Oklahoma, and thus the hiatus at the base of the Chattanooga is great, but like most breaks in the early Paleozoic this break is not evidenced by an unconformity of the highly angular type.

Both the Chattanooga and the Sylamore sandstone member are absent in the exposures of the St. Clair 1½ miles and 4 miles northwest of Bunch.

The Chattanooga is overlain by the Boone formation. The contact in all cases is very sharp, and marked by a most abrupt change in sedimentation. In places the upper contact of the Chattanooga is slightly undulating, and a bed of glauconitic, phosphatic, green clay shale occasionally intervenes between the Chattanooga and overlying Boone

32. Ulrich, E. O., and Bassler, R. S., A classification of the tooth-like fossils, conodonts, with descriptions of American Devonian and Mississpian species: Proc. U. S. Nat. Museum, vol. 68, art. 12, pp. 1-63, 1926.
33. Moore, Raymond C., Early Mississippian formations in Missouri; Missouri Bur. Geol. and Mines, 2nd ser., vol. XXI, p. 26, 1928.
34. Butts, Chas., Mississippian series of eastern Kentucky: Kentucky Geol. Survey, ser. VI, vol. 7, pp. 4-14, 1922.
35. Swartz, Joel H., The age and stratigraphy of the Chattanooga shale in northeastern Tennessee and Virginia; Am. Jour. Sci. 5th ser. vol. 17, 1929.
36. White, Luther H., op. cit., plate I.

formation. If the correlation of the Chattanooga as basal Kinderhook is correct, and the correlation of the St. Joe member of the Boone as Fern Glen is correct, there is an hiatus at the top of the Chattanooga involving the upper Kinderhook formations of Missouri. It is realized, however, that the Chattanooga may be in part the product of lateral gradation of some of these upper Kinderhook formations.

BOONE FORMATION

Character and distribution. The Boone formation is the surface rock over most of Cherokee and Adair counties. It is difficult to obtain accurate measurements of the thickness, but Taff reports thicknesses ranging from 100 feet to 375 feet. Over most of the area it is readily divided into two members, a thin lower limestone member practically free from chert, the St. Joe limestone member, and an upper chert member which is the main part of the formation.

The St. Joe member is present at the base of the Boone in many places in northern Cherokee and Adair counties, and varies greatly in thickness and character. In the west side of sec. 34, T. 17 N., R. 26 E., and at a locality 3 miles to the west it is composed of fine grained, white to pinkish, even-bedded limestone 5 to 15 feet thick. In the NW.¼ sec. 13, T. 17 N., R. 23 E. it is a light-colored crinoidal limestone 10 to 15 feet thick. The exposure in sec. 36, T. 18 N., R. 22 E. presents a different character. Here, according to Taff, "the beds consist of dull blue and earthy fossiliferous limestone in the lower part, followed above by thicker and harder limestone beds, the thickness of the whole being 6 feet."[37] A few miles to the north along Eagle Bluff, Snider describes a series of "dark gray and green shales with thin lenses and nodules of limestone" varying from 5 to 40 feet or possibly more in thickness, due to deposition upon the uneven surface of the Chattanooga and also to an unconformity at the top. He believes these beds to be absent to the north and northwest unless the thin bed of soft green shale at the top of the Chattanooga in the Spavinaw region and along Cabin Creek happens to be the equivalent. According to Snider, in the exposures of St. Joe along Illinois River, it is composed of about 30 feet of thick bedded, crinoidal limestone.[38] The writer has studied the St. Joe at numerous localities in northern Cherokee and Adair counties. Just north of Eagle Bluff the member is composed, from the bottom up, of 6½ feet of massive, rough bedded, sparingly fossiliferous gray to dark gray, fine grained limestone, 1 foot of calcareous shale, 2 feet of calcareous shale and shaly limestone, and 4½ feet of massive, light-colored limestone with a tendency to be crystalline and containing crinoid stems. The shaly beds in the middle pinch out in a distance of 100 yards allowing the two massive limestone beds to come together. Just southeast of Flint, a short distance north of the north boundary of Adair County, the following section, from the top down, was measured:

37. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah Folio (No. 122), p. 3, 1905.
38. Snider, L. C., op. cit. pp. 22-25.

Section of the St. Joe member of the Boone formation southeast of Flint.

	Ft.	in.
CHERT MEMBER OF BOONE FORMATION		
ST. JOE MEMBER OF BOONE FORMATION		
8. Shale; soft, calcareous		6
7. Limestone; massive, fine grained, sparingly fossiliferous; more thin bedded at base	3	0
6. Shale; soft, calcareous		2
5. Limestone; massive, very fine grained	2	10
4. Shale; calcareous with thin beds of limestone	1	6
3. Shale; similar to above bed with many more streaks of limestone especially toward the base; contains many crinoid stems and a few brachiopods	4	0
2. Limestone; massive to thin bedded, dark, dense, finely granular to slightly crystalline, somewhat crinoidal	6	0
1. Clay shale; soft, greenish	1	0
CHATTANOOGA SHALE		

The two sections just described do not resemble the typically coarsely crystalline crinoidal limestone of the St. Joe of parts of Arkansas, but they apparently resemble certain exposures of the St. Joe in the northern part of the Eureka Springs and Harrison quadrangles of Arkansas where the St. Joe is composed of 10 to 15 feet of coarsely crystalline crinoidal limestone at the top separated from a basal massive bed by about 5 feet of thin bedded shaly limestone.[39] In places in Arkansas the St. Joe contains an unconformity in the middle of it believed to be of slight time value because the beds above and below contain a Fern Glen fauna. Siebenthal has studied similar breaks at and near the same horizon in the Wyandotte quadrangle, Oklahoma, and the pinching out of the middle shale member north of Eagle Bluff noted above is correlated as essentially the same phenomenon. The unconformity mentioned by Snider at the top of his "Kinderhook" may be the same thing.

The chert member of the Boone is predominantly chert, although in fresh exposures the limestone is noticeably quite plentiful. Concerning the cherts Snider[40] says;

> The cherts in the lower part of the member are very dense and almost white in color. As a rule, those in the upper part are more porous and of a yellow or brownish color. It is, however, impossible to separate the member into mappable units in view of the small number of good exposures.

In the Joplin district the Short Creek oolite is an important bed near the top of the upper Boone.[41] An oolite at Kingston, Arkansas, some 55 feet below the top of the Boone is probably the same bed.[42] The Short Creek is present in the east half of the Wyandotte quadrangle, Oklahoma, but loses its oolitic character or pinches out west of Spring and Neosho Rivers.[43] So far as known this bed has not been found in the rest of Oklahoma, but its horizon or the horizon of the chert above the Short Creek is present as indicated by fossils collected by Snider.

39. Purdue, A. H., and Miser, H. D., op. cit., pp. 10-11.
40. Snider, L. C., op. cit., p. 25.
41. Smith, W. S. T., and Siebenthal, C. E., U. S. Geol. Survey Geol, Atlas, Joplin folio (No. 148), 1907.
Moore, Raymond C., Early Mississippian formations in Missouri: Missorui Bur. of Geol. and Mines, vol. XXI, 2nd ser., 1928.

Age and correlation. The lithology, stratigraphic position and fauna of the St. Joe member in Oklahoma indicate that it is the westward extension of the typical St. Joe of Arkansas. The typical St. Joe is Fern Glen, lowermost Osagian, in age.[44] The so-called Kinderhook fauna of Snider seems to be more nearly a Fern Glen fauna, and the shaly character of the strata containing it is in all probability merely a local variation from the more typical lithology of the St. Joe. Moore concurs with the writer in assigning this fauna to the Fern Glen, but warns against assuming that no beds of true Kinderhook age are present between the Chattanooga and the St. Joe in this region. "I have seen at one or two places in southwestern Missouri, and one of my students has reported in northern Arkansas a place where beds which are probably truly Choteau are present. In the Arbuckle Mountain area the Sycamore limestone is Choteau in age, which indicates that the Kinderhook sea extended well to the southwest."[45] Snider reports lower Burlington fossils from the St. Joe along Illinois River, and Taff says that the St. Joe of the Tahlequah quandrangle, exclusive of the outcrop in sec. 36, T. 18 N., R. 22 E., and also the lower beds of the chert member contain a Burlington fauna. He reports *Spirifer grimesi* Hall, which occurs in the St. Joe of Arkansas, and in the Burlington and Keokuk; and also *Schizoblastus sayi* Shumard, a form which has not yet been reported from rocks of the Fern Glen-St. Joe zone, but which does occur in the lower Burlington. A form showing affinities with *S. sayi* has been found in the New Providence shale of Kentucky considered to be Fern Glen in age.[46] The Fern Glen-St. Joe and the Burlington contain many forms in common, and this form may yet be found in rocks of the former zone.

In at least one exposure in the Eureka Springs quadrangle, Arkansas, just west of the type locality of the Boone, the Fern Glen fauna persists up into the Boone above the St. Joe member. In Boone County, Arkansas, the remainder of the Boone is said to be mostly Burlington and Keokuk in age except for the beds above the Short Creek oolite which are considered early Warsaw.[47] Moore is in partial agree-

42. Purdue, A. H., and Miser, H. D., op. cit., p. 10.
43. Siebenthal, C. E., op. cit., p. 190.
44. Girty, George H., Faunas of the Boone limestone at St. Joe, Arkansas: U. S. Geol. Survey Bull. 598, 1915. Also see Moore, Raymond C., op. cit.
45. Moore, Raymond C., personal communication.
46. Butts, Charles, Mississipian series of eastern Kentucky: Kentucky Geol. Survey, ser. VI, vol. 7, p. 59, 1922.
47. Purdue, A. H., and Miser, H. D., op. cit., p. 11.

ment with these correlations except that he believes that the upper Burlington is absent, the lower Burlington is partially developed and the Short Creek oolite in addition to the cherts above is Warsaw in age.[48] He gives the same correlation for the Boone of northeastern Oklahoma and southwestern Missouri. Snider collected Burlington fossils from the lower part of the chert member in Oklahoma, and lower Warsaw fossils from the upper cherts near Stilwell, Adair County. The continuity of the Boone in Oklahoma with that of Arkansas and southwestern Missouri coupled with the evidence presented above indicates that the Boone ranges in age from Fern Glen to lower Warsaw in age possibly containing within it an hiatus representing upper Burlington time. The correlation of the Boone is considered further in the paragraphs dealing with the correlation of the Mayes formation. There the writer will point out the possibility that the Boone is represented in the Caney shale of the Arbuckle region. According to recent correlations by Ulrich the upper part of the Arkansas novaculite of the Ouachita area may be Boone in age.[49]

Stratigraphic relations. The Boone formation rests unconformably upon the Chattanooga shale except at two localities northwest of Bunch where it rests directly upon the St. Clair. The unconformity is evidenced in the field by a local thin bed of phosphatic, glauconitic shale at the top of the Chattanooga, by the somewhat uneven surface of the Chattanooga in places, and by the patchy development of the St. Joe member. In northern Arkansas the St. Joe is nearly always present, and rests on beds varying in age from St. Peter to Chattanooga. Locally there are unconformities within the St. Joe, and at one place at the top of beds of Fern Glen age in Arkansas. The patchy development of the St. Joe. in Oklahoma may be partially due to a post-Fern Glen unconformity of local proportions. In wells a glauconitic zone which may mark an unconformity is often found at the top of the Fern Glen.

The upper surface of the Boone in Cherokee and Adair counties is even and without evidences of unconformity. North of the boundary of Cherokee County in the vicinity of Pryor, Mayes County, hills of Boone chert are seen rising through the overlying Chester formations.[50] In the Harrison and Eureka Springs quadrangles, Arkansas, the upper surface of the Boone is slightly uneven, and the overlying Hindsville limestone is often conglomeratic.[51]

MAYES FORMATION

Name. The term Mayes was applied by Snyder[52] in 1915 to the group of beds, largely limestone, which lies between the typical cherty Boone formation and the shale of the Fayetteville formation.

48. Moore, Raymond C., op. cit., pp. 253-256 and correlation chart.
49. Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geol. Survey Bull. 45, p. 33, 1927.
50. Snider, L. C., op. cit., p. 26.
51. Purdue, A. H., and Miser, H. D., op. cit., p. 12.
52. Snider, L. C., op. cit., pp. 27-35.

The upper part of the group is of Chester age, largely lower Fayetteville, and makes up the greater part of the formation in Mayes County, the type locality, and in the counties to the north.[53] The lower part of the group is the age of the "Spring Creek" and upper Boone limestones of the Batesville district, Arkansas, and is best developed in western Cherokee County, eastern Muskogee County and to some extent in southern Mayes County.

In order to clarify the situation it is necessary to give a brief resume of the Mississippian stratigraphy of northern Arkansas. The section in this area is as follows:

Mississippian formations in northern Arkansas.

	Feet
CHESTER GROUP	
Pitkin limestone	0-100
Fayetteville shale	10-400
Upper shale member with limestone lenses	0- 70
Wedington sandstone member	0-150
Lower shale member with limestone member at or near base	10-180
Batesville sandstone with Hindsville limestone member	200
MERAMEC GROUP	
Moorefield shale	0-250
"Spring Creek" limestone	18+
Upper Boone limestone	55+
OSAGE GROUP	
Boone limestone, major portion	200-300
KINDERHOOK GROUP	
Chattanooga shale	0- 80

In Boone County, Arkansas, the Boone formation, the upper part of which is of early Warsaw age, is overlain unconformably by the Hindsville limestone member of the Batesville sandstone of Chester age. To the southeast toward Batesville the Moorefield shale and underlying "Spring Creek" limestone come into the section. The "Spring Creek" is usually included as a part of the Moorefield shale, but Girty has shown that on faunal grounds it should be separated from the Moorefield. The Boone formation apparently maintains its identity throughout the area, but in the Batesville area the beds mapped as upper Boone are in their upper part darker, finer grained, and more siliceous than typical Boone, and contain near the middle beds of black and dark gray shale and calcareous sandstone. Also the fauna of this upper Boone instead of being an early Warsaw fauna, is a "Spring Creek" fauna.[54] Likewise the fauna of the middle Boone of the Batesville area, instead of being a typical

53. Girty, George H., personal communication.
54. Girty, George H., The fauna of the so-called Boone chert near Batesville, Arkansas: U. S. Geol. Survey Bull. 595, 1915.

Keokuk-Burlington assemblage, presents certain radical differences.[55] As a result of his studies Girty suggests that the "Spring Creek" be classified as upper Boone.[56]

It is this "Spring Creek"—upper Boone fauna that is found in the lower part of Snider's Mayes.[57] An attempt should be made to follow the Arkansas nomenclature in the naming of eastern Oklahoma formations, but in this case it is hardly feasible to do so for the name Spring Creek is invalid, and the upper part of the Boone of the Batesville area has not been proved to be the exact equivalent of the upper part of the Boone of Boone County. After canvassing the subject rather widely Girty concluded that the more conservative hypothesis is to correlate the upper part of the Boone of the Batesville area with the Warsaw of the typical Boone, and to correlate the middle part of the Boone of the Batesville area with the Keokuk-Burlington part of the typical Boone. The writer believes that until this hypothesis is proved by the detailed tracing of beds, the name Boone should not be applied to the rocks containing the "Spring Creek" fauna, and that a suitable name should be found.

In Oklahoma the term Mayes has been applied to the rocks containing this "Spring Creek" fauna, but has also been applied to rocks of Chester age. The writer proposes to restrict the term Mayes to the rocks containing this fauna, and to classify the upper beds of Snider's Mayes, mainly developed north of Cherokee County, as lower Fayetteville except in a few cases to the north of Cherokee County where beds of Batesville age seem to be present. The Mayes thus restricted is developed mainly in western Cherokee and Muskogee counties, but does occur in southern Mayes County.[58] Perhaps it would be better to discard the term Mayes, and to apply a new name to the beds of "Spring Creek" age. However, the name Mayes has gained wide circulation among Oklahoma geologists, and most of them use the term in approximately the same sense the writer proposes.

Character and distribution. The Mayes formation is made up of limestone, black argillaceous limestone, and black limy micaceous slaty shale, and is often abundantly fossiliferous. It is best developed in the Muskogee quadrangle where, south of Fort Gibson, the writer has measured 70 feet of black argillaceous limestones and shales with the base not exposed. The same peculiar lithology has been noted in the vicinity of Hulbert, and along Grand River in southern Mayes County.[59] It is apparently absent, or at least

55. Girty, George H., The fauna of the Middle Boone near Batesville, Arkansas: U. S. Geol. Survey Prof. Paper 154 B, 1929.
56. Girty, George. H., U. S. Geol. Survey Prof, Paper 154 B, p. 29, 1929.
57. Girty, George H., personal communication.
58. Snider, L. C., op. cit., p. 34 and faunal chart. Note fauna of collections 3, 4, 5, and 8 A, of Snider's Mayes.
59. Snider, L. C., op. cit., p. 29. Bed 2 of Snider's Grand River section is this material.

is thinner, in the Tahlequah quadrangle where the lower Fayetteville limestone is reported to rest upon the Boone formation.

Age and correlation. The fauna of the Mayes formation of the Fort Gibson area is identical with that of the "Spring Creek" and upper Boone limestones of the Batesville district, Arkansas.[60] Snider also recognized the correct age of the lower part of his Mayes in Cherokee, Mayes and Muskogee counties.[61] Without question the Mayes is equivalent to a portion of the Caney shale of the Arbuckle area.

The exact position of the Mayes and equivalents in the standard Mississippian column, however, is uncertain. It is older than Chester because beds of Chester age overlie it, and because it is totally lacking in typical Chester forms of life.[62] Snider classified the Mayes as Chester, but, as pointed out, he included beds of Fayetteville age in his Mayes. His collections showing the typical "Spring Creek" fauna do not contain typical Chester fossils such as *Diaphragmus elegans*. The Mayes and equivalents have generally been classified as Meramecian, and this is as definite as the present evidence warrants. If the upper Boone of the Batesville district is of early Warsaw age, as suggested by Girty, the "Spring Creek" must be Warsaw, or very nearly Warsaw, for the upper Boone and "Spring Creek" contain the same fauna and have certain lithologic characteristics in common. It follows that the Mayes formation, containing as it does the "Spring Creek" fauna, may be simply a portion of the upper part of the Boone of northeastern Oklahoma completely transformed in lithologic and faunal characteristics to the southwest. The writer inclines to this interpretation, but he believes that more actual tracing of beds should be done before it can be definitely proved. The mapping of these beds done thus far has not been done with this particular problem in mind. In this connection it is interesting to note that the beds mapped as Boone in secs. 12 and 13, T. 15 N., R. 20 E., and secs. 7 and 18, T. 15 N., R. 21 E., are black limestones and limy shales typical of the Mayes formation.

The problem is of regional proportions. In the words of Girty:[63]

> Our Burlington and Keokuk rocks appear to be part of a limestone lens of almost continental proportions. It can hardly be doubted that the Madison limestone and its correlatives come within the same general period of time, and it seems probable that these western limestones were originally, even if they are not now, continuous with those so well known in the Mississippi Valley. My own belief is that the Burlington and Keokuk rocks formed one lobe of a widespread limestone lens chiefly developed

60. Girty, George H., personal communication.
61. Snider, L. C., op. cit., p. 34 and faunal chart. Note character of the fauna from localities 3, 4, 5 and 8 A, of Snider's Mayes.
62. Girty, George H., personal communication.
63. Girty, George H., U. S. Geol. Survey Prof. Paper 154 B, p. 77, 1929.

> in western seas. To the south and east, on the other hand, this limestone lens surely gave way to clastic deposits, for one can scarcely doubt that the "Knobstone group" of Indiana and Kentucky, the Waverly group of Ohio, the Marshall formation and Coldwater shale of Michigan, and in part the "Siliceous group" of Tennessee were in a broad way contemporaneous. Although these formations, which comprise sands, both fine and coarse, and shales of various colors including black, with but small proportions of intermingled calcareous matter are so strikingly different from the Burlington and Keokuk in lithologic characteristics, they differ even more strikingly in ther faunal content. If these faunal and lithologic transitions took place, it seems likely from all the evidence that the sediments and faunas of the Batesville region now known as Boone were in the transition zone where the calcareous lens was merging with its clastic equivalent.

The writer believes that the clastic equivalent of this great lens to the southwest may be the basal part of the Caney shale, the fauna of the limestone facies having been completely replaced by a black shale fauna. The Caney under this interpretation would contain not only the equivalent of the typical Mayes (the possible equivalent of the Warsaw part of the Boone) and the equivalents of the Fayetteville and Pitken, but also the equivalent of the Osage portion of the Boone formation at its base.

The evidence afforded by the numerous borings between Cherokee County and the Arbuckle Mountains, though now generally construed to show that the horizon of the Boone formation is lacking in the Arbuckle area because its fauna and lithology are not there, can be interpreted, and not without reason, to demonstrate that the Boone grades laterally to the south and southwest into limy shales and black limestones which are surely the basal part of the Caney shale.

Stratigraphers familiar with subsurface conditions in Oklahoma are agreed that the black limestone facies of the "Mississippi lime" so well developed underground in the Muskogee area can be traced continuously into the outcropping basal part of the Caney shale. The problem is to connect the black limestone of the Muskogee area with the outcrop only a few miles to the east. It was the belief of Buchanan[64] that this black limestone is the Mayes formation, a formation younger than Boone, and that the Boone is completely cut out just west of its outcrop by an unconformity at the base of the Mayes. Buchanan now believes that the black limestone in question may be partially equivalent to the Warsaw portion of the Boone, but still believes that the Osagian part of the Boone is cut out just west of its outcrop[65] Under this interpretation the Boone could not be represented in

64. Buchanan, George S., The distribution and correlation of the Mississippian of Oklahoma: Bull. Am. Assoc. Pet. Geol. vol. XI, pp. 1307-1320, 1927.
65. Buchanan, Geo. S., personal communication.

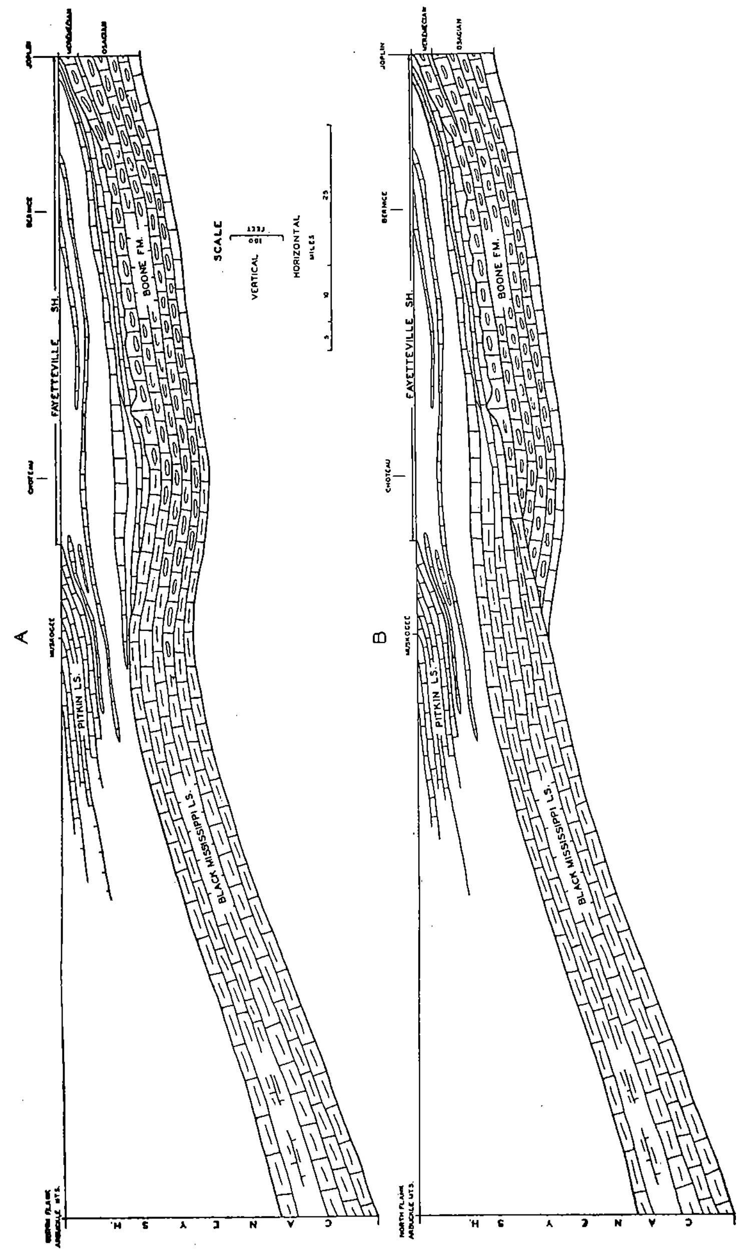

Figure 4. Cross-sections showing possible relation of Boone and Mayes formations to the Caney shale: A. Writer's interpretation. B. Buchanan's interpretation.

the Caney shale. The writer must agree that the black shaly limestone has nothing in common with the typical cherty Boone formation, but that it is identical with the Mayes, a formation which may be uppermost Boone in age. However, the presence of occasional thin beds of fine grained light colored limestone and cherty limestone within the black limestone section of the Muskogee area coupled with the regional considerations outlined above, lead the writer to consider this black limestone section as a remarkable variant of the Boone formation. In addition, as the black limestone is traced underground into Kansas it is found to merge laterally with the "Mississippi lime" of Kansas, which is generally considered to be of Boone age. In central and northern Oklahoma thin beds of black limestone are found intercalated with light colored cherty limestones of the Boone facies. It would seem that the replacement of the cherty limestones of the Boone formation by black argillaceous limestone began at the top of the Boone progressing downward until the entire section of cherty beds was replaced. Under this interpretation the basal part of the Caney shale would be Boone in age. Both the writer's and Buchanan's interpretations are given in figure 4.

A more thorough study of the outcrop must be made before either hypothesis can be proved. It must be established that the Mayes formation as delimited by the writer either rests upon the top of the Warsaw part of the Boone or is a black limestone facies of it. Under the circumstances only the most detailed tracing of beds coupled with faunal studies of the entire Mayes and Boone formations can furnish the desired evidence. In addition the most southwesterly exposures of the Boone as mapped must be carefully examined for the presence or absence of beds of black shaly limestone, especially at the base of the Boone, and the accompanying faunas studied in detail. Until this is done the correlation of the black limestone facies of the "Mississippi lime" must remain in doubt. The writer regards his hypothesis as a possible explanation of the true conditions, but feels a distinct lack of field data with which to substantiate his suspicions.

To summarize: The Mayes formation is the age of the "Spring Creek" and upper Boone limestones of the Batesville district. Arkansas. In the light of the evidence presented to date the latter formations are believed to be the possible equivalents of the upper Boone limestone of Boone County of early Warsaw age, but the possibility that they are younger than Warsaw cannot be totally dismissed. The black shaly beds of the Mayes and equivalents were deposited under conditions totally unlike those under which the crystalline limestones and cherts of the typical Boone were deposited, and hence the unlike faunas of the Mayes and typical Boone can be attributed to environmental conditions as logically as to actual difference in age. However, the actual tracing of the

Mayes facies into the typical Boone facies has not been done, and the writer deems this necessary when the fauna and lithology of the beds in question do not offer conclusive proof as to their correlation. The writer favors the hypothesis of lateral gradation from beds of limestone and chert into beds of black shaly limestone and shale, and suggests that the entire Boone may have been replaced to the southwest by black shaly limestone and shale which form the basal part of the Caney shale. The fauna of the Caney shale is not a Boone fauna, but a black shale fauna of the type found in the Fayetteville, Moorefield and Mayes formation. That this fauna or closely related faunas could have existed earlier than Mayes time when conditions of environment were right is indicated by certain faunas of probable Fern Glen age in Tennessee[66] and by the presence of certain rather typical forms of this black shale fauna in the Sycamore limestone of Kinderhook age. Perhaps the term Mayes is more properly a facies name than a formational name.

Stratigraphic relations. The writer has not seen the lower and upper contacts of the Mayes formation. Apparently there is no evidence of unconformity between the Mayes and Boone in the area under consideration.[67] The Batesville sandstone and Moorefield shale which underlie the Fayetteville shale in Arkansas are not present in Cherokee and Adair counties; hence there is an hiatus between the Mayes and overlying Fayetteville. So far as known no physical evidences of this hiatus are present.

FAYETTEVILLE SHALE

Character and distribution. The Fayetteville shale is a widespread belt of shale separating the Mayes formation from the Pitkin limestone. It occurs in the southern part of Cherokee and Adair counties, and along the western margin of Cherokee County. In the Tahlequah quadrangle[68] the formation is described as two shale members separated by a sandstone member. The lower shale member is a black fissile shale in the lower part with lighter colored shales in the upper part grading upward into the Wedington sandstone member and containing a limestone member close to its base which Snider included in his Mayes. It varies from 110 feet in the northeastern part of the quadrangle to about 20 feet in the southwestern portion. The Wedington sandstone member is exposed only in the northeastern part of the quadrangle, eastern Adair County, and attains a thickness of 40 feet. It thins to the south and west at the same time becoming shaly allowing the upper and lower shale members to come together. The upper shale member is a gray shale containing a bed of fossiliferous limestone and attaining a thickness of 30 feet. It thins westward,

66. Girty, George H., Fauna of the so-called Boone chert near Batesville, Arkansas; U. S. Geol. Survey Bull. 595, p. 19, 1915.
67. Snider, L. C., op. cit., p. 26.
68. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), pp, 3-4, 1905,

and in the western part of the quadrangle the Fayetteville is composed almost entirely of black shale except for the limestone beds near the top and near the base. To the west in the Muskogee quadrangle,[69] and to the northwest in the Pryor quadrangle[70] the formation is composed of black shale with a limestone bed at a variable distance below the top and another at the base included by Snider in his Mayes formation. In these quadrangles the Fayetteville varies from 20 to 90 feet in thickness.

Age and correlation. The basal limestone of the Fayetteville contains a fauna of Chester, Upper Mississippian, age.[71] This basal limestone is apparently more persistent in Oklahoma than in Arkansas, and north of Cherokee and Adair counties becomes well developed, making up the greater part of Snider's Mayes formation.[72]

The black fissile shales of the Fayetteville are often fossiliferous, containing cephalopods and pelecypods. Often *Caneyella nasuta* Girty which also occurs in the Moorefield shale of Arkansas, and the Caney shale of the Arbuckle Mountain area of Oklahoma is abundant.[73] This fauna is also Chester in age.

In Arkansas a fauna of Chester age has been obtained from the Wedington sandstone member of the Fayetteville formation.[74]

The upper shales and lenticular limestone member contain an abundant fauna of brachiopods, bryozoans and a pentremite.[75] This fauna is also of Chester age, and is said to be much like that of the overlying Pitkin limestone.

The exact position of the Fayetteville within the typical Chester section of the Mississippi Valley is unknown. Most of the fossils considered by Weller to be horizon markers within the Chester have not as yet been found in the Chester of Oklahoma and Arkansas. Furthermore, the deposition of black shale in Oklahoma and Arkansas permitted the growth of black shale faunas which

69. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (No. 132), p. 3, 1906.
70. Snider, L. C., op. cit., p. 36.
71. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 3, 1905; Muskogee folio (No. 132), p. 3, 1906.
Purdue, A H., U. S. Geol. Survey, Geol. Atlas, Winslow folio (No. 154), p. 3, 1907.
Girty, George H., New genera and species of Carboniferous fossils from the Fayetteville shale of Arkansas: Ann. N. Y. Acad. Sci. vol. XX, No. 3, Part II, pp. 189-238, 1910.
Purdue, A. H., and Miser, H. D., U. S. Geol. Survey, Geol. Atlas, Harrison and Eureka Springs folio (No. 202), p. 13, 1916.
72. Girty, George H., personal communication.
73. Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Harrison and Eureka Springs folio (No. 202), p. 13, 1916.
74. Purdue, A. H., and Miser, H. D., U. S. Geol. Survey, Geol. Atlas, Harrison and Eureka Springs folio (No. 202), p. 13, 1916.
75. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 3, 1905; Muskogee folio (No. 132), p. 3, 1907.
Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey, Geol. Atlas, Fayetteville folio (No. 119), p. 4, 1905.
Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Harrison and Eureka Springs folio (No. 202), p. 13, 1916.

are foreign to the typical Chester section. The typical Chester section can be traced southward into northern Alabama, but as the section is traced southward through Alabama black shales containing black shale faunas come into the section and finally replace the limestone, sandstones and calcareous shales of the typical Chester sequence, resulting in the Floyd shale of the southern Shades Valley, Alabama.[76] The same gradation into black shales appears to have taken place to the southwest from the typical Chester section in Illinois. The Arkansas and eastern Oklahoma section containing alternating black shales, limestones and sandstones is in a position analogous to certain sections in northern Alabama, and the Caney shale of central Oklahoma is in the position of the Floyd shale. The Fayetteville shale can be traced underground in Oklahoma into the Caney shale. The limestone members disappear, and the Fayetteville is essentially nothing but black shale, somewhat calcareous, long before the Caney outcrop is reached.

Perhaps the best correlation that can be made on the basis of the evidence published to date is that made by Weller in 1915 when he correlated the Fayetteville with the Okaw, middle Chester, of southwestern Illinois.[77] After analyzing all the faunas listed to date from the Mississippian of Oklahoma and Arkansas, the writer arrived at the same conclusion.

To the north in the Joplin region the equivalent of the Fayetteville is found in the calcareous and shaly phases of the Carterville formation.[78]

Stratigraphic relations. The Fayetteville shale appears to lie with perfect conformity upon the Mayes formation in Cherokee and Adair counties, but to the north hills of the Boone formation are seen rising through the Chester beds.[79] Granting that the correlations adopted in this paper approach the truth, the upper Meramecian and lower Chester are absent. Certainly there appears to be no equivalent of the Batesville sandstone and underlying Moorefield shale of the Arkansas sequence. There is thus an hiatus between the Mayes and Fayetteville formations which is not evidenced in Cherokee and Adair counties by a basal conglomerate or discordance in dip.

The contact of the Fayetteville with the overlying Pitkin also appears entirely conformable. However, in northern Arkansas Ul-

76. Butts, Charles, Geology of Alabama; Alabama Geol. Survey. Special Report 14, 1926; U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175), 1910; Bessemer-Vandiver folio (No. 221), 1927.
77. Snider, L. C., op. cit., pp. 39 and 43.
78. Smith, W. S. T. and Siebenthal, C. E., U. S. Geol. Survey Geologic Atlas, Joplin folio (No. 148), 1907.
79. Snider, L. C., op. cit., p. 26.

rich, and Purdue and Miser[80] suggest a slight break between the formations.

PITKIN LIMESTONE

Character and distribution. The Pitkin limestone overlies the Fayetteville shale throughout Cherokee and Adair counties. In the Tahlequah quadrangle it varies in thickness up to 70 feet. Where it is thinnest the beds are granular, earthly and shaly; the thickest sections contain massive beds of fine grained drab limestone.[81] In the Muskogee quadrangle the Pitkin varies little from a thickness of 50 feet, and consists of interbedded fine grained massive layers and softer granular and somewhat oolitic layers. The Pitkin thins rapidly to the north,[82] and has not been observed north of Cherokee County. The massive fine grained strata crowded with *Archimedes* are not easily confused with any other formation found in the area.

Age and correlation. The Pitkin limestone contains a fauna of Chester, upper Mississippian, age.[83] The fauna is said to be quite like that of the upper Fayetteville, and it may, therefore, be upper Okaw (Glen Dean) in age; but Weller and Snider incline to the view that it corresponds to that of the Menard limestone of the Mississippi Valley section of upper Chester age.[84] The abundance of *Archimedes* in the Pitkin, and its position in the section suggest that it may be the equivalent of the Bangor limestone (mostly Glen Dean) of the Alabama section. However, the faunal evidence presented by Weller and Snider coupled with a possible break in sedimentation at the base of the Pitkin argue in favor of a Menard age for the limestone. The Menard is not noted for an abundance of *Archimedes,* and the most typical species of the Menard have not been found in the Pitkin. The fauna of the Pitkin, however, is incompletely known, and therefore its exact age must remain in doubt until more work has been done. Ulrich once suggested that the Pitkin may contain at its top beds younger than any known Chester in the Mississippi Valley due to a longer period of erosion between Mississippian and Pennsylvanian time in the Mississippi Valley.[85]

80. Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, p. 109, 1904.
    Purdue, A. H., and Miser, H. D., U. S. Geol. Survey, Geol. Atlas, Harrison and Eureka Springs quadrangle folio (No. 202), p. 13, 1916.
81. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 4, 1905.
82. Snider, L. C., op. cit., p. 41.
83. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 4, 1905; Muskogee folio (No. 132), p. 3, 1906.
    Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (No. 154), p. 3, 1907.
    Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (No. 119), p. 4, 1905.
    Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Harrison and Eureka Springs quadrangle folio (No. 202), pp. 13-14, 1916.
    Ulrich, E. O., U. S. Geol. Survey Prof. Paper 24, p. 109, 1904.
    Snider, L. C., op. cit., pp. 41-43.
84. Snider, L. C., op. cit., p. 43.
85. Ulrich, E. O., U. S. Geol. Survey, Prof. Paper 24, p. 109, 1904.

Stratigraphic relations. In Cherokee and Adair counties the Pitkin lies with conformity upon the Fayetteville, but in parts of northern Arkansas a slight break may exist. (See page 41). The contact of the Pitkin with the overlying Morrow formation is one of unconformity. Both the Pitkin and the overlying Hale sandstone member of the Morrow formation vary considerably in thickness, and the Pitkin is cut out by post-Mississippian erosion north of Cherokee County.

PENNSYLVANIAN

MORROW FORMATION

Character and distribution. The Morrow formation overlies the Pitkin limestone throughout Cherokee and Adair counties. The formation consists in ascending order of the Hale sandstone member, the limestone member, and the upper shale member.

The Hale is composed of sandstone, but contains locally important shale and fossiliferous limestone beds, and thins irregularly to the west from a thickness of 110 feet in southeastern Adair County to a few feet in western Cherokee County. In the latter area it is often absent or represented by a thin shale bed at the base of the limestone member.

The limestone member is a hard, fine grained to crystalline rock usually containing a shale in the middle which often contains beds of sandstone and limestone. The member becomes shaly at the top appearing to grade into the upper shale member. In eastern Adair County the quantity of interbedded shale is much greater than in western Cherokee County where limestone greatly predominates.[86] Northward from the Muskogee quadrangle the limestone member thins rapidly, and becomes more sandy especially at its base.[87] In western Cherokee County where the Morrow limestone lies directly upon the Pitkin limestone in many instances some confusion may exist regarding the separation of the two beds. Roundy reports a few places in eastern Oklahoma where rocks of Morrow age are mapped as Pitkin.[88] The two beds can usually be distinguished by the lighter color and more crystalline nature of the Morrow limestone, and by the presence of numerous corals and absence of abundant *Archimedes* in the Morrow. The limestone member is thickest in western Cherokee County where it attains a thickness of 200 feet in places. It is thinnest to the east and northwest.

The upper member of the Morrow is blue to black shale with local deposits of sandstone and fossiliferous limestone, and at

86. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 4, 1905; Muskogee folio (132), p. 3, 1906.
87. Snider, L. C., op. cit., pp. 44-45.
88. Letter by Hugh D. Miser to Chas. N. Gould dated March 17, 1928.

one locality coal.[89] The member reaches a maximum thickness of 100 feet, and in general thins westward. It varies in thickness due to erosion prior to the deposition of the overlying Winslow formation.

Age and correlation. The Morrow formation contains an abundant and varied fauna. The formation is continuous with the Morrow group of Arkansas. The Hale sandstone member of the Oklahoma Morrow is the same as the Hale formation of Arkansas, and the middle limestone member in all probabilities represents the Brentwood limestone member of the Bloyd shale.[90] However, the greater thickness of the limestone in Oklahoma and the relative thinness of the Hale may possibly be due to a partial replacement of the Hale sandstone by limestone, an entirely plausible condition because of the calcareous nature of the Hale. The upper shale member in all probability represents the shale of the Bloyd, and the thin limestone beds of this shale are in the position of the Kessler limestone member of the Bloyd. Coal found in the Bloyd between the two limestone members is found at one locality in Oklahoma. To the south the equivalent of the Morrow is the Wapanucka limestone of the Arbuckle Mountain region. Certain shales below the limestone of the Wapanucka are also known to contain a Morrow fauna.

The fauna of the Morrow formation is of great interest because it represents one of the oldest Pennsylvanian faunas known. In its generic expression the fauna may be said to have a Mississippian aspect because of the presence of *Pentremites, Cromyocrinus, Anisotrypa, Archimedes, Glyptopora, Brachythyris, Eumetria* and *Sphenotus,* but only the *Eumetria* is specifically indentical with Mississippian forms, the other genera being represented by new species. These genera, with the exception of *Pentremites,* are rare. In all, only four common forms in the Morrow, *Fenestella serratula, Rhombopora tabulata, Rhombopora attenuata,* and *Spiriferina transversa,* and two rare forms *Dielasma arkansanum* and *Eumetria vera,* are unquestionably identified with Mississippian species. On the other hand some 22 species of a Pennsylvanian aspect were introduced in Hale time, and none of the 49 species of a Pennsylvanian aspect found in the Morrow has been found in the Mississippian, whereas many are typically Pennsylvanian. These factors coupled with the identification of Pottsville plants from the coal bed by David White[91], and the presence of an unconformity at the base leave little doubt as to the early Pennsylvanian age of the Morrow.[92]

89. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (132), p. 4, 1906.
90. Mather, Kirtley F., The fauna of the Morrow group of Arkansas and Oklahoma: Bull. Denison Univ. Sci. Lab., vol. XVIII pp. 59-284, 1915.
91. White, David, Geol. Soc. America Bull. vol. 6, 1895, p. 316; also Twentieth Ann. Rept. U. S. Geol. Survey, Pt. 2, 1900, p. 817.
92. Mather, Kirtley F., op. cit.

Stratigraphic relations. The Morrow formation rests unconformably upon the Pitkin limestone, but the unconformity is usually not marked by discordance in dip. The Hale sandstone member and the underlying Pitkin limestone both vary in thickness, and the Pitkin is cut out at the north boundary of Cherokee County due to post-Mississippian erosion. In northern Arkansas the Pitkin is also cut out to the north, and pebbles of Pitkin limestone are found in the overlying Hale sandstone.[93] There is also an unconformity at the top of the Morrow which cuts deeply into the upper shales, and which cuts out the entire Morrow formation north of Cherokee County.

WINSLOW FORMATION

Character and distribution. The Winslow formation is exposed in extreme southeastern Adair County, and in the southern half of Cherokee County. Equivalent beds in extreme northwestern Cherokee County are mapped as Cherokee. The lower 200 to 450 feet of the Winslow are composed of shales and interbedded shaly sandstones except for local more massive sandstones and occasionally conglomeratic sandstones at the base. Above this lower series in the Tahlequah quadrangle comes a series of more massive and harder sandstones with some interbedded shales and shaly sandstones some 450 feet thick. The sandstone beds of this zone thicken to the east and are more shaly to the west in the Muskogee quadrangle. In the latter quadrangle a thin coal bed occurs in this series. In the Tahlequah quadrangle the upper 150 to 200 feet of the Winslow are composed mainly of shale with some thin sandstone beds, and are mapped as the Akins shale member. The same horizon is represented to the west in the Muskogee quadrangle by about 100 feet of shale, variable sandstone beds and local beds of coal, but is not mapped as Akins shale because the more shaly nature of the underlying sandstone series makes mapping of the shale-sandstone contact difficult and inaccurate. When traced northward the Winslow formation as a whole is seen to become less sandy and more calcareous,[94] and merges with the Cherokee shale.

Age and correlation. The Winslow formation is Pennsylvanian in age, but has not yielded sufficient fossils for a more detailed correlation. By areal geologic mapping Taff determined the equivalency of the Akins shale member and the upper part of the McAlester formation. Also he determined that a part of the upper sandstone series is equivalent to the Hartshorne sandstone, and that the lower 600 to 800 feet of the Winslow are Atoka in age. In the Muskogee folio,[96] published after the Tahlequah folio, he was inclined to assign all but the lower 200 to 400 feet of the Winslow to the

93. Purdue, A. H., and Miser, H. D., op. cit.
94. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (No. 132), p. 4, 1906.
95. Taff, J. A., U. S., Geol. Survey Geol. Atlas, Tahlequah, folio (No. 122), p. 5, 1905.
96. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (No. 132), p. 4, 1906.

McAlester. Briefly, according to Taff, the Winslow contains equivalents of the Atoka, Hartshorne, and McAlester formations, but the limits of these formations within the Winslow are indefinite. The Winslow is continuous with the Cherokee shale to the north, and with the Winslow formation of Arkansas.

Stratigraphic relations. The Winslow lies unconformably upon the Morrow formation. The contact of the two formations is usually discernible, especially in those instances where the Winslow rests upon the heavy limestones of the Morrow, but in a few instances the contact is difficult to locate because of the sandy nature of the upper shale member of the Morrow. The variations in thickness of this shale member, and the local conglomeratic character of the lower Winslow sandstones are evidences of unconformity. Like most unconformities of the Ozark region this unconformity is not angular except when considered broadly. In general the unconformity cuts more deeply into the Morrow formation as it is traced westward across the area under discussion, and cuts out the entire Morrow formation north of Cherokee County.

QUATERNARY

TERRACE SAND AND RIVER ALLUVIUM

Character and distribution. Along the immediate valleys of the Arkansas and Grand (Neosho) Rivers terrace sand consisting of fine yellow sand and silt with local patches of quartzose gravel at or near the base occurs. These terrace deposits are found from the borders of the river bottoms upward more than 100 feet. Both the Arkansas and the Grand (Neosho) Rivers, but especially the Arkansas, have developed flood plains, composed of sand, silt and gravel.

Age and correlation. Taff[97] assigns these deposits to the Quaternary system. The terrace deposits are referred to as Pleistocene, and the river alluvium as Recent.

SUBSURFACE FORMATIONS

PRE-CAMBRIAN

GRANITE

The oldest rock exposed in northeastern Oklahoma is the granite outcrop in Spavinaw Creek about sixteen miles north of Cherokee County. Although once considered a granite dike, it is now generally conceded to be a granite peak of pre-Cambrian age.[98] Granite is logged from 1,395 to 1,440 feet in the Adair Oil and Gas Company's No. 1 Brown, NE.¼ SE.¼ NW.¼ sec. 32, T. 19 N., R. 25 E., and from 1,760 to 1,831 feet in the Gahoma Oil

97. Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (No. 132), p. 5, 1906.
98. Gould, Chas. N., op. cit., p. 54.

Company's Crittenden No. 1, C. NE.¼ SW.¼ sec. 35, T. 19 N., R. 23 E. The log of the Cherokee Oil and Gas Company's Brixey No. 1, SW.¼ NE.¼ NW.¼ sec. 36, T. 19 N., R. 21 E., evidently a poor log, gives the top of a "red lime," probably granite, at 1,115 feet. The total depth of the hole is 2,857 feet in "brown sandy lime." No cuttings are available from these wells.

CAMBRIAN, OZARKIAN AND CANADIAN FORMATIONS

Only the upper 15 feet of the Canadian are exposed in the area under discussion. It has already been pointed out that each exposure of the upper Canadian beds presents a distinct problem in age and correlation. (Pages 7-8). In the Ozark region of Missouri and Arkansas is the following section of Cambrian, Ozarkian, and Canadian from the top down: Black Rock limestone, 200 feet; Smithville limestone, 200 feet; Powell limestone, 200 feet; Cotter dolomite, 500 feet; Jefferson City dolomite, 400 feet; all upper Canadian age; Roubidoux sandstone of middle Canadian age, 200 feet; Gasconade formation of uppermost Ozarkian age, 265 feet; Proctor dolomite of upper-middle Ozarkian age, 60 feet; Eminence chert of lower-middle Ozarkian age, 200 feet; Potosi dolomite of upper-lower Ozarkian age, 300 feet; Derby-Doerun formation, 70 feet; Davis formation, 100 feet; Bonneterre dolomite, 400 feet; and Lamotte sandstone, 300 feet all of upper Cambrian age. The thicknesses given above are maximum thicknesses. Each formation varies greatly in thickness and it is probable that the thickness of 3,400 feet obtained by adding the above thicknesses is never attained in any locality. In the Arbuckle Mountains the same interval is in excess of 8,000 feet, and consists from the top down of the Arbuckle limestone over 7,000 feet thick, mainly of Canadian age, the Royer marble[99] 500 feet thick of Lower Ozarkian age, and the Reagan formation up to 500 feet in thickness of Upper Cambrian age.[100]

The post-granite, pre-Burgen interval is 910 feet thick in the Adair Oil & Gas Company's Brown No. 1, apparently of about the same thickness in the Cherokee Oil & Gas Company's Brixey No. 1, but apparently much greater in the Gahoma Oil Company's Crittenden No. 1. The interval is much thinner than it is at the outcrop in Missouri or in the Arbuckle Mountains. Any attempt to postulate the exact age of any part of this interval is mere guess work. In Missouri the Canadian and Ozarkian formations are all separated by unconformities, and the top of the Canadian is marked by a distinct break throughout the North American continent. Depending upon the extent of these unconformities and

99. Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geol. Surv. Bull. 45, p. 28, 1927.
100. This classification of the Arbuckle Mountain section is being revised by E. O. Ulrich. He has already published a preliminary note of his work. (Bull. Geol. Soc. America, vol. 40, No. 1, pp. 85, 86, 1929).

the topography of the granite basement the post-granite, pre-Burgen interval will vary from place to place. Considerable work is now being done on siliceous residues by the Missouri Geological Survey and others, and this work will doubtless be of value in subdividing this important interval where cuttings are available.

PRE-ST. CLAIR, POST-FERNVALE FORMATIONS

The base of the St. Clair limestone is not exposed in southern Cherokee and Adair counties, and farther north where older rocks are exposed the Chattanooga formation rests upon the Fernvale limestone. The problem of which beds underlie the St. Clair in the southern part of the area is, therefore, a problem of subsurface.

SYLVAN SHALE

A diamond drill boring at Marble revealed a few feet of greenish shale below the St. Clair which in all probability is the Sylvan shale.[101] The same shale has been found in other borings drilled immediately to the south of the area under discussion. Undoubtedly the Sylvan also underlies the St. Clair in southern Cherokee and Adair counties, for the Sylvan to the writer's knowledge is never known to be absent in any area where the St. Clair or other limestones of the Hunton group are present.

GLAUCONITIC AND OOLITIC MEMBERS OF THE CHIMNEYHILL LIMESTONE

Below the equivalent of the St. Clair, the pink-crinoidal member of the Chimneyhill limestone, in the Arbuckle Mountains are the glauconitic member of the Chimneyhill and the underlying oolitic member.[102] The glauconitic member averages 15 feet in thickness and is of Brassfield age; the oolitic member averages 5 feet in thickness and is either Brassfield or Edgewood in age. Both are locally absent along the outcrop, and often absent in wells. The glauconitic member has been noted in wells drilled just south of Cherokee County, and the oolitic member doubtfully recognized. It is believed that these beds may underlie the St. Clair limestone at least locally in Cherokee and Adair counties.

STRUCTURE

GENERAL

Cherokee and Adair counties are situated upon the southwest flank of the Ozark uplift, a broad domal fold the axis of which passes southwest from the St. Francis Mountains, Missouri, through these counties. So far as exposures permit the determi-

101. White, Luther H., op. cit., p. 19.
102. Reeds, Chester A., The Hunton formation of Oklahoma: Am. Jour. Sci. 4th ser., vol. 32, 1911.

nation of structure the folding of the north half of Adair County and of northeastern Cherokee County is gentle, the attitude of the strata in general being rather flat. From this part of the area the strata dip more steeply to the south and southwest, and are thrown into broad faulted synclines. The faults are of the normal type, generally downthrown to the northwest, and trend northeast-southwest. They are of small throw; the greatest displacement is about 600 feet. Some of the faults pass into anticlines. A few anticlinal folds apparently not closely associated with faulting are found.

FAULTS AND FOLDS

The most northwesterly fault in the area under consideration, known as the Locust fault, is a normal fault downthrown to the west bringing the Chester formations in contact with the Boone.

Just east of the southwestern extremity of the Locust fault in secs. 6 and 7, T. 17 N., R. 20 E., a small north-south fault with downthrow to the west brings the Boone formation in contact with the Pitkin limestone.

Southeast of the Locust fault and north of Hulbert a complicated system of faults brings the Boone in contact with younger formations up to the Winslow. One fault trending northeast from the CWL. T. 17 N., R. 20 E., intersects an arc-shaped fault trending roughly east and west in about sec. 28, T. 18 N., R. 20 E. The downthrow of these faults is to the southeast. Two short parallel curved faults intersect the arc-shaped fault in sec. 31, T. 18 N., R. 21 E. Between the two small faults is an elevated block of Boone. A third curved fault merges with the most southerly of the parallel faults, and intersects the arc-shaped fault at its eastern extremity leaving a downthrown block of Winslow.

A fault with the downthrown side to the northwest extends from near the SW. cor. T. 17 N., R. 20 E., south of Hulbert, to the SW. cor. T. 18 N., R. 22 E. The rocks to the north of the fault are strongly flexed upward as a result of drag. To the northeast this fault is lost in the chert covered hills of the Boone formation, but the folding on Illinois River which brings the Ordovician rocks to the surface is in the strike of this fault, and may be closely related as suggested by Snider.[103]

South of the last mentioned fault is a broad syncline, the southern limit of which is faulted by a long fault downthrown to the northwest which extends in a northeasterly direction from the Arkansas River just south of Fort Gibson, Muskogee County, to a point some 2 miles south of Tahlequah. The anticline along Baumgarner Hollow is in the strike of this fault. The gentle north-

103. Snider, L. C., op. cit., pp. 55-56.

ern limb of the syncline is broken by three small faults also trending northeast-southwest and downthrown to the northwest. One of these small faults is lost in the Boone hills just north of Tahlequah, but may resolve itself into the anticline on the Illinois River northeast of Tahlequah.

Another fault downthrown to the northwest extends from a point about 2 miles east of Greenleaf in a northeasterly direction to the chert covered hills of the Boone formation south of Welling. It also faults the south flank of a syncline. The fault grades into an anticline to the southwest, and the folding along Barren Fork is in the strike of the fault to the northeast.

Extending from the southwestern corner of Cherokee County northeastward is a syncline also bordered on the southeast by a fault which extends from the NE. cor. T. 13 N., R. 21 E., to sec. 25, T. 15 N., R. 23 E. This fault is downthrown to the northwest, and grades into an anticline to the southwest. The syncline is broken along its axis by a fault extending from sec. 8, T. 14 N., R. 22 E., to a point east of Waukillau. Another shorter fault passes south of, and parallel to, the latter fault through Cookson. This fault is downthrown to the southeast, whereas the longer fault along the axis of the syncline is downthrown to the northwest, the result being an elevated synclinal block between the faults.

The largest fault in the area enters Adair County at its southwest corner and passes northeast past Bunch to a point north of Lyons. Unlike most of the larger faults described, its downthrow is to the southeast. Between this fault and the fault bordering the syncline described in the last paragraph is an elevated anticlinal block plunging to the southwest. East of the fault the general dip of the rock is to the south except where the strata are displaced by the small fault which crosses the northern portion of T. 14 N., R. 25 E. Like the larger fault the downthrow of the small fault is to the southeast.

Two small faults are present in eastern Adair County. One just south of Baron faults a small basin. It strikes in a northerly direction; the downthrown side is to the west. The other, just east of Stilwell, strikes in an easterly direction at right angles to the axis of an illdefined syncline. The downthrown side is to the south.

ANTICLINES

Two anticlines in southwestern Cherokee County directly associated with faults at their southwest extremities have already been mentioned. The anticlines along Illinois River, Baumgarner Hollow, and Barren Fork to be discussed in the following paragraphs are located to the northeast of, and in the strike of faults, but the Boone formation on which very little structural work can be done crops out in the intervening area, making it impossible to determine the exact relationship of the faults to the folds.

The anticline at the great bend in the Illinois River just northeast of Tahlequah is an asymmetrical fold with its highest point in sec. 31, T. 18 N., R. 23 E. where the Burgen sandstone rises in cliffs 100 feet above the river. While doing stratigraphic work in this area the writer noted several minor undulations and faults along the flanks of the anticline. These minor folds and faults are responsible for the extension of the Tyner outcrop northward beyond Eagle Bluff. In the southwestern part of sec. 13, T. 18 N., R. 22 E., the top of the Tyner formation is far enough above the river to permit the exposure of Burgen, but poor and uncertain exposures and covered areas made it impossible to determine the presence of Burgen with any degree of certainty. The exposure of Tyner in Baumgarner Hollow may mark a minor undulation on the flank of the larger fold.

The Barren Fork in T. 17 N., R. 24 E. cuts through the flank of an anticlinal fold the high point of which is probably north of the stream.

While mapping the Ordovician along Illinois River in the Siloam Springs quadrangle several folds were observed. The work in this area was strictly reconnaissance in nature, but the larger structural features were quite apparent and well brought out by the areal distribution of the formations. Two periods of folding, one in pre-Chattanoogan time, and one in Pennsylvanian time complicate the structure somewhat. Figures 2 and 3 (pp. 17 and 27) should be kept in mind during the following discussion.

The distribution of the undifferentiated Tyner and Burgen along Illinois River in T. 18 N., R. 23 E., and T. 19 N., Rs. 23 and 24 E. marks two anticlinal folds. The axis of the larger fold passes northeastward from sec. 2, T. 18 N., R. 23 E. The rocks dip north and west from the axis to the sharp bend in the Illinois River in sec. 24, T. 19 N., R. 23 E. where they again begin to rise into another fold the apex of which is probably to the northwest of the bend. The larger fold appears to be part of a line of folding which extends in a northeastward direction from the anticline just northeast of Tahlequah to the anticline just west of Flint, Oklahoma, which brings the Canadian dolomite to the surface.

A syncline intervenes between the anticline just discussed and another one located in the vicinity of the mouth of Rock Branch in T. 19 N., R. 25 E. This anticline is rather sharp, and is well expressed by the areal geology. A minor fold brings the Burgen sandstone to the surface a short distance to the southeast of this fold.

Three small anticlines, one in sec. 36, T. 14 N., R. 23 E., which brings the St. Clair limestone to the surface, one in sec. 3, T. 17 N., R.

20 E., and adjoining section to the north, which brings the Morrow formation to the surface, and one in secs. 29 and 30, T. 18 N., R. 20 E., which brings the Chattanooga shale to the surface are so close to faults as to suggest that they are the result of warping accompanying faulting.

In western Cherokee County there are two small sharp anticlines, the axes of which trend at right angles to the axes of the broad synclines. These folds are also close to faults, but they are sharper folds than those described above. One of these in sec. 36, T. 14 N., R. 21 E., brings the Boone formation to the surface over a small area. The other in sec. 1, T. 16 N., R. 19 E., and cutting across sec. 6, T. 16 N., R. 20 E., into sec. 36, T. 17 N., R. 19 E., also brings the Boone to the surface. The former fold is domal, whereas the latter is a sharp elongate anticline.

The distribution of the Chattanooga shale along streams marks several gentle anticlinal folds not already mentioned. These are located as follows: sec. 36, T. 17 N., R. 25 E., and adjoining section to the east, sec. 20, T. 16 N., R. 25 E., along Spring Creek in T. 19 N., R. 21 E., and extending into sec. 30, T. 19 N., R. 22 E., and sec. 12, T. 19 N., R. 20 E., and just southeast of Watts. In sec. 12, T. 19 N., R. 20 E., the Ordovician is brought to the surface over a small area on the north bank of Spring Creek.

It is not to be assumed that the streams which reveal many of the anticlines cut the crests of these folds. In some instances where the writer has noted that the strata dip toward the stream, the stream has merely cut a flank of the anticline.

AGE OF FOLDING

The faults and folds just described were formed during a period of diastrophism subsequent to the deposition of the Winslow formation. They are, therefore, of post-McAlester age, if Taff's correlation of the upper Winslow is correct. Detailed structural work on the projection of the anticline into which the fault which crosses the NE. cor. T. 13 N., R. 21 E., passes to the southwest, demonstrates nicely that this fold passes beneath the undisturbed beds of the Savanna sandstone.[104] The folding, therefore, took place at least in this one instance at the close of McAlester time. It is interesting to note that Morgan describes a period of uplift and block faulting affecting the Stonewall quadrangle toward the close of Savanna time.[105] Since Savanna time the rocks of Oklahoma have been subjected to several periods of deformation.

Cherokee and Adair counties were undoubtedly subjected to folding of a gentler nature at an earlier date. In northern Arkansas, which belongs to the same structural province, exposures permit of a closer

104. Powers, Sidney, personal communication.
105. Morgan, Geo. D., Geology of the Stonewall quadrangle, Oklahoma: Bur. Geol. Norman, Okla., Bull. 2, pp. 17-21, 1924.

study of these periods of deformation.[106] Without attempting to describe the entire geologic history of these areas, the results of the more important periods of deformation will be set down in the following paragraphs.

Considering the Osage anticline, Arkansas, as an example, it is found that the Powell limestone, uppermost Canadian, is absent from the crest of the fold in two places, and that in these localities the Cotter dolomite is more strongly flexed than the younger beds. This is attributed to post-Canadian folding and erosion. The complete break in deposition at the close of Canadian time affected the entire continent, but the exact conditions in Cherokee and Adair counties are unknown because the top of the Canadian is exposed in only one locality.

The next important period of folding and subsequent peneplanation; namely, that of late Devonian, pre-Chattanoogan time, manifests itself both in Arkansas and Oklahoma by the overlap of the Chattanooga formation on the eroded edges of the older rocks. This overlap has already been described (page 28.)

Another period of folding and subsequent erosion of continental proportions took place in post-Mississippian, pre-Pennsylvanian time. As a result of this the Pitkin limestone is absent from the Osage anticline, the Fayetteville shale is thinner than usual, and the Mississippian formations are more strongly flexed than the Pennsylvanian. Also in northern Arkansas the Pitkin limestone thins northward due to erosion. This is also the case in Cherokee County.

A complete break in sedimentation occurred at the close of Morrow time. Subsequent erosion removed the Bloyd shale from parts of Arkansas, and cut deeply into the upper Morrow shale in Oklahoma. On the Carrollton dome, Arkansas, the Winslow is arched much less than the Morrow.

OIL AND GAS GEOLOGY

DEVELOPMENT

No commercial production of oil or gas has been obtained to date in Cherokee and Adair counties, but several showings have been reported. Authentic records of most of the test wells drilled are not in existence. The logs of some of the test wells are given in the Appendix. In the following paragraphs the writer will give what little information is available on the other borings that have been drilled in these counties.

The Stilwell Oil and Gas Company's Paden No. 1 drilled in the NW.¼ SE.¼ sec 7, T. 15 N. R. 26 E., was dry, and abandoned at a total depth of 2,265 May 27, 1916. The J. H. Devenburg well drilled by Shonefelt, et al, in the SE.¼ SE.¼ NE.¼ sec. 34, T. 16 N., R. 25

106. Purdue, A. H., and Miser, H. D., op. cit., pp. 16-19.

E., was dry and abandoned at a total depth of 600 feet. The test well put down by Rice, et al, in the SE.¼ SE.¼ NW.¼ sec. 20, T. 17 N., R. 20 E. was dry at a total depth of 1,850 feet. The well drilled by Shuler and George in the NE.¼ NW.¼ sec. 30, T. 17 N., R. 20 E., was abandoned June 12, 1919, at a total depth of 1,512 feet without finding showings of oil or gas. The boring in sec. 12, T. 17 N., R. 22 E., encountered a strong flow of sulphur water. Its total depth is reported at depths varying between 1,000 and 1,414 feet. A shallow unsuccessful boring is reported to have been drilled in sec. 2 or 3, T. 18 N,. R. 23 E. The S. S. Whitford and Company's Ghormley No. 1 in the NW.¼, SW.¼, NE.¼, sec. 18, T. 17 N., R. 22 E., made enough gas between 300 and 350 feet to supply some of the surrounding farm houses.

The Portland Oil and Gas Company's Whitlock No. 1 in sec. 24, T. 18 N., R. 21 E., was abandoned as a dry hole. A well drilled in sec. 21, T. 17 N., R. 21 E., found some oil, and a well drilled in sec. 21, T. 17 N., R. 20 E., encountered a sand with a fair showing of oil at 800 feet. Slight showings of oil and gas have been reported from wells drilled in secs. 8, 21, and 23, T. 17 N., R. 20 E.[107]

OIL AND GAS POSSIBILITIES

STRUCTURE

The structure has already been described. (pages 48-53) Numerous anticlinal folds are known to occur, and many others may be present in the area of the Boone outcrop. The well drilled in the NE.¼, SW.¼, sec. 35, T. 19 N., R. 23 E., was located close to the apex of a broad anticline. The well drilled in sec. 12, T. 17 N., R. 22 E., was drilled on the southwest flank of a sharper anticline. The well drilled in the SW.¼, NE¼, NW¼, sec. 36, T. 19 N., R. 21 E., was located near the eastern end of a broad anticlinal fold. The other wells have not been drilled on known anticlinal structures, and the two most pronounced anticlines, the one southwest of Hulbert, the other southeast of Greenleaf, have not been drilled.

RESERVOIR ROCKS

Numerous sandstone beds in the Winslow formation, the Hale sandstone member of the Morrow formation and the Wedington sandstone member of the Fayetteville formation are of sufficient porosity to be good reservoir rocks for the storage of oil or gas, but these formations are at, or very close to, the surface over a great part of Cherokee and Adair counties and, therefore, cannot be considered seriously as possible reservoir rocks in these counties.

107. Information in this paragraph taken from Shannon, C. W. (and others) Petroleum and natural gas in Oklahoma. Part II. A discussion of the oil and gas fields, and undeveloped areas of the State, by counties. Oklahoma Geol. Surv. Bull. 19, 1917.

The Sylamore sandstone (Misener sand of the oil fields) is more deeply buried in southwestern Cherokee County, and may locally be thick and porous enough to form an excellent reservoir. Also the St. Clair and Frisco limestones and certain sand beds in the Tyner formation may locally be quite porous. The Burgen sandstone which underlies the entire area except where it is exposed is a most excellent reservoir rock. It is most deeply buried in the western and southern parts of the district.

The eroded upper surface of the Canadian dolomitic limestone is often porous, and produces considerable oil in certain places in Oklahoma. To date production has been found in these limestones over 500 feet below the top. Locally sandstone beds occur. In the Shell Petroleum Corporation's Owens No. 1 recently drilled in the NW.¼ NE.¼ sec. 25, T. 16 N., R. 19 E., the top of the Canadian was encountered at 423 feet, and penetrated to 616 feet 9 inches. In this well the Canadian is mostly cherty and non-cherty dolomitic limestone with occasional thin sand beds one of which was porous enough to hold a large supply of water. The interval from the top of the Canadian to the granite is in all probability mostly dolomitic limestone with a few sand beds. Some sand beds are reported in this interval from the well drilled in the SW. Cor. sec. 4, T. 17 N., R. 20 E., but little confidence can be placed in the drillers' interpretations of the lithology of this interval because the dolomitic limestone is often broken up by the drill into a fine "sand." If the stratigraphy of this interval is anything like it is in northern Arkansas, beds of porous sand can be expected. The well recently drilled by the Independent Oil & Gas Company in the NE. Cor. sec. 6, T. 16 N., R. 27 W., Madison County, Arkansas, found the top of the Canadian at 630 feet, a 5 foot sand bed at 775 feet, a 13-foot sand bed at 1,490 feet, a 5-foot sand bed at 1,625 feet, a 42-foot sand bed at 2,048 feet, and no sand between the dolomitic limestones and the granite.

In short, several good reservoir rocks are present in Cherokee and Adair counties, some of them; namely, some Winslow sandstones, the Hale sandstone, the Sylamore sandstone, the St. Clair and Frisco limestones, some Tyner sandstones, the Burgen sandstone and the upper portion of the Canadian dolomitic limestones, known to produce oil and gas farther west in Oklahoma where they are deeply buried.

SOURCE ROCKS

The source of the oil produced in Oklahoma today is a subject upon which little of a conclusive nature can be said. The dark shales of the Winslow, Morrow, Fayetteville, Mayes, and Chattanooga formations can be considered as possible source rocks. The Chattanooga black shale is considered the source of all pre-Boone oil by a large school of geologists. Another school, increasing in numbers, believes that the

Simpson formation and Tyner formation are the source rocks of this oil, and still another school is debating the possibility of the enormous thickness of Cambrian, Ozarkian and Canadian dolomitic limestones, some of them teeming with the remains of past life, being the source of much of the oil. All of these rocks are present in Cherokee and Adair counties, but most of them are at, or very near, the surface. If the speculations of the last mentioned school of geologists prove to be at least in part true, the possibilities of oil and gas in these counties are enhanced because the rocks of these ages are more deeply buried, and in many cases probably more steeply but not too steeply folded. Also the Cambrian, Ozarkian, and Canadian formations are well punctuated by unconformities, and it is a generally known fact that many of the producing horizons of the great oil pools of the world are along unconformities.

CONCLUSIONS

The writer cannot encourage prospecting for oil and gas in Cherokee and Adair counties. Several anticlinal folds are present, and the stratigraphic column contains many good reservoir rocks and also rocks generally conceded to be source rocks. However, the horizons known to produce oil in commercial quantities in Oklahoma today which also occur in these counties either crop out or are very close to the surface and have thus far yielded but small shows of oil and gas. It is entirely possible that small unimportant producers smiliar to a few in southeastern Wagoner County may be found. The possibilities of the area seem to be bound up in the possibilities of finding oil in the great series of Cambrian, Ozarkian, and Canadian sediments which lies between the Burgen sandstone and the granite. The drilling of test wells to the pre-Cambrian on top of the anticline southwest of Hulbert and on the top of the anticline southeast of Greenleaf would more definitely test the possibilities of these counties.

APPENDIX

WELL RECORDS

Sec. 15, T. 14 N., R. 24 E., Adair County, Oklahoma

Formation	Top	Bottom
Surface	0	40
Sandstone	40	140
Limestone	140	145
Limestone	160	165
Limestone	171	175
Limestone	185	193
Limestone	204	215
Limestone	220	247
Limestone	255	260

Formation	Top	Bottom
Limestone	265	268
Sandstone	275	285
Limestone	285	310
Sand	310	340
Lime	345	370
Sand	370	376
Lime	385	390
Lime	415	595

Shell Petroleum Corporation R. T. Owens No. 1 NW.¼ NW.¼ NE.¼ sec. 25, T. 16 N., R. 19 E., Cherokee County, Oklahoma

Formation	Top	Bottom
Yellow clay 12½ inch at 20	0	21
Creek gravel, 10 inch at 30	21	31
Brown lime	31	55
Limy shale	55	91
Cherty lime	91	135
Black shaly lime	135	156
Gray shale	156	160
Fernvale limestone	160	178
Lithographic limestone	178	182
Dolomitic limestone	182	190
Dolomitic limestone with green shale beds	190	220
Green shale, 8¼ inch at 223	220	237
Sand	237	239
Sandy shale, Show oil and fresh wtr.	239	246
Green shale and dolomitic limestone	246	256
Dark green shale, some red	256	273
Dolomite	273	290
Shaly dolomite	290	300
Dark greenish sandy shale	300	310

Formation	Top	Bottom
Dolomitic sandstone, 6⅝ inch at 317	310	320
Dark and green sandy shale	320	322
Dolomite	322	325
Dolomitic sandstone	325	337
Sand, Hole half full of fresh water	337	370
Green sandy shale	370	373
Sand	373	374
Green sandy shale	374	380
Green sandy shale and sand	380	388
Dolomite	388	392
Green sandy shale	392	393
Sand, dry	393	423
Dolomite	423	478
Sand, 3 bbls. of water, sulphur)	478	481
Dolomite	481	490
Sand, Hole full of water (Sulphur)	490	493
Dolomite	493	525
Sand	525	530
Dolomite	530	543
Sand	543	550
Dolomite	550	616¾

J. L. Haner, et al, Ross No. 1 *NE.¼ NE¼ NW.¼ sec.* 18, *T.* 16 *N., R.* 20 *E., Cherokee County, Oklahoma*

Formation	Top	Bottom
Soil	0	12
Gravel	12	20
Lime boulders, 10" at 22	20	40
Lime gray, 8¼" at 50	40	56
Sand, blk., small gas	56	58
Lime, black, 1 M. gas at 70	58	85
Lime, gray,	85	119
Shale, blk., water	119	144
Lime gray	144	162
Slate, black, Water	162	209
Lime, gray	209	244
Shale, green	244	250
Sand, white, 6-⅝" at 251	250	252
Shale and lime	252	269
Lime gray	269	277
Shale, green	277	281
Sand, brown, Oil showing	281	285
Shale, green	285	290
Shale, black	290	299
Shale, green	299	309
Lime, gray	309	338
Shale, blk.	338	345
Lime, gray	345	371
Sand, white	371	391
Shale, green	391	396
Sand, white	396	417
Green shale breaks, lime gray	417	425
Sandy-sand, white	425	463
Lime, gray, T. D.	463	508

R. W. Barber—Keener well SW.¼ SW.¼ sec. 4, *T.* 17 *N., R.* 20 *E.*

Formation	Top	Bottom
Soil, water	0	10
Boulders	10	15
Blue slate	15	20
Lime	20	35
Sand, water	35	40
Blue clay	40	42
Blue lime	42	52
Clay	52	62
Lime and Slate	62	80
Sand, water	80	90
Sand, lime	90	115
Gumbo and Slate	115	130
Lime	130	135
Light slate	135	140
Shell	140	142
Sand	142	149
Blue slate	149	162
Lime	162	250
Blue shale	250	252
Lime	252	262
Blue shale	262	294
White shale	294	297
Brown shale	297	309
Lime	309	312
Brown slate	312	334
Brown lime	334	364
Light shale	364	372
White lime	372	374
Soapstone	374	384
Gray lime	384	394
Flinty lime	394	404
Gray sand, water	404	409
Sand, lime	409	438
Gray sand, lime	438	482
Blue lime	482	525
Blue slate	525	527
Blue lime	527	530
Brown shale	530	535
Black shale	535	569
Lime	569	577
Brown shale	577	608
Lime	608	610
Blue shale	610	623
Green shale	623	635
Reddish brown shale	635	641
Blue slate	641	680
Flint sand	680	685
Brown shale	685	695
Salt sand, show oil—no water	695	785
Lime	785	798
Salt sand	798	809
Lime	809	852
Sand, water	852	869
Lime	869	884
Slate	884	886
Sand	886	892
Pay sand, good show green oil	892	893
Gray sand	893	898
Miss. lime	898	1310
White lime	1310	1315

(Continued on page 59)

Formation	Top	Bottom
Gray lime	1315	1327
Slate	1327	1332
White lime	1332	1337
Brown lime	1337	1342
Brown lime, sandy	1342	1357
White lime	1357	1360
Dark lime	1360	1370
Gray sand	1370	1375
White sand, pack	1375	1395
Salt sand	1395	1398
Blue lime	1398	1403
Gray lime	1403	1423
Black sand	1423	1426
Gray sand	1426	1433
White lime	1433	1458
Gray sand	1458	1468
White sand, show oil 1473—1502	1468	1473
Gray sand	1473	1483
Brown sand	1483	1492
White sand	1492	1502
Gray lime T. D.	1502	1532

Oklahoma Land Development Company, Becker No. 1 *SE. Cor. NW.¼, sec.* 23, *T.* 18 *N., R.* 19 *E.*

Formation	Top	Bottom
Lime surface	0	35
White lime	35	60
Hard coal	60	62
White shale	62	103
White lime, 10" at 120	103	120
Black shale	120	200
Brown sandy lime	200	240
Light shale	240	300
White lime	300	320
Blue flint	320	360
Sandy lime	360	400
Blue lime	400	407
Gray sandy shale, water at 445 ft.	407	500
White lime, 8¼" at 782	500	1258
T. D.		1258

Cherokee Oil & Gas Company, Brixey No. 1 *SW.¼ NE.¼ NW.¼ sec.* 36, *T.* 19 *N., R.* 21 *E., Cherokee County, Oklahoma.*

Formation	Top	Bottom
Surface gravel and top soil	0	20
Black shale	20	80
Grey lime, 10" at 160	80	160
Blue lime	160	300
Black lime	300	420
Black shale	420	510
Black lime	510	600
Black sandy shale, showing of oil	600	620
Bkn. lime and shale	620	736
Grey lime, hard	736	890
Blue sandy shale	890	941
Blue soapstone	941	967
Black lime	967	1002
Green sandy shale, showing of oil	1002	1016
White lime	1016	1115
Reddish lime	1115	1212
Blue shale	1212	1230
Black lime	1230	1310
Grey lime	1310	1360
Pink lime, 8¼" at 1400	1360	1400
Bkn. formation sand and shale	1400	1440
Black lime, good gas	1440	1456
Grey lime	1456	1519
White sand	1519	1592
Sandy lime	1592	1620
Grey sand	1620	1700
Blue lime	1700	1766
White lime, 6⅝" at 1850	1766	1850
Brown sand, Showing oil	1850	1860
Red lime	1860	1990
Brown lime	1990	2160
Brown shale	2160	2170
Red lime	2170	2195
Brown lime, dark	2195	2280
Bkn. brown and red sandy lime	2280	2360
Bkn. black shale	2360	2410

(Continued on page 60)

Formation	Top	Bottom
Red lime	2410	2466
Bkn. red and brown, good dark brown oil sand, oil showing good 2510-2513	2466	2513
Red lime, hard	2513	2570
Brown sandy lime	2570	2620
Red lime, hard	2620	2705
Brown sandy lime	2705	2790
Red lime, hard	2790	2850
Brown sandy lime, T. D.	2850	2857

Gahoma Oil & Gas Company, Crittenden No. 1, NE.¼ NE.¼ SW.¼ sec. 35, T. 19 N., R. 23 E., Cherokee County, Oklahoma.

Formation	Top	Bottom
Gravel, dirt	0	8
Lime	9	91
Bkn. lime, wtr. sand	91	93
White lime	93	170
Bkn. lime, wtr. sand	170	172
White chalky lime, soft, open	172	191
Shale	191	194
Lime	194	683
Finely lime hood, reddish, 8¼" at 760 ft.	683	784
White lime, very hard	784	1552
Black lime, coarse	1552	1761
Red granite, very hard, No show oil nor gas, T. D.	1761	1831

Adair Oil & Gas Company, Artie Brown No. 1, NE.¼ SE.¼ NW.¼ sec. 32, T. 19 N., R. 25 E., Adair County, Oklahoma.

Formation	Top	Bottom
Doby	0	4
Lime	4	10
Flint	10	14
Lime	14	18
Flint, 10" at 20 ft.	18	25
Lime	25	77
White sand	77	82
Flint	82	234
Lime	234	259
Flint	259	289
Black shale	289	364
White sand, fresh water	364	417
Blue shale	417	421
Sand	421	422
Blue shale, showing gas	422	425
White sand	425	484
White lime, cased 905 ft. with 6¼ csg.	484	1025
Black lime	1025	1395
Granite, T. D.	1395	1430