OKLAHOMA GEOLOGICAL SURVEY

Chas. N. Gould, Director

Bulletin No. 45

Fossiliferous Boulders in the Ouachita "Caney" Shale and the Age of the Shale Containing Them*

By

E. O. Ulrich

United States Geological Survey

NORMAN

NOVEMBER, 1927

*Published by permission of the Director of the United States Geological Survey.

CONTENTS

ILLUSTRATIONS

FOSSILIFEROUS BOULDERS IN THE OUACHITA "CANEY" SHALE AND THE AGE OF THE SHALE CONTAINING THEM*.

INTRODUCTION

The following report on the fossiliferous boulders collected from about forty exposures of "Caney" shale in the Ouachita region of eastern Oklahoma mainly by J. A. Taff, C. D. Smith, Millard Shaler, and myself during the field seasons of 1899, 1904, and 1905 is based primarily on studies and determinations made by me in 1909 or 1910. Smaller collections were made during 1898 in the McAlester quadrangle by J. A. Taff, G. H. Girty, and G. I. Adams. Since 1910 a few other small lots of such pebbles have been received, among them one collected and submitted for determination in March of this year by W. T. Thom, Jr., and others collected mainly in April and May by Sidney Powers, J. A. Taff, H. D. Miser, and Sidney Paige.

As is well known, these boulders were at first regarded as weathered pieces of a ledge of limestone lying between the Jackfork sandstone and the base of the Caney shale. Some of the pieces of this limestone collected by Taff and his assistants prior to 1904 contained unquestionable Ordovician fossils. On this account the Atoka folio bears regrettable but permanent witness to the error of placing the underlying Jackfork sandstone and Stanley shale into the Ordovician part of the stratigraphic column. My connection with the case dates from 1903 when the manuscript for another folio treating of a nearby area with similar rocks was submitted to me for critical reading and comment. After my two preceding seasons' experience in the Arbuckle and Wichita Mountains and in central Texas I simply could not accept the Jackfork sandstone as Ordovician. Either the structural relations of the concerned formations had been misinterpreted or something must be wrong about the supposedly overlying limestone with Ordovician fossils.

It is hardly necessary to say that unquestionable paleontologic evidence of the post-Ordovician age of the Jackfork and Stanley formations was quickly procured during the succeeding field season. Consequently, too, it was at once apparent that the limestone pieces with Ordovician fossils in the overlying Caney shale must be pebbles or boulders in a peculiar conglomerate. After much further study of the occurrence and lack of assortment of the boulders we reached the conclusion that they are not to be considered as pebbles of an ordinary basal conglomerate but rather as similar in origin to the boulders in the Ordovician Rysedorph Hill conglomerate in eastern New York and those in the still older ledges of limestone conglomerate in the Levis shale op-

*Printed by permission of the American Association of Petroleum Geologists. Read before the Association at the Tulsa meeting, March 26, 1927.

posite the city of Quebec. Both of these cases I had interpreted as owing their origin to occasional transportation and indiscriminate droppings of loose surface rock imbedded in drifting and melting land or shore ice. It is interesting to note the perhaps significant fact that these older instances of ice transported boulders agree further with the Ouachita Caney case in that the boulders occur in the lower parts of black shale formations.

Another matter at issue when I joined Mr. Taff in the investigation of the Stanley and Jackfork formations was the precise age of the shales described and mapped by him under the name Caney. If the Jackfork and perhaps Stanley also proved, as I believed, to be of early Pennsylvanian age, then it followed conclusively that the black shale overlying the former in the Ouachita area must also be younger than Mississippian, to which it had been assigned. Moreover, if the fossils found in this shale proved to be in transported masses of older formations then we might assume without fear of contradiction that the shale in which they occur is at least as young or younger than the youngest of the fossiliferous boulders. That our efforts to unravel these related problems were not unavailing may be left to the critical judgment or the reader.

In the following matter I shall discuss, first, the great variety and vertical range of beds indicated by the fossils in the boulders of the Ouachita Caney shale and in more general terms the areas in which the beds were exposed and from which they were transported; second, the localities of the places where fossiliferous boulders were found; third, in relative detail, by lists of the fossils arranged according to the several ages indicated and where the boulders containing them were collected; fourth, differentiation of the two distinct Caney shales, reasons for restricting the name of the Mississippian bed, and proposal of a new name for the boulder-bearing Pennsylvanian shale; fifth, comparison of the respective sequences of Paleozoic formations in the two areas; and sixth, the orgin of the scratches observed on many of the boulders. The facts thus brought out established to my complete satisfaction that two quite distinct shales have been confused under the name Caney by Taff and all subsequent authors who have described exposures of either of these shales in Oklahoma or described fossils found in them. The younger of these two shales is confined so far as known to the Ouachita area, contains fossiliferous boulders of many kinds in its lower part but seems devoid of contemporaneous fossil remains, and is of Pennsylvanian age; the other is of Mississippian age, has a fauna of its own but contains no such erratics, and is confined to the north and west of the Ouachita area. To avoid confusion the latter shale will be referred to simply as the Caney shale whereas the younger shale will be distinguished provisionally by calling it the Ouachita Caney. In final paragraphs devoted to a brief discussion of the nomenclatural aspects of the case I shall propose the new name Johns Valley shale for the latter.

OUACHITA CANEY BOULDERS OF MANY KINDS AND AGES.

GENERALIZED LITHOLOGIC CHARACTER AND FAUNAL CONTENTS

Boulders of at least a dozen readily distinguishable kinds of limestone, many of silicified oolite, four or more kinds of sandstone, and others of arenaceous or calcereous shale, the last often in small pieces, were observed, a few still partly embedded in the matrix but mostly weathered out and strewn over many of the bare outcrops of the lower 50 feet or possibly 100 feet or more of the Ouachita Caney shale. At most localities those composed of limestone predominated, at other places the pieces of limestone were less abundant than those of either the sandstones or the cherts, and at still other places the fragments of shale were the most common. However, at practically all places where such erratics were observed all four kinds of rock—limestone, chert, sandstone, and shale, and some of them of widely different ages—were found associated in varying proportions at essentially the same level in the shale.

These boulders are often of considerable size, masses two to more than five feet across being not uncommon. Indeed, one that showed Ordovician fossils all along its exposed edge of more than 20 feet was observed in the side of the mountain about a quarter of a mile east of Compton Cut.

To give a concrete example of the variety of fossiliferous boulders associated in the same zone at a single outcrop of the lower part of the Ouachita Caney shale I shall cite the facts observed about 10 miles west of Bengal at locality 35 (see following list). Of the boulders collected here one is a rough mass of chert with an unnamed cephalopod known to occur in the Canadian part of the Arbuckle limestone. Many others found here indicate more or less widely separated Ordovician zones and subzones found in place to the west in the Simpson, Bromide, and Viola formations. The character of the limestone matrix in each of these faunally distinct zones is quite different from the others. Then there was a singe pebble of crystalline limestone that contained an incomplete but identifiable specimen of *Maclurina cuneata*. The matrix is like that of the very widely distributed Fernvale limestone of the Richmond group which usually lies between the top of the typical Viola and the base of the overlying Sylvan shale in the Arbuckle region. Finally, we collected chips from the surface of two or three rather large fine-grained oolitic boulders that were incrusted with partially silicified early Silurian (Upper Medinan or Alexandrian) fossils known to occur in the similarly oolitic lowest member of Taff's Hunton formation.

At other localities, (Nos. 17, 24, 31, 37, and 39 of the following list, three of them near Bengal), Ordovician boulders precisely like those at locality 35 were found associated with fossiliferous erratics of still younger zones. At two of these (Nos. 17 and 37), we found boulders with fossils of an early Middle Devonian zone, whereas the other three outcrops afforded pieces of limestone with fossils that seem comparable only with species of the Morrow fauna. Of the latter group locality 31 is probably the most important because here the boulder bed seems to lie close to the Jackfork sandstone.

REMNANTS (?) OF POSSIBLE LEDGES

Considering the experience of the past hundred years in determining the age of sedimentary rocks by matching their lithologic and fossil peculiarities, it seems utterly impossible that all, or even any two, of these readily discriminated faunal associations could have lived at the same time. Yet it is nothing less than this impossible condition that is demanded by the recently expressed view that the limestone boulders of the Caney are not transported erratics at all but owe their origin to fracturing and partial dissolution of a bed of "Carboniferous" limestone deposited over the top of the Jackfork sandstone and beneath or within the basal part of the Caney shale. I saw nothing whatever about these boulders that might warrant even the suggestion that they are remnants of a bed of limestone that had been subjected to and broken up by solution agencies. When found embedded in the shale there is no residual material about them. On the contrary they usually present the expected appearance of surface-weathered limestones that had been more or less cleanly washed before being dropped and embedded in the mud that made the shale. Encased in the relatively and impervious shale water solution of the limestone masses would naturally be minimized if not quite prevented.

I do not wish to deny the possibility that an actually contemporaneous ledge of limestone was locally formed in the Ouachita area at the time these boulders were dropped into the black mud which subsequently made up the basal part of what is here provisionally referred to as the Ouachita Caney shale. On the other hand, I must say I have neither seen nor heard of conclusive evidence of the existence of this possible bed of nonconglomeratic limestone in areas underlain by Jackfork sandstone. In fact, even the exposures in Johns Valley (my locality 6, Antlers quadrangle), mentioned by others as affording the most convincing evidence of the existence of such a ledge, are definitely discredited by the fossils collected long ago by Taff and myself and more recently by others from its supposedly intermittent exposures. These fossils include an unquestionable coiled cephalopod (Tarphyceras seelyi?) of Canadian age, a number of Ordovician species that fall into groups, each of which is definitely characteristic of some special zone of that system, also two or three Silurian species, and finally a number of Middle Devonian species that occurred together in a loose piece of the supposed ledge.

Granting the possibility that these faunally and therefore chronologically very different boulders were locally cemented by calcareous deposit so as to form ledges within the body of the shale cannot be urged as antagonizing the views here entertained regarding the original geographic and stratigraphic position of the several blocks and the means of transporting them to their present place in the Ouachita Caney shale.

If such local ledges actually existed, or exist today, in the Ouachita Caney they would be essentially paralleled in origin and character by the ledges of conglomerate in the lower part of the much older Levis shale at Levis, Quebec.

GEOGRAPHIC ORIGIN OF THE BOULDERS

With possibly a few exceptions the Ouachita Caney boulders were derived from formations wholly absent from the Ouachita sedimentary basin. As near as can now be determined the location of the beds from which they were taken is to the west 50 or more miles, in the Arbuckle Uplift of south-central Oklahoma. The possible exceptions are the chert boulders with Middle Devonian fossils, the pieces of dark shale, many of them with characteristic cephalopods and bivalves of the Caney fauna of literature, and the subcrystalline limestone pieces which contain fossils regarded as of early Pennsylvanian age. The first and last and perhaps all three of these kinds may have come in part or wholly from just beyond the fault-bounded north side of the Ouachita area where formations similar in lithologic characters and faunal contents occur in place.

That at least the pre-Devonian erratics were transported from beds occurring, as regards most of them, only to the west of the Ouachita sedimentary basin is conclusively established by the known distribution of many of the species and genera of fossils contained in them. As examples tending to prove this statement I would mention, first, the presence of such Upper Canadian species as *Maclurites ? affinis,* which occurs to the west in the Arbuckle limestone on the flanks of the Arbuckle and Wichita Mountains but is unknown to the east until we find it in the Newala limestone of Alabama, where it is confined to the eastern belt of the southern third of the Appalachian Valley region. To the northeast this gastropod and other members of its fauna have not been found in either Tennessee or Virginia, but they occur again in southeastern Pennsylvania, the Champlain Valley, and finally in Newfoundland.

The case is similar with respect to the species of *Cryptolithus* which occur in certain of the Ouachita Caney boulders and are at home in the Viola limestone but unknown to the east. The Trenton and Cincinnatian deposits about Cincinnati, in Pennsylvania, and New York contain species of this genus, but all of them are different from those found in Oklahoma. Again, the known distribution of many of the Lower Simpson and Bromide fossils is no less corroborative of the same conclusion. Some of the Lower Simpson species are known outside of southern Oklahoma only in the Upper Pogonip of Nevada and in corresponding deposits in Newfoundland.

The facts with respect to the fossils of Black River and early Trenton ages differ in that many of those found in the Ouachita Caney boulders and in place in beds lying on the southern and northeastern flanks of the Arbuckle Uplift between the typical Bromide and the base of the typical Viola occur elsewhere in America only to the north in Iowa, Minnesota, and Wisconsin.

Finally there is the small fauna of the oolitic basal member of the early Silurian Chimneyhill formation which is best developed on the northeast side of the Arbuckle region. It has not been observed in Arkansas nor in Missouri except near the Mississippi north of St. Louis where it is represented in the lithologically similar Noix oolite. Members of the same fauna occur in northeastern Illinois, and at least one of the species of the oolitic boulders is as yet unknown elsewhere except in the Island of Anticosti.

Obviously, then, the pre-Devonian boulders in the Ouachita Caney could have been floated there only from the west and evidently mainly from weathered exposures of the concerned formation on the northeast side of the Arbuckle Uplift.

Further evidence supporting this conclusion is afforded by the observations of Wallis[1] in the Atoka quadrangle and subsequently those by Morgan[2] in the Stonewall quadrangle. Both mention the local presence of similar erratics in shales and limestones properly referred by them to the Wapanucka formation. Wallis describes a limestone "breccia" lying near the top of the Wapanucka as composed of angular fragments of "limestone similar in appearance to the Arbuckle limestone" and fragments of oolite that "may be of Chimneyhill age" (early Silurian). Morgan, on the other hand, found numerous pebbles of slate with others of chert and limestone relatively rare, all of which he concludes "might have been derived from the Caney and Woodford formations." In my opinion either and probably both of these occurrences of pebbles—evidently derived from formations exposed nearby on the northeast side of the Arbuckle Uplift—are of essentially the same age and derivation as those found in the Ouachita Caney shale.

The means of transporting these boulders and the fact that two chronologically quite different shales have been confused under the term Caney will be discussed under following separate headings.

LOCALITIES WHERE FOSSILIFEROUS BOULDERS AND PEBBLES WERE FOUND

Fossiliferous boulders and pebbles were found in the lower part of the Ouachita Caney shale at the following localities:

McALESTER QUADRANGLE (Also locality 41)

1. N. of center of line between secs. 28, 29, T. 2 N., R. 15 E. Taff and Girty, November 24, 1898.
2. Head of branch on NW. side of Caney basin. Probably center of sec. 33, T. 1 N., R. 16 E. Taff and Ulrich, 1904.
3. NE. ¼ sec. 4, T. 1 S., R. 16 E.
4. SE. ¼ sec. 4, T. 1 S., R. 16 E. Branch Caney Creek. Taff and Ulrich, August 19, 1904.

---

1. Wallis, B. F., Oklahoma Geol. Survey Bull. 23, pp. 69-72, 1915.
2. Morgan, Geo. D., Geology of the Stonewall quadrangle: Bureau of Geology, Bull. 2, 1924.

ANTLERS QUADRANGLE

5. S. ½ sec. 18, T. 1 S., R. 14 E. Taff and Ulrich.

6. SW. ¼ sec. 18, T. 1 S., R. 14 E. Taff and Ulrich.

7. NE. ¼ sec. 20, T. 3 S., R. 14 E. C. D. Smith, September 7, 1904: Taff and Ulrich, 1904.

8. Little NE. of center of sec. 16, T. 3 S., R. 14 E. On small branch of Caney Creek. Ulrich, 1904.

9. On branch in SW. ¼ sec. 32, T. 2 S., R. 14 E. Taff, September 6, 1904.

10. Near NE. ¼ of SW. ½ sec. 32, T. 2 S., R. 14 E. In gulch leading to McGee Creek. Taff, September 20, 1904.

11. Near NE. corner of SW. ¼ sec. 32, T. 2 S., R. 14 E. In gulch leading to McGee Creek. Taff, September 2, 1904.

12. NW. ¼ sec. 19, T. 1 S., R. 14 E. Ulrich, Taff, Mesler, 1904.

13. SW. ¼ sec. 2, T. 2 S., R. 13 E. Patapo Creek. Taff and Shaler, September 2, 1904.

14. Boulders of chert from branch of Caney Creek. SW. ¼ sec. 3, T. 1 S., R. 16 E. Taff and Ulrich, August 16, 1904.

15. Center E. side SW. ¼ sec. 10, T. 1 S., R. 16 E. Taff and Girty, 1898.

16. N. center of S. ¼ sec. 23, T. 2 S., R. 14 E. NE. of Tutt's ranch-house in branch of creek. Shaler, September 8, 1904.

WINDING STAIR QUADRANGLE (See also number 42)

17. NW. ¼ sec. 2, T. 1 S., R. 16 E. Another branch of Caney Creek. Taff and Ulrich, August 19, 1904.

18. SW. ¼ sec. 22, T. 4 N., R. 22 E., in gulch running N. C. D. Smith, July 20, 1905.

19. SE. ¼ sec. 36, T. 4 N., R. 22 E. Taff, September 1, 1908.

20. SE. ¼ sec. 21, T. 4 N., R. 22 E. Taff, July 20, 1905.

21. Base of N. face of mountain just N. of section line in SE. ¼ of SE. ¼ sec. 22, T. 4 N., R. 22 E. Taff, July 21, 1905.

22. Sec. 25, T. 3 N., R. 24 E. 150 paces N. of ¼ cor. on south side in bed of gully in black shale. C. D. Smith, July 17, 1905.

23. ¼ mi. SW. of Stapp, N. side of ridge near center of sec. 12, T. 3 N., R. 25 E. C. D. Smith, July 15, 1905.

24. ¼ to ½ mi. SW. of Stapp. Taff, July 14, 1905.

25. R. R. cut SW. ¼ sec. 7, T. 3 N., R. 26 E. Taff and Smith, July 15, 1905.

26. Center of sec. 14, T. 3 N., R. 23 E.

27. On section line between secs. 7 and 8, T. 4 N., R. 23 E., 350 paces south of NE. cor. of 7. C. D. Smith, 1905.

28. Winding Stair quadrangle. Caney shale boulders, sec. 21, T. 4 N., R. 23 E. C. D. Smith.

29. Winding Stair quadrangle, Oklahoma. From limestone boulders N. side of sec. 8, T. 3 N., R. 26 E., 1½ mi. E. of Thomasville, now Stapp, Okla. George I. Adams, 1899.

TUSKAHOMA QUADRANGLE (Except number 41)

30. Winding Stair Mt., Frisco R. R. cut near Bengal. Taff and Ulrich.

31. Near Compton. Junction of secs. 17, 18, 19, and 20. Taff, Ulrich, Thom, and others.

32. Cut ½ mi. N. of Compton on Frisco R. R. across Winding Stair Mt. Taff, Ulrich, Shaler, and Smith, July 8, 1905.

33. 250 paces N. of SW. cor. of sec. 23, T. 4 N., R. 21 E. C. D. Smith, July 21, 1905.

34. N. slope of ridge NW. ¼ sec. 28, T. 4 N., R. 22 E. Taff.

35. Winding Stair Mt. E. ½ sec. 32, T. 4 N., R. 20 E. Ulrich and Taff, August 8, 1904; Shaler and Smith, August 6, 1904.

36. NE. ¼ sec. 33 to NW. cor. sec. 34, T. 4 N., R. 20 E. Shaler and Smith, August 6, 1904.

37. Sec. 34, R. 20 E., T. 4 N. Ulrich, 1904.

38. NW. ¼ sec. 27, T. 4 N., R. 22 E. Taff and Ulrich, July 21, 1905.

39. Secs. 17 and 18, T. 4 N., R. 21 E.; along gulch running into Peachland Creek 1,000 feet south of NE. cor. sec. 18. C. D. Smith, July 6, 1905.

40. On township line at W. center of sec. 18, T. 3 N., R. 19 E. J. A. Taff, September 27, 1899.

41. NW. cor. sec. 2, T. 2 N., R. 16 E. McAlester quadrangle. G. H. Girty, November 26, 1898.

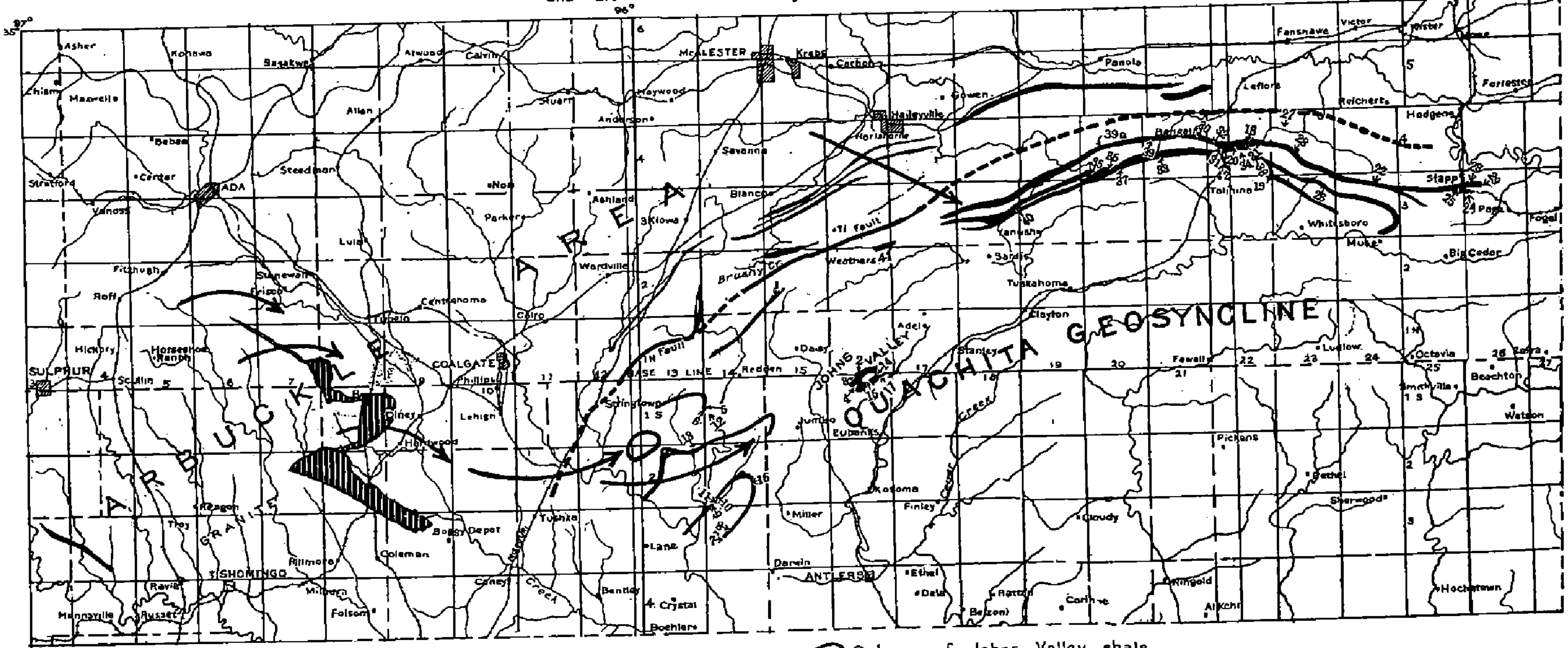
42. Winding Stair quadrangle, Oklahoma, Caney shale boulders. Fossils from limestone boulder in black shale north slope of ridge NW. ¼ sec. 28, T. 4 N., R. 22 E. J. A. Taff.

LISTS OF FOSSILS FOUND IN THE BOULDERS

The following lists give the generic and so far as now advisable also the specific alliances of the fossils found in the Ouachita Caney boulders. The species are arranged biologically and grouped according to their association in the boulders and their known or inferred positions in the stratigraphic column. The nomenclature and vertical sequence and correlation of the concerned Paleozoic formations is as given in the correlation table.

Though the fossiliferous boulder material in hand is not completely worked out the following lists comprise an aggregate total of about 189 species. Distributed according to periods, 3 of these are referred to the Canadian, 105 to the Ordovician, 26 to the Silurian, 15 to the Devonian, 23 to the Mississippian Caney shale, and 20 to the early Pennsylvanian. By far the majority of the generically or specifically determined fossils occur in limestones, others are preserved in cherts, and a few in shale or sandstone. Many of the limestone boulders observed in the Caney seem to be barren of recognizable organic remains. Indeed the boulders falling into the last category greatly predominate at most places, but matched by lithic characters alone many of them may be referred to their particular stratigraphic positions and sources with

SKETCH MAP OF ADJACENT PARTS OF ARBUCKLE AND OUACHITA AREAS OF OKLAHOMA.
Showing numbered localities at which fossiliferous boulders have been found, source of boulders and distribution of Caney and Johns Valley shales.



Approximate location of supposed overthrust fault separating formations of the two areas.
Principal outcrops of Mississippian Caney shale.
Outcrops of Johns Valley shale.
Arrows indicating source of boulders and direction of transporting currents.

Figure 1.

reasonable confidence. This is true especially of the early Silurian oolites which, whether silicified or in their original limy condition, are unmistakably characterized and traceable to outcrops of the lower member of the Chimneyhill formation to the west on the flanks of the Arbuckle Uplift.

As regards the preservation of the fossils, they are in every case as good as one finds them in the undisturbed beds from which they were long ago transported to their present positions in the lower part of the shale.

CANADIAN (ARBUCKLE LIMESTONE) FOSSILS

A few pebbles with gastropods of Canadian age were found at locality 16, a coiled cephalopod at locality 4, and a characteristic trilobite at locality 20.

Maclurea affinis Billings, a widely distributed Upper Canadian gastropod originally described from specimens found in Newfoundland and since found at many places in the Appalachian Valley, particularly in the Beekmantown of Pennsylvania and the Newala limestone of Alabama. In Oklahoma it occurs in the upper third of the Arbuckle limestone.

Tarphyceras cf. seelyi. A fairly good specimen of this characteristic Upper Canadian genus of coiled cephalopods was found by Mr. Sidney Powers at my locality 4, in sec. 4, T. 1 S., R. 16 E., Johns Valley, Oklahoma. The species is the same or at least very closely allied to T. seelyi which was described from the Fort Cassin, Vt., member of the Beekmantown. The matrix of the specimen is a fine grained, in part oolitic, light colored limestone with blotches of yellow impure material. Precisely similar rock has been observed in the Arbuckle limestone, but so far this cephalopod has not been found in place.

Goniotelus[3] sp., very much like an undescribed species occurring in the Fort Cassin limestone in Vermont. The same trilobite or a close relative occurs in the upper fifth of the Arbuckle limestone.

ORDOVICIAN

Bromide (Upper Chazyan and provisionally including Black River) and Viola (? late Trenton and Cincinnatian) fossils

At least eight or ten distinct faunules of Ordovician age are suggested by comparison of the numerous lots. For present purposes, however, it seems inadvisable to attempt discrimination of the minor faunal zones. Accordingly, in listing the fauna as a whole, I have restricted my desire to separate them to the addition of either the letter B or T—signifying Bromide or Black River and Trenton-Cincinnatian respectively—to the names of species whose stratigraphic range is approximately established. Further desirable information is given by numbers following the names of the fossils which correspond to those in the preceding list of localities at which fossiliferous boulders have been found. Most of the species not thus referred to either the Bromide-Black River or the Trenton-Cincinnatian suggest or more positively indicate an earlier Chazyan stage of the Simpson.

3. **Goniurus** Raymond having been preoccupied I propose to substitute the name **Goniotelus.**

List of Chazyan, Black River, and Trenton fossils found in Ouachita Caney boulders

Dystactospongia cf. rudis B. 18.
Dystactospongia cf. minor B. 5, 30.
Receptaculites cf. mammilaris B. 18.
Ischadites sp. B. 2.
Nidulites cf. pyriformis B. 4, 10, 12, 16, 27, 30, 32.
Nidulites sp. (small celled) B. 9, 23, 24.
Pasceolus cf. globosus B-T. 4, 31, 32, 37.
Stylarea parva B. 27, 31.
Fragments of cystids and crinoids at many localities.
Climacograptus sp. 6, 10, 35.
Climacograptus sp. T. 2, 15, 33.
Crepipora sp. 27.
Prasopora contigua B. 26, 35.
Rhinidictya sp. 31.
Pachydictya occidentalis B. 31.
Lingula cf. riciniformis B-T. 32.
Lingula rectilateralis T. 15, 20.
Lingula sp. 6, 21, 31.
Lingulops sp. T. or higher, 5, 6.
Paterula n. sp. B-T. 6, 10, 15, 21, 22, 35.
Leptobolus cf. walcotti loc.?
Leptobolus cf. insignis T. 20.
Conotreta sp. B. 6, 22.
Rafinesquina cf. minnesotensis B. 6.
Rafinesquina cf. alternata T. 1, 8, 29.
Rafinesquina n. sp. B. 10, 21, 22, 26, 33.
Rafinesquina ulrichi T. 10, 31, 33, 35.
Strophomena incurvata B. 13, 35.
Strophomena n. sp. B. 11, 31, 35.
Strophomena n. sp. (small) B. 6, 7, 10.
Clitambonites sp. 9.
Orthis aff. tricenaria B. 9, 23, 24, 31, 35.
Pianodema subaequata var. B. 10, 21 22.
Dalmanella cf. rogata B. 6, 7, 10, 21, 22, 26, 37.
Heterorthis clytie var. T. 1, 22, 25.
Hebertella cf. bellarugosa B. 31.
Dinorthis pectinella B-T. 10, 22, 25, 26.
Valcourea n. sp. B. 1, 7, 9, 10, 23, 24, 35.
Plectambonites aspera (Ruedemann not James) T. 1, 2, 9, 17, 19. 22, 25, 34, 35.
Plectambonites n. sp. B. 5, 10, 37.
Plectambonites n. sp. T. 1, 2, 6, 8, 10, 13, 18, 22, 26, 33, 35, 36.
Plectambonites small sp. 35, 41.
Christiania cf. trentonensis T. 35.
Christiania n. sp. (lamellose) B. 7, 10, 35.
Cliftonia occidentalis B. 5, 10, 35.
Camarella aff. longirostris B. 5, 41
Camarella n. sp. 15, 32.
Hallina ? n. sp. B. 21.
Ctenodonta sp. B. 16.
Ctenodonta sp. T. 15.
Cyrtodonta near affinis and parva. B. 9.
Eurymya cf. subplana B. 3.
Tetranota bidorsata? B-T. 6, **23, 24.**
Bellerophon sp. T. 29.
Raphistoma sp. undet. B. 22.
Raphistomina n. sp. aff. denticulata. 6, 27.
Lophospira spironema B. 6, 9.
Lophospira bicincta B. 26.
Maclurites aff. bigsbyi B. 6, 7, 9, 22, 23, 35.
Holopea sp. B. 4, 15.
Cameroceras sp. B. 6, 9.
Cyrtoceras? sp. 32.
Actinoceras sp. 37.
Lonchodomus sp. B. 9.
Cryptolithus n. sp. T. 3, 6, 15, 21, 31, 41.
Cryptolithus n. sp. No. 2 T. 3, 6, 15, 32, 41.
Harpina aff. H. rutrellum B 27.
Illaenus cf. americanus B. 9, 24, 27, 35.
Isotelus sp. undet. T. 1, 14, 35.
Homotelus sp. B. 22, 32, 35.
Homotelus sp. T. 35.
Remopleurides cf. striatulus B. 6, 35.
Robergia sp. 39.
Proetus cf. concinnus T. 15.
Calymene sp. T. 3.
Pterygometopus aff. callicephalus B. 1, 6, 11, 15.
Pterygometopus sp. T. 6, 35.
Leperditia cf. fabulites B. 7, 21.
Aparchites sp. B. 21.
Aparchites sp. B. 6.
Schmidtella sp. undet. B. 21.
Primitia mammata B. 35.
Eridoconcha n. sp. 6.
Kloedenia? n. sp. B. 13.
Eurychilina ventrosa B-T. 21, 35.
Eurychilina cf. reticulata B-T. 35.
Eurychilina cf. dianthus B. 21, 35.
Eurychilina cf. aequalis and striatomarginata B. 35.
Bythocypris granti? B. **5, 10, 35.**
Bythocypris sp. B. 6, 9, 24, 32.

Regarding many of the species of the above list that are marked as new species or as comparable to published species it is to be noted that the same or closely related forms are known also in presumably contemporaneous faunas in the eastern belts of the Appalachian Valley. These occur particuarly in the Chambersburg limestone and basal Martinsburg shale of Pennsylvania and northern Virginia, in the formations of the Blount group in Tennessee, and in the Little Oak limestone of Alabama. Furthermore, most of the cited species are known from rocks in place in the Arbuckle Uplift to the west in central Oklahoma. In the latter region they occur in the upper part of the series of beds referred to by Taff[4] to the Simpson formation—for which the designation Bromide formation has since been proposed by me[5]—and in overlying beds that Taff usually added to the base of his Viola limestone.

In view of the fact that characteristic Arbuckle limestone fossils have been found in these Ouachita Caney shale boulders it seems strange that none of the boulders contributed positively identifiable representatives of the Lower Simpson faunules. Another notable fact is that the above and next following list include at least 20 species that have not been found in place in the Ordovician formations to the west. Evidently the northeast side of the Arbuckle region contains locally developed deposits that we did not search for fossils. Among these unplaced species is the *Pasceolus,* which is one of the most striking and commonest of the boulder faunas.

Cincinnatian (probably upper beds of Viola)

A block of creamy white porous chert containing many small fossils was collected at locality 14. The following genera and species were identified:

Hemiarges n. sp.
Calymene? n. sp.
Head of a small, undetermined and probably new genus of trilobites.
Cyclora cf. minuta.
Conularia? sp.
Eurychilina sp.
Ceratopsis cf. robusta
Bythocypris sp.
Macrocypris? sp.
Aparchites sp.
Rafinesquina cf. ulrichi
Paterula? sp.
Dalmanella aff. multisecta
Dalmanella sp.
Linstromia sp.

I cannot match this fauna precisely with any known to me. However, its general aspect indicates late Ordovician rather than Mohawkian; and it may indeed belong to some very early Silurian (Richmond) age. The last is suggested by comparison with fossils collected in Iowa and southern Minnesota out of the Clermont shale and Wykoff limestone of the Richmond group. The boulder probably was transported from some bed lying high in the Viola limestone or in the Sylvan shale in the Arbuckle region.

4. Taff, J. A., Preliminary report on the geology of the Arbuckle and Wichita mountains, in Indian Territory and Oklahoma: U. S. Geol. Survey Prof. Paper No. 31, pp. 23-26, 1904.

5. Ulrich, E. O., Revision of the Paleozoic systems, pl. 27, 1911.

FOSSILS OF SILURIAN AGE

Early Richmond limestone boulders

Locality 11 afforded a single small pebble of fine-grained yellowish gray slightly argillaceous limestone with a brachiopod shell that agrees very well with *Plectorthis* (*Austinella*) *whitfieldi*, a characteristic species of the Wykoff limestone in southern Minnesota.

Several specimens of a related species, *Plectorthis* (*Austinella*) *kankakensis*, were found in the weathered surface of a boulder of bluish crystalline limestone at locality 14. The rock suggests the widely distributed Fernvale limestone of which, moreover, the mentioned shell is highly characteristic. The Fernvale with this fossil is commonly present at the top of the Viola on the flanks of the Arbuckle Uplift. The formation is found also to the east in northern Arkansas but seems to lack the mentioned shell in that area.

A single specimen that agrees very well with *Maclurina cuneata* (Whitfield) was found at locality 35. The matrix of the shell is a crystalline limestone reminding most of the Fernvale formation, but so far this gastropod has not been found in place to the south of Iowa and Wisconsin. In those states it occurs in the Stewartville dolomite, which usually lies next above the Galena.

Sylvan shale boulder?

At locality 32 we collected a weathered fine-grained ferruginous and originally probably calcareous piece of sandstone with abundant valves of *Leperditia caecigena* on the bedding planes. This probably came out of the Sylvan shale. This ostracod was found originally in a bed near the top of the Richmond in southern Indiana. Since then it has been observed in many widely separated localities as far northwest as the Big Horn limestone in Wyoming.

Upper Medinan (Alexandrian) boulders

Fossiliferous boulders from a formation of Alexandrian age were found at localities 4 and 35. Those from the first of these places were procured mainly as silicified pseudomorphs from the weathered surface of a ledge-like mass, 5 feet by 15 feet, of sparingly oolitic, light gray dense-textured limestone. Those from the second locality occurred in similar but highly oolitic limestone. Typical oolite boulders, in both their original calcareous condition and silicified, were not uncommon at these and other localities, but with the exceptions described they showed no external evidence of fossils.

Fossils from Boulders at Localities 4 and 35

Locality 4.

Lindstromia sp.
Zaphrentis sp.
Coral suggesting Romingeria but probably of another genus
Crinoidal fragments in abundance
Triplecia (? Cliftonia) n. sp.
Camarotoechia cf. neglecta
Rhynchotreta cf. lepida
Ostracoda of two or three bythociprid genera

Locality 35.

Zaphrentis cf. ambigua
Romingeria-like coral
Bryozoan suggesting Hemiphragma sp.
Schuchertella? small species
Rhipidomella sp. aff. hybrida
Camarotoechia fringilla
Ostracoda of various simple types like Bythocypris

These fossils, also the lithic character of the boulders from which they were taken, are clearly indicative of the oolitic lower member of Reeds' Chimneyhill formation[6] which constitutes the lowest of four formational units into which Reeds divided Taff's more inclusive Hunton limestone.

Considerable interest attaches to the fact that one of the species—*Camarotoechia fringella*—found in the highly oolitic boulder is known elsewhere only in the lower part of the Gun River formation of the Island of Anticosti. Though the age of the upper part of the Gun River has been definitely proved to be Lower Clinton[7] the presence of the mentioned shell in this Caney boulder suggests that the lower part of the Gun River formation includes deposits of Upper Medinan age.

The Romingeria-like coral seems the same as one occurring with similar shells in a loose mass of highly fossiliferous fine-grained limestone found nearly forty years ago in Will County, Illinois. This rock was never traced to its bed but probably belongs in or near the zone of the Channahon limestone which also is referred to the Alexandrian group of the Medinan series.

FOSSILS OF DEVONIAN AGE

Boulders containing Devonian fossils and indicating practically the same stratigraphic horizon were collected at localities 17 and 37, in the McAlester and Tuskahoma quadrangles, respectively. In both cases the boulders were of chert, the one from locality 17 (Johns Valley) being about 1 foot square and 6 inches thick. Most of the fossils were gotten out of it and comprised all of the species given in the following list:

Lingula cf. paliformis
Phosphatic shell, about the size and otherwise similar to the Ordovician genus Paterula. Probably n. gen. and sp.
Chonetes hudsonicus camdenensis
Chonetes sp.
Anoplia nucleolata
Ambocoelia umbonata
Anoplotheca cf. camilla
Anoplotheca cf. acutiplicata
Camarotoechia cf. altiplicata
Ostracoda of many undescribed species belonging to the genera Craterellina, Octonaria, Kirkbya, and Bythocypris and undetermined genera of Beyrichidae.

This fauna, also the cherty rock in which it is found, is strongly indicative of the Camden chert of Tennessee. The bed from which the boulders were derived almost certainly represents the mentioned

6. Reeds, Chester A., The Hunton formation of Oklahoma: Am. Jour. Sci., vol. 32, p. 258, 1911.

7. Ulrich, E. O., and Bassler, R. S., Maryland Geol. Survey, Silurian volume, pp. 368-372, 1923.

Tennessee formation. Formerly the Camden was supposed to be of Oriskany age, but as shown by Dunbar[8] it is more nearly of the age of the Onondaga.

In seeking the derivation of these early Middle Devonian erratics it is highly important to note that this same fauna occurs in the cherty beds on Brushy Creek (center west side sec. 5, T. 2 N., R. 15 E.) referred by Taff to the top of his "Hunton" formation. This locality is now only about 12 miles north-northwest of the place where the Caney boulder with most of these Camden fossils was found.

MISSISSIPPIAN (MAINLY RESTRICTED TYPICAL CANEY) FOSSILS

Loose and usually small and but slightly water-worn pieces of bluish gray calcareous shale and calcareous nodules are scattered over the surface of the darker Ouachita Caney shale at many of the outcrops searched for fossiliferous boulders. Some of these pieces contain fossils, and occasionally the larger of these—particularly the silicified fragments of broken shells of *Actinoceras vaughanianum*—occur entirely free of their original matrix. At first these fossils were regarded as remains of the life of the sea in which the shale was deposited; and as the species were recognized as the same as those found in the Caney shale of the Arbuckle region it followed that the two shales were unquestionably assigned to the same age. However, when I came to study the fossils of the associated limestone boulders and found among them a number that contained unmistakable Morrow species, the prevailing view of the equivalence of the two shales had to be abandoned. The Mississippian age of the Caney fauna being conceded and the early Pennsylvanian age of the Morrow stage, which succeeded the time of the Caney fauna and includes the limestone and shale deposits in Oklahoma referred to the Wapanucka formation, being now generally accepted the absolute distinctness of the two "Caney" shales is established beyond dispute.

However, this conclusion raised the question how did the fossil remains of the Arbuckle Caney fauna get into the Ouachita Caney shale? But after the extremely varied ages of the associated limestone and chert boulders had been established by their fossil contents this question practically answered itself and in the same manner as it accounted for the presence of the older remains. In other words, the Caney fossils, like those of Ordovician, Silurian, and Devonian ages, were made available by weathering to eroding and transporting agencies that finally released and dropped them into the bottom muds of the Ouachita Caney basin.

Doctor Girty, to whom all our Caney material was submitted for study and report, published excellent descriptions of this interesting fauna[9]. Of the 40 or more species and varieties described in this report

8. Dunbar, Carl O., Stratigraphy and correlation of the Devonian of western Tennessee: Bull. 21, Tenn. Geol. Survey, 1919.

9. Girty, G. H., The fauna of the Caney shale of Oklahoma: U. S. Geol. Survey Bull. 377, 1909.

as having been found in outcrops of the Mississippian Caney shale the following 21 forms are stated to have been collected also from exposures of the Ouachita Caney shale. Practically all of these remanie came from the same localities in the Antlers and Tuskahoma quadrangles at which the older fossils listed on preceding pages were found. Information as to this distribution of the Caney fossils is recorded in Girty's tabulated list (*op. cit.*, pp. 9 and 10) of species under his locality numbers 2075, 3948, 3983, 3984, 3986, 3987, and 3988 (Antlers quadrangle) and 2047, 2057, 3982, and 3985 (Tuskahoma quadrangle). So far as known the Ouachita Caney has no fauna of its own.

List of Caney fossils found in the Ouachita Caney shale.

Lingula albapinensis
Caneyella wapanuckensis
Caneyella nasuta
Levidentalium venustum
Macrocheilus? sp.
Orthoceras wapanuckensis
Orthoceras caneyanum
Orthoceras cribiliratum
Orthoceras indianense
Orthoceras sp.
Actinoceras vaughanianum
Bactrites smithianus
Gastrioceras caneyanum
Gastrioceras richardsonianum
Goniatites choctawensis
Goniatites newsomi
Goniatites 2 undet. sp.
Adelphoceras meslerianum
Eumorphoceras bisulcatum
Trizonoceras lepidum
Trizonoceras typicale

Sycamore fossils

Five or more of the total of 46 species and varieties assigned to the Caney fauna by Girty seem to me to have come from a lower Mississippian horizon, namely from the often sandy shale into which the underlying Sycamore limestone locally grades laterally, especially to the east of Washita River. On account of its lithologic character these shaly equivalents of the Sycamore were assigned to the Caney. The Sycamore species referred to—all of them brachiopods—are included by Girty in his list for locality 2077. Those of the species collected from this place and of whose Sycamore age I am reasonably confident are: *Lingula paracletus?*, *Lingulidiscina newberryi caneyana*, *L. newberryi ovata*, *Productella sp.* (*? P. hirsutiformis*), *Chonetes planumbonus choctawensis*, and *Liorhynchus sp.*

Reference to Girty's report will show that three of these supposed Sycamore species—the second, third, and fourth—were recognized by Girty also in the Ouachita Caney collections (localities 3983 and 3986, both in Johns Valley). They have, therefore, a definite connection with the main subject of the present paper.

EARLY PENNSYLVANIAN BOULDERS

Boulders of brownish weathering, originally probably grayish blue, slightly argillaceous and occasionally pebbly crinoidal limestone, containing about 20 species of the following genera, were collected at localities 24, 31, and 39: *Cystodictya, Rhombopora, Fenestella, Polypora, Lioclema?, Fistulipora, Composita, Nucula,* and *Pleurotomaria.*

Each of these genera is represented by one, two, or three species, and all are either the same or closely allied to species known to occur in the limestones of the Morrow group in northwestern Arkansas and the Wapanucka limestone which is typically developed along the northwestern edge of the Ouachita area in Oklahoma. It should be borne in mind, however, that these early Pottsville faunas are more or less modified recurrences of the Spergen fauna. Accordingly it is to be expected that the fauna in these youngest of the Caney boulders also resembles stages of evolution of the Spergen fauna found in the intermediate Chester formations in the Mississippi Valley. But the resemblance in the latter cases is clearly inferior in closeness to that observed in comparing the Ouachita Caney boulder fossils with Morrow fossils. Besides, no Chester limestone beds are known to occur in nearby areas at all likely to have contributed boulders to the Ouachita Caney shale in the places where these were found.

The importance of these Pennsylvanian erratics in determining the age of the containing shale and the actual distinctness of the latter from the Mississippian Caney shale of the Arbuckle region is too obvious to require emphasizing.

JOHNS VALLEY SHALE: PROPOSED NEW NAME FOR THE OUACHITA CANEY

The presence of early Pennsylvanian (Wapanucka) erratics in the lower part of the Ouachita Caney shale is, of course, the main part of the evidence that induces me to refer this shale to a position above the Wapanucka in the Pennsylvanian system. Their presence further establishes the previously suspected fact that the Caney fauna in the shale is to be accounted for in the same manner as the blocks of limestone and chert with Canadian, Ordovician, Silurian, and Devonian fossils that are commonly associated with the likewise transported Arbuckle Caney and Wapanucka debris.

The stratigraphic relations of the two hitherto confused black shales being thus demonstrated the question arises which of the two should continue to bear the name Caney shale? In ordinary cases the generally accepted rule of stratigraphic nomenclature according to which the name should be retained by the beds at the place from which the name was originally taken gives a reasonable and quite satisfactory basis for answering such questions.

The name Caney was given by Taff to both shales and was really taken from a small settlement, about 6 miles north of Eubanks, in the upland valley of the gently synclinal mountain that delimits the northwest side of Kiamichi River valley. This settlement is now called Johns Valley, but at the time (1898-1902) Taff and his associates were studying and mapping the formations in Oklahoma it was known locally as Caney. However, this name seems never to have been associated with this place on any published map. Moreover, the name had already been applied to a town still known as Caney on the Missouri, Kansas & Texas Railroad near the center of the Atoka guadrangle (see topographic sheet, edition of 1900). Here it is located on a wide outcrop of Trinity sand, some 50 miles southwest of the outcrop of the shale in Johns Valley. Evidently, then, this is not an ordinary case in which the rule of nomenclature mentioned above may be applied without serious doubt as to the justice of the proceeding. In fact if Mr. Gould had not inquired of and received a letter from Mr. Taff stating[10] that the even yet undescribed outcrop of black shale on Cane Creek in northwest Pushmataha County is the locality from which he took the name Caney one could not learn from published sources which place Taff had in mind as the type locality of the formation.

Another point to be borne in mind is that when Taff in 1901 used the name Caney shale for the first time in the Coalgate folio (No. 74) he described only the Mississippi black shale. The younger Ouachita black shale that only those who worked with him in the field knew he regarded as the same formation was never mentioned in any of his published papers proir to 1925. As only published data count in such cases the facts just mentioned should be sufficient by themselves to preclude or at least make inadvisable the further use of the term Caney for the Pennsylvanian shale.

But there are other reasons that not only in my opinion but in the minds of many other geologists—Mr. Taff among them—are even of greater weight than those discussed in preceding paragraphs. Foremost of these is the fact that whereas published information regarding the Ouachita Caney shale amounts to practically nothing, that pertaining to the lithological and faunal characteristics and the stratigraphic position of the Mississippi Caney shale is found in many well-known published works. Beginning with the descriptions by Taff in the publications of the U. S. Geological Survey, namely, the Coalgate, Atoka, and Tishomingo folios, Professional Paper No. 31 and Bulletin No. 377 by Girty, many descriptions of and more casual references to the Mississippian Caney shale have appeared in publications of the Oklahoma Geological Survey and other media of publication. All these would be rendered null and void and much confusion must result if the name Caney were to be restricted to black shale deposits strictly equivalent in age to that on Cane Creek in Pushmataha County.

As one of the two shales must be renamed and as all reasonable concessions should be made to avoid confusion so far as possible I feel compelled to adopt the obviously least confusing solution of the difficulty. Accordingly I propose the name Johns Valley shale for the Pennsylvanian black shale typically exposed in the center of the Tuskahoma syncline, particularly in the north half of T. 1 S., R. 16 E. Here the formation rests on the Jackfork sandstone and is overlain by sandy shales and sandstones referred to the Atoka formation.[10a] This exposure of the Johns Valley shale is further typically developed in that its lower part contains an abundance of large and smaller often fossiliferous

10. Taff J. A., as quoted by Gould, Chas. N., Index to the Stratigraphy of Oklahoma: Oklahoma Geol. Survey Bull., p. 23, 1925.

10a. The presence of deposits of Atoka age in Johns Valley has been questioned by recent investigators.

erratics of limestone and other types of sedimentary rock that originally were parts of older formations found in place beyond the northern and western limits of the Ouachita area. As yet the Johns Valley shale is not known to contain a fauna or flora of its own.

AGES OF THE JACKFORK AND STANLEY FORMATIONS

Much difference of opinion respecting the ages of the Jackfork and Stanley formations is found in literature pertaining to the rocks of the Ouachita area. The extensions of these formations into Arkansas were referred by Branner[11] to the Lower Pennsylvanian. Subsequently Taff[12] placed them into the upper part of the Ordovician, a view abandoned by him[13] after our study of the boulders in the overlying "Caney," or as I now propose to call it, the Johns Valley shale. Girty[14] in the same year refers them to the middle or lower Mississippian, being driven to this view by the mistaken belief that the Ouachita and Arbuckle Caney shales are equivalent formations. In 1911[15] I reassigned both formations to the base of the Pennsylvanian system. Since the last date the pendulum has swung between relatively narrow extremes the preponderance of views, as expressed chiefly by Miser in 1921 and 1926, Honess in 1923 and 1924, and Gould in 1925, favoring reference of both formations to the middle or upper Mississippian.

Reconsideration of the whole question in the past four or five years tends to confirm my previously entertained view respecting the age of the Jackfork. According to both the faunal and diastrophic evidence now available the Jackfork sandstone comports perfectly with my co ception of what the initial deposits of the Pennsylvanian system should be. The Stanley, on the other hand, accords in all respects better with what one should expect of the inferred closing conditions of the Mississippian, or rather my Tennesseean system. The Stanley agrees very well in position and lithologic character with the Parkwood formation of Alabama and Tennessee to which I now regard it as essentially equivalent. Neither of these two formations, namely the Stanley and the Parkwood, is strictly a marine deposit, and both doubtless represent the recessional and therefore mainly emergent closing stage of the Tennesseean. In most other American areas of exposed late Paleozoic rocks this closing stage is indicated only by an unconformable contact of Mississippian and Pennsylvanian formations and absence of the intervening depositional record that is largely included in the Stanley and Parkwood.

Compared with formations to the north of the Ouachita area in Oklahoma it seems certain the Stanley has no representative there. I doubt also that there is any in northern Arkansas. The Pitkin is the

11. Branner, J. C., Thickness of the Paleozoic sediments in Arkansas: Am. Jour. Sci., 4th ser., vol. 2, 1896.
12. Taff, J. A., U. S. Geol. Survey, Atoka folio (No. 79), 1902.
13. Taff, J. A., U. S. Geol. Survey Bull. 380, p. 289, 1909.
14. Girty, G. H., U. S. Geol. Survey Bull. 377, 1909.
15. Ulrich, E. O., Revision of the Paleozoic Systems: Geol. Soc. America Bull., vol. 22, pp. 477 and 528, pl. 29, 1911.

youngest of the Chester deposits in that area and in my opinion decidedly older than the Stanley. The Jackfork however, may be represented in part and possibly entirely by the profusely fossiliferous limestones and more or less highly calcareous shales generally referred to the Wapanucka formation. Considering the great thickness of the Jackfork it may be that its lower part includes older post-Mississippian deposits than any so far observed in either the Wapanucka of Oklahoma or in the Morrow group of northern Arkansas. Such a question might be answered only after a very thorough comparison of fossil faunas in which particularly the minor modifications of the species would be subjected to minute scrutiny. This has not yet been done even with the abundant and rather well preserved fossils of the several zones of the Morrow and the Wapanucka. It is impossible at present in the case of the Jackfork sandstone in which marine organic remains are rarely abundant. Even when a thin layer is found holding such remains in considerable quantity their preservation is too imperfect for satisfactory detailed investigation. So far as Jackfork marine fossils have come into my hands they are rather disappointing in that they permit no closer determination than that the species agree better with characteristic Morrow and Wapanucka forms than with those of any other known horizon. The Bryozoa and other fossils collected by me 20 years ago from the midst of the sandstone on Jackfork Mountain itself suggest only kinds known to occur in the limestones of the Morrow group. I am hoping for more definite criteria when the plant remains are finally determined.

RELATIONS OF THE WOODFORD, SYCAMORE, CANEY, AND WAPANUCKA FORMATIONS

With this opportunity before me I feel and submit to the need of saying that the Wapanucka should include the shaly lower beds with essentially the same early Pennsylvanian fauna that Morgan[16] describes in his report on the Stonewall quadrangle as the "Upper Caney." Doubtless one experienced in recognizing stratigraphic breaks between lithologically simulating formations would succeed in finding the contact between the Mississippian and Pennsylvanian deposits studied by him. On general principles I must differ also from his conclusions (1) that the Sycamore formation " together with the upper portion of the Woodford and the lower portion of the Caney is partially equivalent to the Moorefield shale, the Batesville sandstone, and the Fayetteville shale of Arkansas" (*op. cit.*, p. 50) and (2) "that the upper part of the Caney is of Pennsylvanian age and partially equivalent to the Morrow formation and that the lower part is late Mississippian, approximately equivalent to the Moorefield, Fayetteville, and Batesville formations of Arkansas" (*op. cit.*, p. 56).

The Woodford, beyond all question, falls within the early Kinderhookian epoch represented by the Chattanooga and Ohio shale in the

16. Morgan, Geo. D., Geology of the Stonewall quadrangle, Okla.: Bureau of Geology Bull. No. 2, p. 53, 1924.

Ohio and southern Appalachian valleys. The evidence in hand indicates that the black shales of this time, however varying in thickness, make an irregularly outlined but continuous sheet from the Arbuckle area to the Appalachian Valley. Where thinnest only the upper beds of the black shale series are present, the variations in thickness being thus shown to be due to overlap. This sheet is followed by other Kinderhook units, consisting usually of limestone and other kinds of rock than black shale. These superposed beds are exceedingly spotty and variable in areal distribution, and among them is the Sycamore limestone.

Proceeding with the Arbuckle section, I have seen nothing that could by any reasonable stretch of imagination be correlated with the Fernglen, Burlington, or Keokuk formations of the Osage series nor of the Warsaw which locally in the Ohio and Appalachian valleys makes a formation of considerable thickness. The Caney, as here restricted, rests on the Sycamore, a variable and but locally developed late Kinderhook formation. If the Caney correlates, as I believe, with the Moorefield shale of Arkansas, which must fall somewhere in the Meramecian and may correlate with a similar black shale that in southwestern Virginia lies between unquestionable representatives of the Warsaw and St. Louis limestones, then it must lie unconformably on the Sycamore with a stratigraphic hiatus between them corresponding in time value to the whole of the Osagian and the succeeding Warsaw. If, on the other hand, the Caney correlates either with the Batesville sandstone or the Fayetteville shale, both of which are of Chester age, then the hiatus between the Sycamore and the Caney is greatly increased in time value. The measure of the depositionally unrecorded interval in the last alternative can be adequately appreciated only after one has seen the enormous and continuously exposed thickness (about 2,300 feet) attained by the Lower Chester (Montesana) limestones in the Mississippian belts north of Bristol, Va.

Finally, there is the break between the shale with the Middle Mississippian Caney fauna and the "Upper Caney" with the early Pennsylvanian fauna. In this case too the hiatus must be very great since of the Oklahoma formations it represents all of the Stanley and, of those elsewhere, all of the middle and upper beds of the Chester group as developed in southwestern Virginia where they include much limestone and attain an aggregate thickness of fully 5,000 feet.

Simulating faunas in cases like these are explainable only on the basis of principles involved in the recurring invasions of a slowly modifying fauna of a particular sea, as in the demonstrated cases of the Spergen, the Catheys-Maysville-Richmond; the Stones River-Lowville, and the Chazyan-Blount faunas, in each of which the successive recurrences often are very difficult to distinguish.

Though the inferences readily drawn from these statements may seem to complicate the interpretation of Oklahoma's geological history it can not be denied that they add to its interest. That such paleogeographic changes occurred here is not to be viewed as extraordinary; nor should we object to change of conceptions with advancing knowledge, for precisely similar changes are being made and accepted wherever the stratigraphy and fossils are being subjected to intensive study. Crustal warping and oscillating seas are the order of the day in modern stratigraphy.

DEPOSITS IN THE OUACHITA BASIN CONTRASTED WITH THOSE IN THE ARBUCKLE UPLIFT

As conceived by me the now greatly deformed and northwardly thrusted Ouachita depositional basin, bounded at least in its western half by the distribution of the Johns Valley shale, the Jackfork sandstone, and Stanley shale and below these by its peculiar early Mississippian, Middle Devonian, Silurian, Ordovician, Canadian, and Cambrian deposits, was wholly separate from the pre-Pennsylvanian troughs and basin to the north and northwest. The present surface boundary between the deposits of the two basins I place more or less indefinitely in the valley north of the Winding Stair Mountain. (See map, p.---). Most probably it is marked by a great overthrust fault. Whether this fault agrees in any part of it with the Choctaw fault as drawn on recent maps or is wholly distinct and lies in the largely unworked area between the Choctaw and Winding Stair faults I am not prepared to say. However, I believe I may claim without fear of contradiction that the three narrow fenster-like areas of Caney shale and older formations near Wesley and along branches of Brushy Creek on either side of Ti lay originally to the north of the former topographic boundary of the Ouachita Basin.

In my opinion the Ouachita Mountains are comparable in genesis to the Alps of Europe and the Himalayas in Asia. Their relation to the Gulf of Mexico is the same as that of the Alps to the Mediterranean and that of the Himalayas to the Indian Ocean. In other words, the rocks of the Ouachitas were deposited in a subsiding basin that lay a hundred or more miles to the south of their present position. To the south of the original Ouachita basin lay an older foreland that, although included in, is not strictly the same as the "Llano" of Schuchert or "Llanoria" of Dumble, Powers, and more recently Miser.[18a] Subsequently—probably during early Mesozoic times—the deposits of the Ouachita basin were thrusted over its northern boundary into the middle and eastern parts of the geosyncline, in the western part of which the Arbuckle sequence of almost entirely different deposits was laid down. The eastern half of this geosyncline was at times separated from the western Arbuckle half by the north-south trending Spavinaw axis.

The overthrusting of the Ouachita basin deposits is believed to have been accomplished by compressive forces acting mainly from the region of the Gulf with minor abetting results occasioned by southward migration of the entire continent. This hypothesis agrees with the now generally accepted explanation of the origin and structure of the Alps.

18a. Miser. Hugh D., Llanoria, the Paleozoic land area in Louisiana and eastern Texas: Am. Jour. Sci., 5th ser., vol. 2, pp. 61-89, 1921.

The main difference between the two cases is that the major compression and elevation of the Ouachitas occurred much earlier. That the Ouachitas were ever as high as the Alps of today cannot, as yet, be said. However, they might have been, and certainly sufficient time has elapsed since the acme of their elevation to have reduced them to their present relatively humble altitudes. In whatever manner this question of former height may finally be answered our inquiry must start with the fact that the Ouachitas of today are merely the stumps of formerly much higher mountains.

PRE-PENNSYLVANIAN SECTION ON BRUSHY CREEK

In Miser's map of Oklahoma these probable fensters are represented as exposing Caney shale, which makes up the greater part of their several areas, and more limited outcrops of limestone marked with the symbol *DSOt* signifying Talihina chert. I know only the middle and largest of these areas, having gone across it where it is bisected by Brushy Creek. The only limestone seen here by me lies directly under the Woodford shale. It contains highly siliceous ledges and some with fossils that I regarded as clearly indicating the age of the Camden chert of Tennessee and the lower part of the Arkansas novaculite. I made this correlation in 1908, and so far as known no reason to modify it has developed since. The best assemblage of this early Middle Devonian fauna that I have found at an Oklahoma locality was contained in the boulder described on page 18. It seems a younger fauna than that of the Bois d'Arc limestone which directly underlies the Woodford shale in the Arbuckle area. If there are any older beds exposed in the Brushy Creek section I failed to note them.

The Brushy Creek section is further notable in that it shows a clearly broken contact between fossiliferous Caney shale on similar shale of the Woodford formation. The contact is marked by a greenish muddy layer, about six inches in thickness, filled with globular phosphatic concretions from less than an inch to two or three inches in diameter. At higher levels in the succeeding deposits the normal Caney fauna was collected from larger limestone lentils and layers of calcareous shale.

In central and eastern Tennessee the top of the Chattanoogan shale is generally marked by a greenish glauconitic bed with globular or subovate highly phosphatic concretions. The resemblance to the contact layer on Brushy Creek is striking, but I do not regard the two simulating occurrences as indicating contemporaneity of formation but rather as correlatable only in orgin. In Tennessee, also in northeast Arkansas, such a layer is present whether the succeeding deposit is of some later Kinderhook age or of some much younger Osagian formation. In the Brushy Creek occurrence the succeeding Caney shale evidently is a still younger formation. We may assume then that the origin of these phosphatic concretions is dependent primarily on exposure of the surface of the underlying shale to subaerial conditions.

Incidentally, and before I forget entirely to do so, it may be mentioned that some of these globular concretions were found with Ordovician limestone boulders and transported pieces of calcareous Caney shale at a number of the Ouachita boulder localities, among them the type of the Johns Valley shale. One of the concretions still incased in Johns Valley shale exhibited signs of surface weathering before transportation.

PALEOZOIC FORMATIONS ON FLANKS OF ARBUCKLE DOME

As shown in the correlation table on pages 30-1, marine deposition in the Arbuckle Uplift began with the Reagan sandstone, an Upper Cambrian formation with an abundant fauna that has its nearest relatives in central Texas and the far west. This sea doubtless invaded the Arbuckle area from the Pacific side of the continent. Over this comes the Royer marble, a previously unnamed Lower Ozarkian formation, about 500 feet thick, that was included by Taff in the basal part of his great Arbuckle limestone. The fauna found in this formation also invaded from the west of the Rocky Mountains but in this case by way of the Marathon Basin of west Texas. Beyond the latter area it is known from Nevada and to the north in western Alberta. As the same Lower Ozarkian fauna is found also in Greenland and in Quebec it probably originated in the Arctic realm. Neither Middle nor Upper Ozarkian deposits occur in Oklahoma. These, though best developed in the southern Appalachian Valley, are well represented in the Ozark Uplift but evidently pinched out southwestward before reaching present-day outcrops of early Paleozoic rocks in Oklahoma[17].

The remainder of Taff's Arbuckle limestone is assigned to the Canadian period. Although it comprises beds that are clearly determinable by their fossils as Lower, Middle, and Upper Canadian, it is yet a fact that the several faunas are more readily correlatable with Canadian faunas in west Texas, Nevada, Utah, Alberta, Greenland, and western Newfoundland than with those of the same epochs in the Ozarks of Missouri. However, although of the same epochs, it is more than doubtful that both the Arbuckle region and the Ozarks were often submerged simultaneously. On the contrary, experience in regions where the facts could and to a considerable extent have been worked out teaches that the submergence of the two areas is more likely to have been alternate in time than strictly contemporaneous.

In the succeeding cases of the Ordovician formations our inferences as drawn from faunal data are similar to the preceding. For instance, the Simpson formation of Taff comprises at least three faunas of exceedingly diverse origin and geographic distribution. The lower part has a Pacific fauna strictly comparable only with the Upper Pogonip limestone fauna of Nevada; (2) a succeeding Simpson zone (lower Bromide) contains an Atlantic fauna that is not found in out-

17. The Arbuckle section is described in greater detail in a paper devoted especially to it that is being prepared for early publication by the Oklahoma Geological Survey.

cropping Ordovician rocks in northern Arkansas and whose path of migration must now be covered by overthrusted sheets of Ouachita formations; and (3) the closing stage, provisionally added to the top of the Bromide division of the Simpson, that contains a good representative of the Decorah and Prosser faunas of Minnestoa which are regarded as having invaded from the far north. None of these faunas, nor any beds that might contain them, are found in southern Missouri or Arkansas.

If there are any deposits of the age of the Big Buffalo series—of which St. Peter sandstone is the best known and most widely distributed constitutent—in the Arbuckle section I failed to recognize them. Many years ago, before the fact of the general prevalence of surface oscillation and the consequent frequent changes in form and location of submerged epicontinental areas had been impressed on me as it is now and before I had learned very much about the closing stages of the Canadian period and those that introduced the ensuing Ordovician period, I thought it quite possible that the Big Buffalo series might be represented in the lower part of the Simpson. At present, however, that suggestion has lost all of its then plausible possibilities. As the evidence—faunal, lithologic, and diastrophic—stands today the position of the St. Peter and the alternating limestones and sandstones that constitute the Big Buffalo series in northern Arkansas must lie below and not above the unconformable base of the Simpson. However, the adequate discussion of this problem that I am prepared to write would be too lengthy for present purposes and is therefore deferred to the other paper already mentioned as being in course of preparation and in which a number of similar problems that have arisen in the present restudy of Oklahoma stratigraphy will be treated as fully as the importance of each may demand.

The Upper Bromide is succeeded unconformably by the typical Viola limestone. As indicated in the correlation chart, in which the Oklahoma formations are set opposite the particular units of the composite Appalachian and Mississippi Valley time scale to which they are thought to be most nearly related, the Viola is correlated wholly though somewhat indefinitely with Cincinnatian formations, hence is placed higher in the scale than in former efforts. Next above the top of the Viola, with clear evidence of a break between, comes the widely distributed early Richmond Fernvale limestone with which, according to my classification,[18] the Silurian (or Ontarian) system begins in central Tennessee, Missouri, Arkansas (Polk Bayou), Oklahoma, Texas, and elsewhere in the central and western United States. This is followed by the Sylvan shale, a younger Richmond formation that correlates very well with the similar shale of the Maquoketa of Iowa and the Cason shale of Arkansas.

Of succeeding Silurian deposits in the Arbuckle section we have first the Chimneyhill limestone, the lowest of the four formations into

18. Ulrich, E. O., Relative values of criteria used in drawing the Ordovician-Silurian boundary: Geol. Soc. America Bull., vol. 37, pp. 279-348, 1926; and preceding papers published between 1911 and 1925.

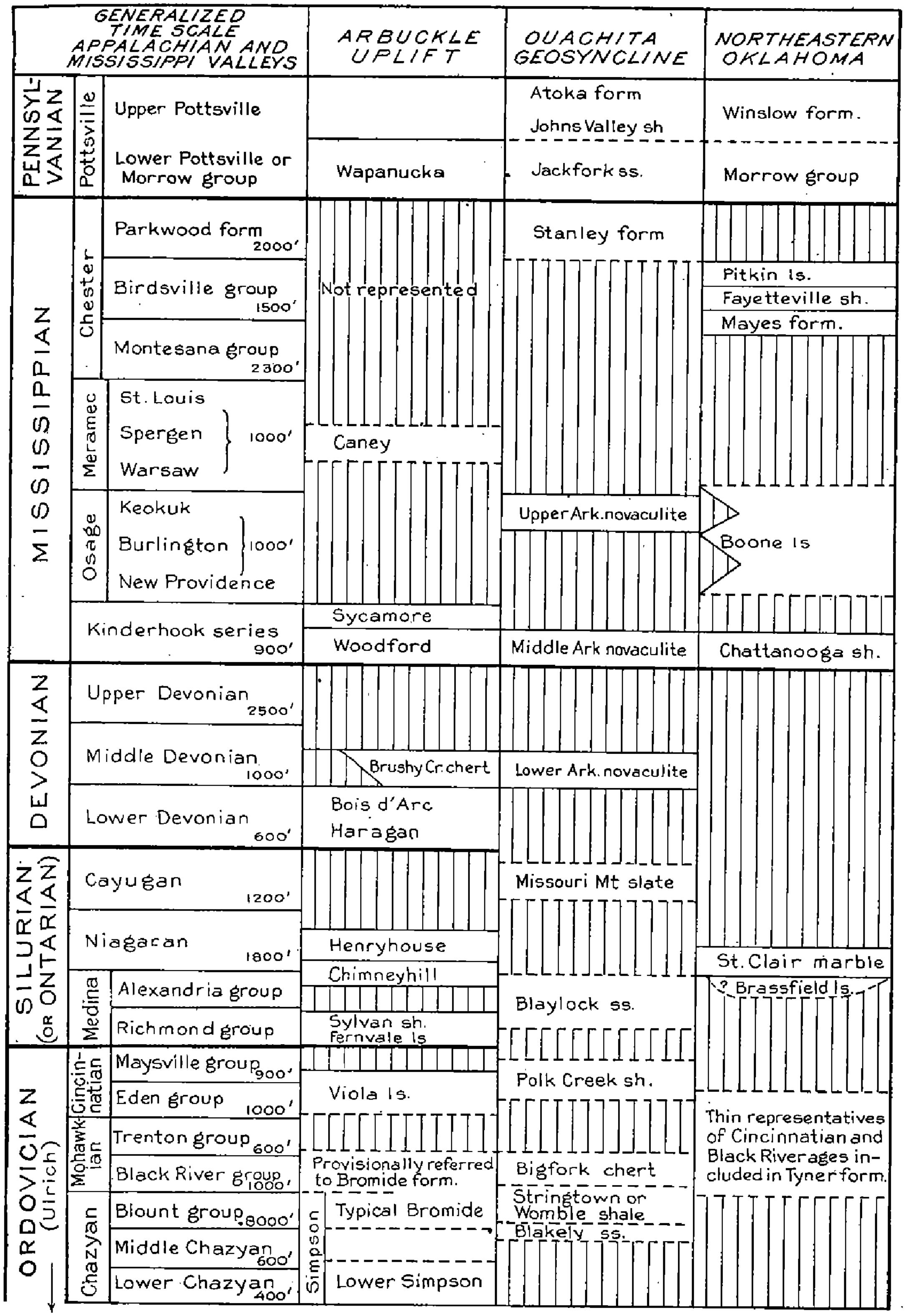

GENERALIZED TIME SCALE APPALACHIAN AND MISSISSIPPI VALLEYS
ARBUCKLE UPLIFT
OUACHITA GEOSYNCLINE
NORTHEASTERN OKLAHOMA
PENNSYL-VANIAN
Pottsville
Upper Pottsville
Lower Pottsville or Morrow group
Atoka form
Johns Valley sh
Winslow form.
Wapanucka
Jackfork ss.
Morrow group
MISSISSIPPIAN
Chester
Parkwood form 2000'
Birdsville group 1500'
Montesana group 2300'
Not represented
Stanley form
Pitkin ls.
Fayetteville sh.
Mayes form.
Meramec
St. Louis
Spergen
Warsaw
1000'
Caney
Osage
Keokuk
Burlington
New Providence
1000'
Upper Ark.novaculite
Boone ls
Kinderhook series 900'
Sycamore
Woodford
Middle Ark novaculite
Chattanooga sh.
DEVONIAN
Upper Devonian 2500'
Middle Devonian 1000'
Brushy Cr. chert
Lower Ark. novaculite
Lower Devonian 600'
Bois d'Arc
Haragan
SILURIAN (OR ONTARIAN)
Cayugan 1200'
Missouri Mt slate
Niagaran 1800'
Henryhouse
St. Clair marble
Medina
Alexandria group
Chimneyhill
? Brassfield ls.
Blaylock ss.
Richmond group
Sylvan sh.
Fernvale ls
ORDOVICIAN (Ulrich)
Cincin-natian
Maysville group 900'
Eden group 1000'
Viola ls.
Polk Creek sh.
Mohawk-ian
Trenton group 600'
Black River group 1000'
Provisionally referred to Bromide form.
Bigfork chert
Thin representatives of Cincinnatian and Black River ages included in Tyner form.
Chazyan
Blount group 8000'
Middle Chazyan 600'
Lower Chazyan 400'
Simpson
Typical Bromide
Lower Simpson
Stringtown or Womble shale
Blakely ss.

Figure 2.

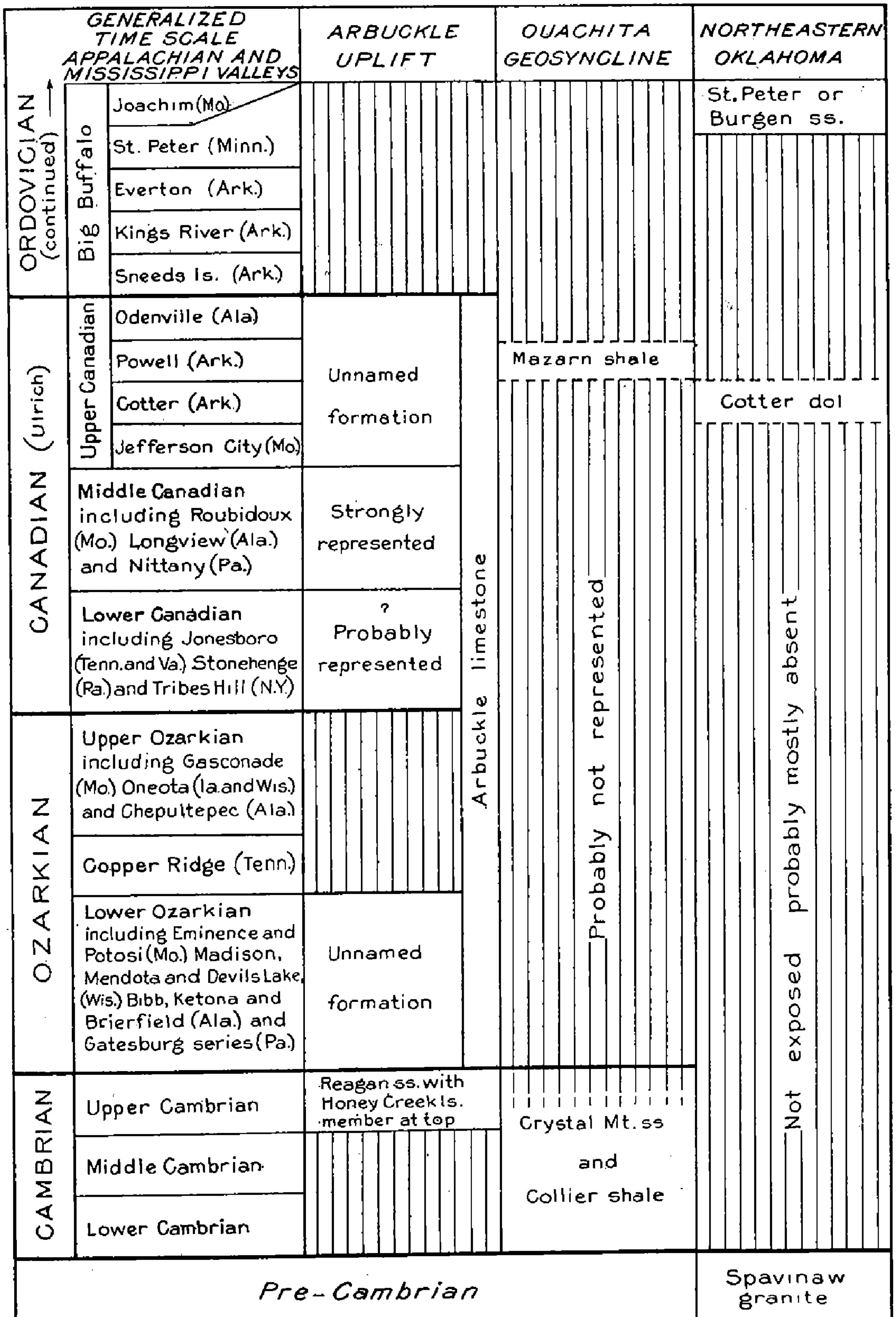

GENERALIZED TIME SCALE APPALACHIAN AND MISSISSIPPI VALLEYS
ARBUCKLE UPLIFT
OUACHITA GEOSYNCLINE
NORTHEASTERN OKLAHOMA
ORDOVICIAN (continued)
Big Buffalo
Joachim (Mo)
St. Peter (Minn.)
Everton (Ark.)
Kings River (Ark.)
Sneeds ls. (Ark.)
St. Peter or Burgen ss.
CANADIAN (Ulrich)
Upper Canadian
Odenville (Ala)
Powell (Ark.)
Cotter (Ark.)
Jefferson City (Mo)
Unnamed formation
Mazarn shale
Cotter dol
Middle Canadian including Roubidoux (Mo.) Longview (Ala.) and Nittany (Pa.)
Strongly represented
Lower Canadian including Jonesboro (Tenn. and Va.) Stonehenge (Pa.) and Tribes Hill (N.Y.)
? Probably represented
Arbuckle limestone
Probably not represented
Not exposed probably mostly absent
OZARKIAN
Upper Ozarkian including Gasconade (Mo.) Oneota (Ia. and Wis.) and Chepultepec (Ala.)
Copper Ridge (Tenn.)
Lower Ozarkian including Eminence and Potosi (Mo.) Madison, Mendota and Devils Lake (Wis.) Bibb, Ketona and Brierfield (Ala.) and Gatesburg series (Pa.)
Unnamed formation
CAMBRIAN
Upper Cambrian
Middle Cambrian
Lower Cambrian
Reagan ss. with Honey Creek ls. member at top
Crystal Mt. ss and Collier shale
Pre-Cambrian
Spavinaw granite

Figure 3.

which Reeds divided Taff's Hunton formation. But this lower division even yet comprises three readily distinguishable members that elsewhere are separated by beds not present in Oklahoma and which are assigned to two distinct groups. Only the two lower members, the "Oolitic" and the "Glauconitic," are properly referable to the Alexandrian group of the Medinan series, whereas the upper, "Pink-Crinoidal," member contains an excellent representation of the Clinton St. Clair limestone fauna of Arkansas. The overlying Henryhouse shale contains an Upper Niagaran fauna closely comparable in composition and derivation with the Brownsport formation of Tennessee. It has nothing whatever in common with any part of the Talihina chert and is a decidedly younger deposit than any bed now referred to the St. Clair limestone.

The next succeeding Haragan shale is, as recognized by Reeds and others, of Helderbergian and hence of Lower Devonian age. The overlying Bois d'Arc limestone evidently is of early Oriskany age. Both of these formations, like the preceding Henryhouse, are thought to have communicated directly with beds deposited in southeastern Missouri and western Tennessee. The Bois d'Arc is claimed by some to be represented in the Talihina chert and the lower part of the Arkansas novaculite. In my opinion, however, there is no valid ground for this correlation.

The Bois d'Arc is succeeded by the more or less cherty shales of the Woodford formation which I correlate with the widely distributed Ohio and Chattanooga shales and classify as earliest Mississippian. Black shales regarded as strictly contemporaneous occur in northeastern Oklahoma, Arkansas, Missouri, Iowa, southern Illinois, Indiana, Michigan, central Tennessee, and in the Appalachian Valley from Alabama to well into southwestern Virginia. In the last State they pinch out northwardly from a maximum thickness of 500 feet and rest with an intervening break on much thicker, often sandy, late Devonian shales that pinch out southwardly in northeast Tennessee. Over the Woodford is the Sycamore limestone which, as said on preceding pages, I regard as of later Kinderhook age. The Sycamore is followed by the Caney shale and this by the Wapanucka formation. Enough has been said about these formations to make further comments unnecessary.

PALEOZOIC FORMATIONS IN THE OUACHITA GEOSYNCLINE

Passing rapidly through these and beginning with the oldest we have the Collier shale and the Crystal Mountain sandstone. Neither of these formations contains fossils, but on other grounds which it seems scarcely worth while to give here I am persuaded to classify them as of Cambrian age. If so, then the succeeding Mazarn shale that has supplied conclusive fossil evidence of its Upper Canadian age must be separated from the Crystal Mountain sandstone by a stratigraphic break of great time value. Over the Mazarn comes the Blakely sandstone which I interpret as the clastic introductory stage of the overlying Upper Chazyan Womble shale. Abundant and excellently preserved graptolites have been collected from a number of subzones of this shale, and these prove beyond all question that the Womble represents the zone of the Athens shale of Tennessee and the Normanskill shale of eastern New York. According to the known vertical distribution of the graptolite zones in the northern and southern parts of the Appalachian Valley region a long interval of nondeposition must have intervened between the last of the Mazarn shales and the beginning of Blakely-Womble time. The time significance of this interval may be best appreciated by a glance at the correlation table.

The next deposit in the Ouachita is included in the Bigfork cherty limestone. Recognizable fossils are not very plentiful in this formation nor are they of well known species. However, enough of shells and graptolites have been collected to make it reasonably certain that this formation is of Mohawkian age. Between it and the underlying Womble shale there is therefore a stratigraphic hiatus that as measured by well exposed and fully determined sections in East Tennessee must amount to some 4,000 feet of limestone and calcareous shale. Next comes the Polk Creek shale from which I have collected many excellently preserved graptolites at localities in both Oklahoma (near Tuskahoma Council House) and Arkansas. Judging from these graptolites I correlate the zone with the Upper Hartfell of Britain and accordingly assign it to a position well up toward the top of the Ordovician. Again there must be a considerable break at its base, also at its top, because the next succeeding formation—the Blaylock sandstone—contains an undeniable British Silurian set of graptolites.

The Blaylock is succeeded by the Missouri Mountain slate. As the latter seems to be without fossils I am not at all certain as to its precise age. If it is younger than Cayugan, to which it is tentatively referred in the chart, then the hiatus beneath would be greater than is indicated by the chart. On the other hand, it may be nearer in age to the Blaylock, in which case the break would be less and the one above it correspondingly greater than shown.

The Arkansas novaculite includes three distinct zones: the lower as determined by scant yet fairly conclusive evidence correlates with the Brushy Creek cherty limestone mentioned on page 27 and the Camden chert of Tennessee, which places it as early Middle Devonian; the middle zone, which is characterized by platy cherts and black shale, has supplied an abundance of conodonts of Chattanoogan types which fix its age as Woodford and early Mississippian; and finally the upper member, which carries no fossils but is assigned on general principles to the time of the Boone chert. Each of these members, as correlated with formations elsewhere, is of necessity separated from preceding and succeeding members and formations by a break of considerable magnitude. Of these the one between the top of the novaculite and the base of the next overlying Stanley shale is doubtless much the greatest, since it represents a time interval of sufficient duration to lay down about 5,000 feet of mainly limestone beds in southwestern Virginia.

Now when the foregoing sequences of formations in the Arbuckle and Ouachita areas are critcally but fairly compared one is struck at once by the exceeding difference in character of deposits, in their faunas, and in their age relations. With the single exception of the Woodford no formation is common to the two adjacent areas, nor can any two be proved strictly of like age. With the mentioned exception it appears that when one of the areas was submerged the other always was elevated above sea level. These facts make accurate correlations between the two sequences exceedingly difficult and to a large extent uncertain as to preciseness. Similar difficulties were experienced in correlating formations in the Appalachian Valley, but after long and painstaking effort reasonably satisfactory results have been attained. That our work there has met with greater success than is likely to reward the efforts of workers in the Ouachita area is mainly due to the fact that the Appalachian Valley is favored by having many overlapping formations that time after time cleared up difficulties that at first seemed insuperable. In the case of the Ouachita formations much progress has been made, and more is possible. But this can not be accomplished by direct comparison with either the Arbuckle or the Ozark sections. Most of the light thrown on the problems has come through comparison with Appalachian and British graptolite zones.

My main purpose of making these comparisons of the stratigraphic units in the Arbuckle and Ouachita sections was to show by many equally striking precedents that the discordant relations herein established between the true and the false Caney shale is the rule rather than the exception for the rocks in these adjoining areas.

SCRATCHED BOULDERS

As is now well known, deeply scratched boulders occur not infrequently with those that have suffered no attrition save that occasioned by simple weathering. Concerning these I have heard it said that good glaciologists deny that the scratches were made by ice. Others, mainly areal and structural geologists, insisted that the scratches were produced by rock movement along the fracture planes. I heard both these views expressed from the day in 1904 when I found and called to the attention of my associates the first scratched Caney boulder on to a week or two ago. Usually the discussions started by such inadequately considered assertions resulted in the critic losing confidence in his particular explanation by admitting that the peculiar type of scratches common to all the scratched Caney boulders could readily enough have been made under conditions in which ice played an important part whereas it would be very difficult to produce them by any ordinary movement within the beds.

Examine any of the multi-scratched boulders—none of the scratches will be found strictly parallel with any other. In fact as many as a dozen scratches, each with its own direction, have been observed on one surface of a boulder less than a foot across. In such cases the scratches often cross each other; and sometimes one or more of them are gently or even sharply curved. Moreover, the scratched surface may vary from slightly concave to distinctly convex, or be irregularly uneven—in fact, just such surfaces as pertain to the loose rocks on the weathering exposed surface of a limestone formation. The scratches

PLATE I.

ERRATIC LIMESTONE PEBBLES IN SANDSTONE BED OF CANEY SHALE.

Locality: Compton cut on Frisco Ry., top of Windingstair Mountain, Oklahoma. Photo by J. A. Taff.

vary from shallow to deep gouged-out excavations and in length without any relation to their depth. In a few instances even some of the scrapings are preserved at the sides of the distal end of the gouge.

In my opinion it is physically impossible that these phenomena can have been produced as slickensiding is by faulting movements of rocks in place or in a fault breccia. Neither could they have been made by the steady flowage of glacial ice. But how about boulders of varying hardness imbedded in the base of floating masses of shore ice? Would they not fill all the requirements? Remember, too, that the larger sizes of the Caney boulders usually show no signs of deep scratching. Also that many of these large limestone masses are armed with projecting knobs and points of very hard chert that is readily capable of scratching the rotting surface of chert blocks in the residual mantle.

After one of these armed masses had been grounded and liberated by melting of the transporting ice it would have become an excellent means of scratching the bottom of softer boulders carried by subsequent incursions and grounding of shore ice. We may readily imagine also how the transporting ice as its bottom came in contact with the previously liberated mass of rock would be likely to free itself by a rotary response to the onward urge of the current that brought it there. This would account not only for the varying directions of the several scratches but also for the curve noted in some of them.

It is thus that in 1904 I accounted for the abundant presence of scratched and unscratched boulders of many ages in the Caney shale. The explanation was accepted then by my associates in the field and also by Hayes and Purdue in 1908 when Taff and I piloted them over some of the best of the boulder localities. I have neither seen nor heard anything since that might cause me to relinquish or seriously modify my original view of the orgin and means of transporting the "Caney" boulders.

SUPPLEMENTARY OBSERVATIONS (September, 1927)

Since writing and delivering the foregoing paper at the Tulsa meeting of the American Association of Petroleum Geologists late in March, 1927, H. D. Miser of the U. S. Geological Survey spent the following three months in the Ouachita Mountains of Oklahoma for the purpose of reviewing the unpublished mapping of J. A. Taff and of studying the age relations of the Carboniferous rocks. Because of the possibility of his discovery of new facts that might require modification of views expressed in my paper it was decided to delay publication till after my return from the field and subsequent discussion of the new evidence. As it turns out his conclusions accord with all my own views except that he believes the Mississippian Caney fauna that occurs in my Johns Valley shale lived, died, and was buried where it is now found. If this is so then the Johns Valley shale and the underlying Jackfork and Stanley formations must be of Mississippian age. Also Mr. Miser recognizes two main boulder beds in the Ouachita Caney shale—one in the lowermost 50 to 100 feet of the shale and the other in the topmost 100 feet of the formation. The lower bed he regards as underlying the shale containing the Mississippian Caney fauna and the upper as overlying a bed of limestone that is lithologically and faunally similar to the Wapanucka (Pennsylvanian) limestone. As a natural consquence of Mr. Miser's conclusions concerning the ages of the two boulder beds it follows that the boundary between the Mississippian and Pennsylvanian is concealed in the shale between the two boulder zones.

As will be noted, the only point of fundamental importance on which Mr. Miser and I disagree arises from his belief that the Caney fossils found in the lower part of the shale formation that is here distinguished as the Johns Valley shale are indigenous to the formation

PLATE II.

SLICKENSIDED SANDSTONE BED IN CANEY SHALE.

Locality: Compton cut on Frisco Ry., top of Windingstair Mountain, Oklahoma. Photo by J. A. Taff.

and place and not, as I regard them, remaniè derived and transported from then exposed outcrops of the Arbuckle Caney shale. In other words, he believes the Caney fossils found in Johns Valley lived in the waters that at the same time deposited both the Arbuckle Caney and the greater lower part of the Ouachita Johns Valley shale. Under this conception the only possible deduction regarding the age of the underlying great series of clastic Stanley and Jackfork deposits, aggregating to a maximum of more than 12,000 feet, is that it is of a preceding age of the Mississippian system. The actual consequence of this deduction —clearly appreciated by Miser—is that the Stanley and Jackfork belong in the hiatus between the base of what Taff and Girty defined as the range of the Caney shale and fauna in the Arbuckle region and the top of the Woodford.[19]

As I view the known facts and probabilities having more or less direct bearing on our problem most of them seem definitely opposed to his belief; and none appears insuperably favorable. It is not my aim to discuss or even mention all of the factors that occur to me, nor is this to be construed as the beginning of a controversy. On the contrary this paper embodies my last word on the subject. However, because it is my final statement I feel the immediate need of showing the improbability of views that are likely to be espoused by others who have or may see the same interesting, but in my opinion deceptive, occurrences that Mr. Miser saw and who would likewise be unable to convince themselves of the remanié nature of certain fossils and concretionary masses that look too much like indigenous occurrences to be readily recognized for what they must be and doubtless are. In such cases it can harly be expected that the truth can be reached by direct comparison of the individual phenomena. It is possible only when these are seen and weighed in the light of all the other factors of the problem. In this case Mr. Miser should be viewed as presenting for careful consideration and discussion field conclusions reached by himself and associates. Whether I have done this well or otherwise and without prejudice the following pages must decide.

Evidently Miser and his associates believe that all of the difficulties of the problem are satisfactorily overcome by his conclusion that my Johns Valley shale comprises two and not only one zone with fossiliferous boulders of many ages. So far as known to me the only differences in his estimate of the faunal contents of the supposedly distinct zones are (1) that the upper one has afforded limestone fragments with lower Pennsylvanian fossils—which, of course, precludes the possibility of the containing bed being of Mississippian age—and (2) that the remains of Caney and older faunas in the upper zone are viewed as erratics of preceding ages whereas the Caney fossils in the lower zone are claimed to be contemporary remains.

Why this discrimination should be made is not yet clear to me. The rare presence of Wapanucka fossils in the one case and their apparent absence in the observed shale outcrops in Johns Valley is at the best only negative evidence that may readily be due to fortuitous circumstances and have no stratigraphic significance. Considering the origin and mode of distributing the erratics in these shales it is not to be expected that boulders of all the ages would be generally and equally distributed throughout those parts of the Ouachita area in which the boulder zone has been searched for fossils. In fact experi-

19. This arrangement of the formations is in part the same as that given by me in the correlation chart of my Revision of the Paleozoic systems (1910). At that time my disposition of the "Caney" was determined by convictions based on the Ouachita Caney (Johns Valley) shale which I then knew better than the Arbuckle Caney and believed, as I do now, to be of Pennsylvian age.

PLATE III.

SCORED ERRATIC LIMESTONE BOULDER FROM CANEY SHALE.

Locality: Compton cut on Frisco Ry., top of Windingstair Mountain, Oklahoma. Photo by J. A. Taff.

ence has proved conclusively that the ages of boulders found at one place often differ very greatly from those found at other places.

Then as concerns the Caney fossils: I saw no essential difference in the mode of occurrence of these at the place where they are said to, and actually do, occur in the lower part of the Johns Valley shale and the other places where it is claimed they occur in a zone near the top of the shale. In view of all the concerned facts, at least in so far as they are known to me, it seems much more difficult of comprehension to explain their occurrence in certain Winding Stair Mountain exposures of black shale as remaniè and in the shale of Johns Valley as contemporaneous remains. Moreover, since in Miser's view my Johns Valley shale contains two boulder beds—one in the lower 100 feet, the other in the topmost 100 feet of the formation and neither of them a real basal conglomerate—his amended interpretation of my arrangement again leaves us completely at sea respecting the location of the contact between two great systems. In fact this straddling of the problem places us in worse position than ever as regards the future classification and mapping of Ouachita formations. Obviously the interpretation adopted by me is vastly more simple and practicable.

Finally, as regards the matter of one or two boulder zones, let me point to a suspicious agreement of figures: namely, as is well known, the lower and only boulder zone recognized by me in the Johns Valley shale lies in the lower 100 feet or so of the formation. The "upper" one on the contrary is said to occur in the topmost 100 feet of the formation. In view of all the other agreements between the two occurrences these figures look suspicions enough to warrant doubt as to actual distinctness. Pending the presentation of really conclusive evidence favoring Miser's conclusion I prefer therefore to maintain my original and present view that there is only one boulder zone and that the supposed upper zone is merely an overturned exposure of the lower. But, after all, the final decision on this point can have no vital effect on the main problem and may therefore be dismissed without further comment.

Now as to the more strictly paleontological aspects of the case: Miser and others with him found shale outcrops in Johns Valley that showed phosphatic concretions and masses of concretionary limestone with Arbuckle Caney fossils in place that they agreed were contemporaneous and not transported remaniè. The shale in which these Caney fossils were imbedded *overlies,* as definitely stated by Miser (see above), the lower boulder zone. This assignment of position seems by itself to be positively fatal to their belief in the contemporaneity of the Caney fossil species in Johns Valley. In the first place, typical Caney fossils do occur in the boulder zone at places in the immediate vicinity of Miser's locality. Some of these were collected by Taff and myself directly associated on the weathered surfaces of the shale matrix with fossiliferous Ordovician and Silurian boulders. One of these collec-

PART OF SCORED ERRATIC FLINT BOULDER FROM CANEY SHALE.

Locality: Caney Creek Valley, western part of Kiamichi Mountain, Oklahoma. Photo by J. A. Taff.

tions was submitted to Doctor Girty, who lists five characteristic Arbuckle Caney species under his locality No. 2075[20].

Should we regard these Caney fossils—because of their associates —as transported remains, hence as Pennsylvanian, or should we ignore their environment and accept them also as having lived and died where they were found? Personally, and despite the fact that no Pennsylvanian boulders were observed in these Johns Valley localities, I saw no reason to question the age equivalence of this and the otherwise similarly fossiliferous boulder zone in Winding Stair Mountain.

Noting that Miser admits the remanie character of the bulk of the fossils found in the shale in Johns Valley—fossils ranging in age from Canadian to at least Sycamore—one is struck by the fact that he denies this status only to those of Caney age. This discrimination seems strange particularily because of the fact that at the places in Johns Valley mentioned the list of collected fossils includes not only Ordovician, Silurian, and Caney species but also a few in shale that in the Arbuckle area, from which most and as I think all of the fossils were transported, seem to be confined to the horizon of the Sycamore limestone. These Sycamore fossils most probably were taken from a bed in the vicinity of Wapanucka, near which place Taff, Girty, and Richardson collected a number of fossils that are clearly not normal members of the Caney fauna out of a bed of sandy shales close to the top of the underlying Woodford chert. They are listed by Girty under his locality No. 2077 (*op. cit.*, p. 9). If the Sycamore zone was laid under tribute when the Johns Valley shale was being deposited why not also the overlying typical Arbuckle Caney?

Since the Caney fossils in the Ouachita area are usually found in boulder beds, and if the lower half of the Johns Valley shale is of contemporaneous origin with Arbuckle Caney, why is the latter entirely free of erratics? I have never seen limestone or chert boulders in the Arbuckle Caney shale, nor have I heard of anyone else having found them. Surely if the shales in question had been deposited at the same time such erratics of much older formations must have been dropped also to the north of the Ouachita area because the southern bands of Arbuckle Caney shale doubtless lay nearer their several sources of supply. So far, however, none has been found even in the small inliers south of the Choctaw fault—among them the one on Brushy Creek—that are lifted to the surface through the cover of Pennsylvanian formations in the little known lowland strip between the two areas[21]. But these erratics set in abruptly and in great abundance in the northernmost bands of the Ouachita Johns Valley shale. These boulder-bearing bands occur on the flanks of Winding Stair Mountain and southwestwardly along its strike, and the first of them lies only about 3 miles south of

20. Girty, G. H., The fauna of the Caney shale of Oklahoma: U. S. Geol. Survey Bull. 377, p. 9, 1909.

21. In this connection it is very important to remember that such erratics do occur in shales and limestones of the Wapanucka formation far to the northwest of Brushy Creek. (See page 10).

PLATE V.

PART OF SCORED ERRATIC FLINT BOULDER FROM CANEY SHALE.

Locality: Compton cut on Frisco Ry., top of Windingstair Mountain, Oklahoma. Photo by J. A. Taff.

the Brushy Creek inlier.[21a] Evidently the two simulating black shales are of quite different ages; and some extraordinarily great changes in climatic conditions must have set in before deposition of the younger of the two formations began.

Now as to the chance of the Caney fauna having lived in the waters that laid down any and particularly the lower part of the Johns Valley shale: As I have just said, great climatic changes must have occurred during the time represented by the deposition of the great Stanley-Jackfork series and the introduction of the succeeding conglomeratic black Johns Valley shale. When the limestone and other lithologic types of erratics were being torn out of their exposed beds on the northeast side of the Arbuckle uplift and carried thence into the post-Jackfork shale depositing waters in the then submerged Ouachita basin it must have been a time of uncommon frigidity. Surely, it required very large masses of ice to transport even the blocks of limestone seen by me in the boulder bed not to mention the largest reported by Miser. Nor is it at all likely that the prevalence of cold and ice-building conditions was merely local or restricted in its effects. Doubtless these effects stretched over the submerged Ouachita area and greatly lowered the temperature of the shallow water in it. Morover, this lowering must have been accentuated by the perhaps annual crop of floating ice broken from the glacial region to the north. Accordingly, I feel convinced that the kinds of life comprising the Caney fauna described by Girty could not have flourished or lived at all in the cold waters in which the Johns Valley shale was deposited. Further support of this probability is afforded by the fact that in this shale formation organic remains of any kind are so far as known wholly confined to the boulder zone or zones if there is more than one.

In his discussion of the Caney fauna (*op. cit.*, p. 14) Girty recognized two "facies," one characterized mainly by brachiopods, the other by cephalopods and species of the peculiar group of bivalve shells to which he applied the name *Caneyella*. With one or two exceptions that probably came from the higher zone the fauna of the brachiopodan facies is incompletely listed by Girty in the table showing the distribution of the Caney fauna under the locality numbers 2077 and 2085. Some of these species I found in the Sycamore limestone west of Washita River, but most of the so-called brachiopod facies came from the shaly eastward extension of that limestone formation. Because of their shaly character the latter beds were included in and mapped as Caney by Taff and others working with him up to 1905. However, in July, 1908, Taff and I studied and traced the beds in and adjacent to the Sycamore from the west of the Washita eastward to Wapanucka. These investigations tended to prove that the brachiopod facies is confined in the Arbuckle region to the horizon of the Sycamore and there-

21a. In a personal communication, Sidney Powers reports an outcrop of dark gray shale with boulders in sec. 25, T. 4 N., R. 17 E. This shale, he says, is very different from the ordinary black shale of the Caney which is quite understandable if this outcrop is, as I believe, either a shaly representative of the Wapanucka or a far advanced part of the overthrusted Ouachita basin deposits.

PART OF SCORED ERRATIC FLINT BOULDER FROM CANEY SHALE.

Locality: Compton cut on Frisco Ry., top of Windingstair Mountain, Oklahoma. Photo by J. A. Taff.

fore that the cephalopod facies is not only a distinctly subsequent appearance but that it alone is entitled to the designation Caney fauna. I make this statement with due reservations as to possible exceptions and therefore do not wish to be understood as denying that species of either may not occur contemporaneously in some places with the other facies.

Though apparently always occurring apart in the Arbuckle area it is yet a fact that species of the two facies often do occur together in the nearby Ouachita outcrops of the Johns Valley shale. Of course I regard this body of shale as younger than the Arbuckle Caney and attribute the association of species of the two "facies" in the boulder zone of the Ouachita formation to the same transporting agency that at the same time brought in also the erratics of many older Arbuckle formations.

Girty suggests (*op. cit.*, p. 14) that the two facies—as I may continue to call them—occur (? contemporaneously associated) in the Moorefield shale of Arkansas. But really we seem to know very little about the true Moorefield shale and its sparse fauna and even less about the actual time relations of this formation to the Spring Creek limestone and certain shale beds near Marshall and Batesville, Ark., that are commonly referred to as possible correlatives of the Moorefield. But granting that the two facies do occur in the Moorefield it would not seriously affect my argument as regards the age of the Caney because the physical evidence of the depositionally unrecorded break between the Sycamore—whether represented by limestone or shale—certainly is not impressive. In fact I failed to convince Taff that there is any break between them at all.

On the same page Girty suggests further that the Caney may correspond not only to the Moorefield but also to the Batesville sandstone and the Fayetteville shale of Arkansas. In my opinion, however, the last two formations are clearly of lower to middle Chester age and distinctly younger than the Arbuckle Caney. As to the Moorefield itself it seems to me that its middle and lower parts at least are older than the St. Louis limestone. Although these parts may be strictly comparable with the typical Arbuckle Caney it is still possible that its lower part is of the age of the Sycamore limestone. Finally, as regards the Sycamore, the preceding correlation table (see page 31) shows that I again assign it to Kinderhook as I did in 1903 when I referred to its shaly equivalent as "Upper Woodford." If these opinions are not seriously in error then the Moorefield would comprise a sequence of members essentially like that of the shale series in the vicinity of Wapanucka which there constitutes the Caney shale as determined and mapped by Taff and Girty.

Shaly limestone interbedded with sometimes dark and often sandy shale and occasionally layers with green sand, of middle to late Kinderhook age and known as the Ridgetop shale, occur locally in middle Tennessee between the top of the early Kinderhook Chattanooga shale and the base of the New Providence formation. This locally developed formation agrees lithologically very well with the Sycamore limestone and shale of Oklahoma and may represent it. Then there is a higher shaly bed in south central Kentucky from which goniatite-like cephalopods, partly described by S. A. Miller[22] and suggesting close relations to Caney species, have been collected. The exact stratigraphic position of this Kentucky bed is not positively known but judging from the geographic location of its outcrop—near Crab Orchard—it should lie somewhere near the usually unconformable contact of the Warsaw and St. Louis limestones. Farther east, as at Saltville in southwestern Virginia, we find a black shale in about the same stratigraphic position. These two more eastern occurrences may have some perhaps intimate relation to the Moorefield of Arkansas and the Arbuckle Caney of Oklahoma. They are mentioned here only as possible indices of the age of the Arkansas and Oklahoma formations, the fixing of whose exact positions in the geological time scale we are finding so difficult and yet perhaps so vital in the solution of the Stanley-Jackfork problem.

If the preceding suggestions have any valid basis in fact, and assuming for the moment that the Johns Valley shale at its type locality is, as held by Miser and others, of the same age as the Arbuckle Caney, then it is clear that the enormous thickness of Jackfork sandstone and Stanley shale which unquestionably *underlie* the Johns Valley shale in the Ouachita area must be as young at least as the Warsaw. But the case becomes even more desperate when we remember that the shale which overlies the Jackfork in Johns Valley has contributed not only Caney fossils but also pieces of shale with species that so far as known are confined in the Arbuckle region to the horizon of the Sycamore. These older shells have as valid a right to be called indigenous as have the Caney fossils with which they were found. Granting this right and realizing the generally accepted fact that the Sycamore fauna is of late Kinderhook age Miser's conclusion unavoidably demands that the great underlying Stanley and Jackfork formations be classified as Lower Mississippian. Accordingly then the remains of plants which have been found in them should find much nearer allies in the Lower Mississippian Pocono or in the late Devonian flora than in the subsequent Middle and Upper Mississippian and still younger Pottsville floras!

I wonder what answer will finally be made to this by David White, who long ago expressed[23] a cautious opinion concerning the age of the small original collections of Stanley plants and is now engaged on a more comprehensive and detailed study of the floral side of the question. Though unwilling as yet (September 20, 1927) to express a final opinion as to their ages he yet declared emphatically that the observed relations of the augmented collections of Stanley and Jackfork plant remains now in his hands to the Pocono flora are far inferior to their alliances with late Chester and Pottsville floras. He added furth-

22. Miller, S. A., North American Geology and Paleontology, p 440, 1889.
23. Quoted by Girty, G. H., The fauna of the Caney shale of Oklahoma: U. S. Geol. Survey Bull. 377, p. 8, 1909.

er that the chances, as determined by now available paleobotanical criteria, of either of the concerned Ouachita formations proving to be older than Chester is very remote.

It seems a pity that so important and everywhere clearly defined boundary as that between the Mississippian and Pennsylvanian systems should be left hanging in the air, as it were, in the Ouachita area. The prevailing hesitation in settling this question is all the more regrettable, if not inexcusable, in view of the fact that the Jackfork sandstone has all the desired qualifications of an initial systemic deposit, including inferred preceding, contemporaneous, and succeeding local physical history, lithologic characteristics, palogeographic attributes, and sequence of diastrophic movements. Besides, all these physical qualifications harmonize thoroughly with the available faunal and floral data that in anywise bear on the major theme of the problem. Thus with a single stroke all the uncertainities are either completely removed or at least reduced, and the late Paleozoic depositional history of Oklahoma becomes understandable and reasonably comparable with the stratified record in other parts of America.

From the foregoing supplementary discussion of the various factors that are believed to have value in my effort to settle the vexing problem of the proper classification of the Ouachita formations adjacent to the Mississippian-Pennsylvanian boundary it seems from whatever angle the problem is attacked the results without exception tend more or less definitely to disqualify the varying views of those who are inclined to differ from my interpretation. The point on which I am particularly desirous of securing unanimity of consent is the acceptance of my firmly grounded conviction that the base of the Jackfork sandstone marks the beginning of Pennsylvanian deposition in Oklahoma. With the support already accorded to my cause by David White, who beyond all doubt is the most trustworthy exponent of late Paleozoic stratigraphic paleobotany, I feel that the success of my present endeavor is assured.