PITKIN LIMESTONE
of
NORTHERN ARKANSAS

WILLIAM H. EASTON

BULLETIN 8

❖

Arkansas Geological Survey
446 State Capitol – Little Rock

STATE OF ARKANSAS

Arkansas Geological Survey

RICHARD J. ANDERSON
Acting State Geologist

BULLETIN 8

PITKIN LIMESTONE of Northern Arkansas

By
WILLIAM H. EASTON

LITTLE ROCK
1942

60 cents per copy

LETTER OF TRANSMITTAL

ARKANSAS GEOLOGICAL SURVEY

Little Rock, Ark.,
June 30, 1942.

Hon. Homer M. Adkins,
Governor of Arkansas,
Little Rock, Arkansas.

Sir:

I have the honor to submit herewith the report, "The Pitkin Limestone of Northern Arkansas," by William Heyden Easton.

This report constitutes an important contribution to our knowledge of the stratigraphy, structure, and geologic history of northern Arkansas.

Respectfully submitted,

RICHARD J. ANDERSON,
Acting State Geologist.

TABLE OF CONTENTS

ILLUSTRATIONS

THE PITKIN LIMESTONE OF NORTHERN ARKANSAS

By William H. Easton

ACKNOWLEDGMENTS

It is with pleasure that I acknowledge my indebtedness to the men who have been of assistance during the preparation of this study. Their advice, co-operation, and suggestions were most gratefully received, and credit for any advances in the knowledge of the Chester group brought forth herein must certainly be shared with them. The writer, however, accepts the responsibility for any and all statements incorporated within this paper.

My special thanks are due Carey Croneis, of the University of Chicago, who suggested the present investigation and has been of inestimable help throughout the pursuit of this work.

The Arkansas Geological Survey financed the field work in part, supplied materials, and was instrumental in obtaining the occasional services of the WPA Mineral Survey of Arkansas in the field. J. H. Bretz, R. T. Chamberlin, and E. C. Olson, of the University of Chicago, have been of valuable service with regard to special problems. A. W. Giles and V. O. Tansey, of the University of Arkansas, were helpful in offering suggestions pertaining to conduct of field work. W. C. Mendenhall and P. S. Smith, of the United States Geological Survey, furnished aerial photographs and personal copies of folios to aid in mapping activities. Donald Trumbo, of Fayetteville, Arkansas, especially should be mentioned not only for his hospitality but for his help in many ways during the conduct of the field work. Finally, I am indebted to many residents of Arkansas who were helpful during the field work and to the graduate students of the Department of Geology and Paleontology of the University of Chicago who have offered suggestions during the preparation of this paper.

INTRODUCTION

THE PROBLEM

The Pitkin limestone is the youngest formation of the Chester group in northern Arkansas and Oklahoma, and as such is important in any study of the Pennsylvanian-Mississippian stratigraphic and faunal break. The fauna of the Pitkin limestine will be described in part, but an analysis of the faunal relations of the Pitkin to the overlying strata and to supposedly contemporaneous formations has not been attempted. The stratigraphy of the Pitkin limestone has been known only for a limited portion of the outcrop and the structural details of the major part of the Boston Mountains are yet to be studied. Consequently, this study has been undertaken chiefly to give as complete an analysis of the faunal relations as possible and to obtain further data concerning the stratigraphy and structure of the formation and the adjacent beds.

PROCEDURE

Ten weeks during the summer of 1939 were spent in collecting from the fossiliferous horizons of the Pitkin, mapping the formation at its most northern and southern exposures, and in studying the stratigraphic and structural features. This work was conducted along the escarpment of the Boston Mountains from Batesville to Fayetteville in Arkansas, and since the Pitkin is known to crop out in Oklahoma, some time was spent in examining the formation from the Arkansas state line to Muskogee, Oklahoma. The winter of 1939-1940 was spent at the University of Chicago in studying the fauna and in interpreting the results of the field work. After formal acceptance of the thesis by the University of Chicago, additional work was done augmenting some parts and modifying other parts of the text.

PREVIOUS STUDY OF THE PITKIN

The geological exploration of Arkansas was inaugurated as a result of the appointment of David Dale Owen, then state geologist of Kentucky, as state geologist of Arkansas, to take office October 1, 1857. Owen started his field work in northeast Arkansas and soon entered the Paleozoic region of the state, where the Pitkin limestone was measured for the first time on Oil Trough ridge. Owen's section is given for historical interest.[1] The elevations are in feet above Oil Trough Bottom.

"At 152 feet, Sandstone.
At 145 feet, Third bench of protruding limestone; exposed for 15 feet.
At 115 feet, Limestone shale.
At 92 feet, Second bench of protruding limestone; exposed for 15 feet.
At 75 feet, Productal black limestone.
At 70 feet, Archimedes limestone.
At 56 feet, First projecting ledge of limestone seen in this part of the ridge."

In some cases "Archimedes limestone" refers only to the Pitkin limestone of today, whereas, in other instances, the upper beds are members of the Morrow group. Hereafter, the name "Archimedes limestone" will be used in this paper until the point in the chronologic order has been reached at which the name "Pitkin limestone" was introduced. The lower limitation of the "Archimedes limestone" was not exact and it is evident that on occasion some of the upper black limestone beds of the Fayetteville shale were included. The term "Archimedes limestone" was useful and convenient in its time, however, for, as Owen stressed in his report, the formation marks a readily identifiable horizon below which no coal can be expected.

Owen's report is a landmark, for, although formations are not delimited exactly, there is little trouble in transferring lithologic descriptions from it into approximate present-day accepted formational names. Owen pointed out the steady increase in elevation of the mountains toward their center and he observed the occurrence of black chert in some of the stream beds in the east. In Newton and Carroll counties Owen studied the well-known outlier called Boat Mountain. Farther to the west he observed the west dip of the formations, which is just the opposite of the gentle dip in the east. In Washington County, where the most comprehensive report on the formation in Arkansas was subsequently written, Owen measured a "typical" section in

---

[1] Owen, D. D., First report of a geological reconnoissance of the northern counties of Arkansas, made during the years 1857 and 1858: Little Rock, p. 34, 1858.

which no "Archimedes limestone" was ~~found because~~ of the post-Mississippian erosion. He does, however, mention the formation in the bluffs at West Fork, where there are splendid exposures.

The study of the "Archimedes limestone" was advanced considerably by the publication in 1891 of Simonds' report. Extensive outcrops of the limestone occur in this area and Simonds seems to have visited almost every important exposure. The first figures of *Archimedes* from the "Archimedes limestone" are in his report, but the fossils were not described. At this time the term "Archimedes limestone" became really entrenched in the literature as an Arkansas formation. The name, however, has been used with reference to certain other formations in the midwest, notably in Missouri.

Simonds mentioned the occurrence, northeast of Fayetteville, of pebbly strata in the formation and traced this rubble zone throughout the county. He described many localities in detail and gave accurate locations by means of land numbers so that his localities are readily found. Simonds' conclusions[1] were that:

> "It is a characteristic formation, well marked and easily identified, hence, of great value as a guide in the location of positions stratigraphically over a large area in the county south of Fayetteville; it attains its maximum thickness at the base of the Boston Mountains, and especially in the outliers on the northern side; it thins out northward and undergoes a decided change lithologically about the latitude of Fayetteville, and finally, as stated by Mr. Harris, degenerates into sandy layers and disappears, being recognized for the last time in 17 N., 29 W., section 16."

Today the formation is recognized essentially as Simonds outlined it, although more recent work has added detailed information and excellent maps.

T. C. Hopkins, in an extensive report, refers to the use of "Archimedal limestone" for lime burning and for building purposes. He points out that use of this formation for building stone is not advisable because the stone does not resist weathering as well as other stones which are as readily

---

[1] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. 1888, vol. IV, pt. I, p. 74, 1891.

obtainable. His discussion of the formation is mostly concerned with a general review of previous work, but the statements of thicknesses provide new and accurate information. Hopkins[1] infers that all the Morrow beds continue unchanged across the face of the mountains, but this is not actually the case.

Ulrich[2] changed the name of the ''Archimedes limestone'' to the Pitkin limestone, in order to comply with the rule requiring the naming of formations from geographic location. Most of the information concerning the Pitkin limestone had been obtained in Washington County, and, since there are fine bluffs of the formation just north of the town of Pitkin (since renamed Woolsey), that name was selected as the name for this formation. The Pitkin is limited to beds overlying the Fayetteville shale and overlain by sandstones and shales of the Morrow group. Ulrich described the Pitkin as mostly limestone with some locally developed sandstone. The formation thins to the north, apparently as a result of near-shore conditions, and contains pebbly strata. The thickness was found to be between ten and forty feet, exceptionally more. This is the youngest Chester formation in Arkansas and, according to Ulrich, may be the youngest Chester formation in the Mississippi valley because other Chester beds have undergone more erosion.

In a short discussion of the relations of the formation, Ulrich points out that because the Brentwood was placed in the Pennsylvanian, therefore the Pitkin limestone must take a higher position than heretofore in the sequence of Carboniferous strata. He says that the disconformity between the Pitkin and the Fayetteville shale must point to a rather younger age for the Pitkin than if the two were conformable. Ulrich's conclusion is that the Pitkin must be no older than the Birdsville formation of Kentucky, which is uppermost of four Chester divisions there.

Adams and Ulrich[3] describe the Pitkin as a fossiliferous limestone forming benches on the north edge of the Boston

---

[1] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. 1890, vol. IV, p. 91, 1893.

[2] Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, pp. 27, 109, 1904.

[3] Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), p. 4, 1905.

Mountains and give the thickness as from a few inches to forty feet.

The Pitkin was mapped accurately for the first time by Taff,[1] who gives thicknesses at several localities in order to show the extreme variability of the formation in thickness over comparatively short distances. The lithology varies from thin shales to limestone and shale beds aggregating seventy feet.

Taff's study[2] of the Pitkin was continued during the preparation of the Muskogee Folio of Oklahoma. The general conclusions are that the Pitkin is characterized by being oölitic in its massive phases but that there are also many thin beds of limestone, the whole series generally forming a unit about fifty feet thick. The structure of this quadrangle is a continuation, in part, of the faulted region to the east in the Tahlequah region.

Purdue[3] notes that the Pitkin limestone is commonly cherty, ranges in thickness from ten to forty feet, and seems conformable above and below. This last point emphasizes the apparent northward shoring of the Pitkin sea and the post-Pitkin erosion that beveled the formation to the north of this quadrangle.

The first detailed faunal study of the Pitkin limestone was made by L. C. Snider.[4] He described the Pitkin as being conformable on the Fayetteville shale but disconformable with the overlying Morrow group. The Hale sandstone generally overlies the Pitkin, but to the north of the Oklahoma Pitkin area the Brentwood limestone is in contact with beds older than the Pitkin. In the Pryor quadrangle there is but little Pitkin limestone and the Morrow group continues to crop out to the north after the Pitkin is no longer present.

Snider lists the fauna of the Pitkin limestone as totaling sixty species. The distinguishing faunal feature of the formation in Oklahoma, according to Snider, is the presence of a pelecypod zone near the base of the formation. Snider correlates the Pitkin limestone with the Pitkin of the Winslow

---

[1] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (no. 122), 1905.

[2] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (no. 132), 1906.

[3] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), p. 3, 1907.

[4] Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, pt. I, 1915.

quadrangle, the Caney shale of the southwest, the Carterville formation of southwest Missouri (if any equivalent of the Pitkin be present at all), the Maxville limestone of Ohio, and the Newman and Greenbrier limestones of the Alleghenies; and finally, Snider considers the Fayetteville and Pitkin correlative with the Okaw and Menard of the Mississippi valley.

The paleontologic section of the report, with collections from ten localities, contains mention of some of the previously described species in addition to descriptions of new forms. This is the first publication of a faunal list and plates of the fossils of the Pitkin limestone specifically.

The Eureka Springs-Harrison Folio is the latest folio to treat of the Pitkin limestone. Purdue and Miser[1] show the formation to consist mainly of limestones ranging from a feather edge to one hundred feet in thickness, being absent in the south-central portion of the two quadrangles. The absence of the Pitkin here is explained by a combination of non-deposition and erosion. Finally, the authors give a short list of Pitkin fossils.

Buchanan,[2] in a consideration of the Mississippian formations of Oklahoma discusses the stratigraphic relations and paleogeography of the Pitkin. He concludes that the close of the Mississippian in that area was marked by the withdrawal of the Pitkin sea into a basin in Oklahoma; that the faunas of the Caney, Mayes, and Moorefield suggest a connection with a North Pacific sea; that the sand in the southwestern extensions of the Pitkin limestone is reworked Simpson sand from the Arbuckle-Wichita area; and that the Chester sea persisted in Oklahoma, where it received Pottsville faunal elements while the Chester fauna was still evolving.

Giles and Brewster[3] measured a section of twenty-one feet of Pitkin limestone on Hale Mountain, but the range of thickness in Arkansas is placed from a feather edge to one hundred feet. The paper is important because it shows the

---

[1] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

[2] Buchanan, G. S., Distribution and correlation of the Mississippian of Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. XI, no. 12, pp. 1318-1320, 1927.

[3] Giles, A. W., and Brewster, E. B., Hale Mountain section in northwest Arkansas: Am. Assoc. Petroleum Geologists Bull., vol. XIV, no. 2, pp. 121-138, 1930.

typical stratigraphic relationships of the Chester and Morrow groups where none of the members is absent.

The most comprehensive treatment to date of the Paleozoic rocks of Arkansas is by Croneis. The Pitkin limestone is discussed by Croneis[1] with regard to the nature and relations of the formation plus its petrolific significance. Faunal lists extracted from Snider and Mather show the relations of the fauna as well as the variety of the species. A plate of characteristic Pitkin limestone fossils is included in the report. The first mention of the odor of hydrocarbons given off from freshly fractured pieces of the Pitkin limestone is made in this report.

The "black marble" of Arkansas has received attention from the time of Owen's first geological survey of the state, but it was not until the publication of work by Bryan Parks[2] that any detailed information concerning the adaptability of the various formations as building stones was available. The Pitkin limestone is discussed in general[3] and many measured sections include the Pitkin either in whole or in part. The map of the formation (and of the Fayetteville shale) constitutes the only recent geologic map of the eastern portion of the Boston Mountains escarpment.

McKnight mapped the Pitkin limestone at three places near St. Joe in the Yellville quadrangle. The characteristics of the limestone are discussed by McKnight[4] and it is pointed out that the thickness of the formation in this quadrangle varies from fifty-five to one hundred feet in less than a mile. The faults that partly limit the outcrop of the Pitkin limestone are carefully mapped.

A recent paper on the Pitkin limestone is by C. A. Moore.[5] He studied the formation in Oklahoma both as to field relations and as to insoluble residues. He considers the Pitkin in Oklahoma to consist of a thick massive limestone, a thinner argillaceous limestone, and a thin granular limestone, in ascending order. The insoluble residues of the Pitkin are not characteristic enough to be of great use in subsurface work.

---

[1] Croneis, C. G., Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, pp. 73-76, 1930.

[2] Parks, Bryan, Black marbles of northern Arkansas: Arkansas Geol. Survey Inf. Circ. 3, 1932.

[3] Idem, pp. 7, 8, 12, 13.

[4] McKnight, E. T.; Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Bull. 853, pp. 81-83, 1935.

[5] Moore, C. A. Morrow group of Adair County, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 24, no. 3, pp. 412-418, 1940.

Another recent article to treat the general geology of any part of the Boston Mountains is a report outlining the findings of the WPA State Mineral Survey in northwestern Arkansas.[1] The geology and mineral resources are discussed, important deposits are located and analyses are given of many samples of rock.

The most recently published work on the Pitkin is by Laudon,[2] in which he describes eleven new crinoids from the formation, all collected from northeastern Oklahoma.

GEOGRAPHY

The Boston Mountains lie in north and northwest Arkansas north of the Arkansas River and south of the White River. The mountains slope gently to the south, but the pronounced Boston Mountain escarpment limits them on the north. The field work upon which this paper is based was conducted chiefly along this escarpment and in the various valleys dissecting it.

The Pitkin limestone crops out in Crawford, Washington, Madison, Newton, Searcy, Stone, and Independence counties in Arkansas. In Oklahoma, where the Boston Mountains are not well defined, there is Pitkin limestone in Mayes, Waggoner, Cherokee, Adair, and Sequoyah counties.

The Boston Mountains have an elevation of slightly more than 2,250 feet on the outlier north of Round Hill Fire Tower in western Searcy County. This is the highest part of the escarpment, for the mountains slope gradually to the east and the west from this region. The valley bottom just east of the outlier mentioned above is 750 feet above sea level, the maximum relief at this place being approximately 1,500 feet.

The drainage of the north part of the Boston Mountains is maintained by the White River and its tributaries, the Buffalo River, the West Fork of White River, War Eagle Creek, Little Buffalo River, and several other smaller rivers and creeks.

A number of different types of maps deal with the area under discussion. The most important of these maps are listed in the bibliography.

---

[1] Johnson, C., and Hoagland, A. D., Mineral resources of Benton, Carroll, Madison, and Washington counties: Arkansas Geol. Survey County Report 2, 1940.

[2] Laudon, L. R., New crinoid fauna from the Pitkin limestone of northeastern Oklahoma: Jour. Paleontology, vol. XV, no. 4, pp. 384-391, 1941.

Several excellent concrete and asphalt roads skirt the environs of the Boston Mountains in Arkansas, but the Fayetteville-Fort Smith highway and the Harrison-Little Rock highway are the only paved roads that actually cross the region. In the main, the other roads are graded gravel, crushed rock, or dirt.

The Boston Mountains plateau is sparsely populated, for the most part, there being no important industries, and the land generally is poor for agricultural purposes. The hardwood forests covering the region, however, are one of the most important natural resources, for they not only provide timber but act as agents that retard run-off and hence help preserve the water supply of the district. Part of the Ozark National Forest is in the Boston Mountains and there are several Federal Game Refuges in the area. The Eureka Springs district is a well known scenic region, but inferior roads have deterred travelers from visiting the heart of this scenic country.

PHYSIOGRAPHY

The Boston Mountains comprise an elevated plateau lying north of the Arkansas River Valley and south of the Ozark Plateaus in eastern Oklahoma and northwestern Arkansas. The mountains consist of a steep north escarpment and a gently sloping south side rising from the wide valley of the Arkansas River. The eastern end of the mountains slopes to the east and disappears under a cover of Eocene and younger deposits of the Mississippi Embayment just west of the White River and southwest of the town of Newport. The mountains slope to the west and gradually become a less well defined topographic unit, although they can be traced to Muskogee, Oklahoma, where they terminate at the Arkansas River. The highest portion of the mountains is in Newton and Searcy counties, Arkansas, where the elevation of the top of the mountains is about 2,250 feet and the maximum relief above the adjacent stream beds is about 1,500 feet.

Hershey[1] considers the summits of the Boston Mountains to be representative of a Cretaceous peneplane which extended to the south and was represented by the summits of the Ouachitas. This plane is located at an average elevation of

---

[1] Hershey, O. H., Peneplain of the Ozark Highland: Am. Geologist, vol. XXVII, pp. 25-41, 1901.

2,000 feet in most places but reaches a maximum elevation of 2,257 feet near Winslow. Five hundred feet below the Cretaceous peneplane Hershey located the main Tertiary or "Tennesseean" peneplane, but he found it hardly recognizable within the Boston Mountains. To the north of the mountains the Tertiary plane stands at an elevation of about 1,700 feet. To the south Hershey considered the Tertiary peneplane to slope from an elevation of 1,700 feet at Winslow to 600 feet at Van Buren, the two points being separated by a map distance of 20 miles. The Lafayette (Pliocene or late Tertiary) base-level is represented 300 feet below the Tertiary peneplane by rock terraces along the valley sides of the War Eagle Fork of White River. Finally, the narrow "Ozarkian" valleys are entrenched beneath the Lafayette base-level, being formed in Quaternary times; none of these valleys has been recognized within the Boston Mountains.

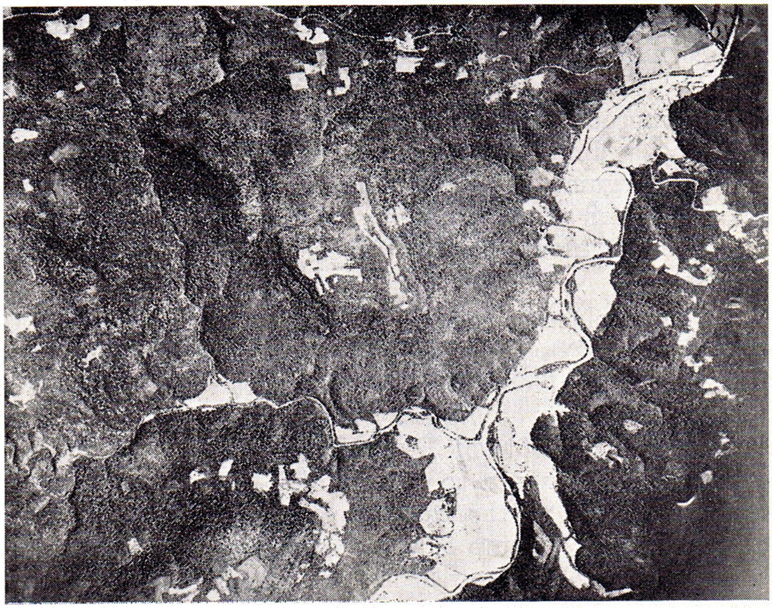


FIG. 1—Aerial photograph of a portion of the Mount Judea quadrangle, showing the bluff and summit rock of the Atoka formation, the lower bluff of the Pitkin limestone, and the wide slope of the Fayetteville shale. (Photo by courtesy of the U. S. Geological Survey.)

Purdue [1] reached conclusions at variance with those stated by Hershey, for he points out that either the drainage of the

---

[1] Purdue, A. H., Physiography of the Boston Mountains, Arkansas: Jour. Geology, vol. IX, no. 8, pp. 694-701, 1901.

Boston Mountains results from elevation of the mountains for the first time, or that the mountains were peneplaned and that the streams in the mountains have been rejuvenated as a result of a second elevation. Purdue thinks the Boston Mountains were lower than the area to the north during the denudation of the latter, the strata at the summit of the mountains being eroded very slightly but the northern continuations of these strata being removed. Elevation of the mountains, which Purdue places in late Tertiary or post-Tertiary time, created the present Boston Mountains. As can be seen, this explanation does not utilize the Cretaceous peneplane proposed by Hershey.

In an article published subsequent to Purdue's work, Hershey[1] reiterated his contention that an older land surface is present north of the Boston Mountains, although he modified some of his previous conclusions regarding the supposed Cretaceous time of the formation of the surface. Hershey states that any uplift of the Boston Mountains would have been accompanied by faulting, but he knew of no large faults near the escarpment. Since the publication of Hershey's paper, numerous faults have been discovered near the escarpment (see section on structure), therefore at least one of Hershey's arguments has been answered. Fenneman[2] gives a short discussion of the problems relating to the physiography of the Boston Mountains, but there is need for more work to be done.

At some places a mountain profile can be observed that shows the gross topographic expression of most of the formations. Such a profile of Boat Mountain can be seen from due east of it on the paved highway between Marshall and Harrison. A similar profile of Point Peter can be seen from the mountain saddle south of Marshall. The Atoka sandstone forms the flat top of the mountains as well as the northward facing bluff near the top of the escarpment. Commonly there is a steep slope or narrow bench below this at the level of the Morrow beds. The Hale and Pitkin are incorporated within the same cliff or bluff which sometimes extends down to include the Wedington sandstone. The base of the mountains slopes away less and less steeply and merges with the plain

---

[1] Hershey, O. H., Boston Mountain physiography: Jour. Geology, vol. X, no. 2, pp. 160-165, 1902.

[2] Fenneman, N. M., Physiography of eastern United States: 1st ed., McGraw Hill Book Company, New York, pp. 657-658, 1938.

to the north. The Fayetteville shale forms the slope and the Boone limestone forms the plain. This plain extends into southwest Missouri adjacent northwest Arkansas, where it is also based on the Boone limestone. In northcentral Arkansas the Boone forms more rugged hills of residual chert with heavy forest cover; this region has been termed "The Barrens." In the Batesville district the rugged topography north of the White River has been carved in the lower Paleozoic rocks.

The topographic expression of the formations of the mountains falls into two general groups of bluffs and benches. Most prominent formation of all is the Atoka, because it is resistant and caps the mountains. Several sandstone units in the formation are cliff-makers and the thicker ones stand out clearly in this heavily forested region, thus offering markers helpful in tracing structural features. Shale beds below the Atoka weather more rapidly than overlying sandstones and hence great blocks of the latter break away from the cliffs and roll or creep far down the mountains. Most of the streams on the escarpment side of the mountains head in the Atoka formation and the streams on the south slope of the mountains also have cut their valleys mainly in the Atoka.

The Morrow beds below the Atoka weather rapidly in the shaly phases and leave the limestone bluffs and ledges unsupported, so there is commonly a low slope with weathered limestone blocks upon it at the Morrow horizon. This slope may merge with that of the Atoka and Hale formations, if these two contain shaly phases in their lower and upper parts respectively. The Hale sandstone is sandier and more resistant in the west than in the east and hence is a bluff-maker in the former district. Usually the contact between the Hale and Pitkin is clearly defined at the top of the Pitkin bluff or cliff.

The Pitkin limestone is the most prominent bluff or cliff-maker in the mountains, since it is thicker than any other single resistant bed. The great bluff about half way up the escarpment is formed by the Pitkin limestone. The verticality of this bluff is maintained by the continual breaking away of large blocks of limestone. The mechanics of this movement depend upon the presence of a system of joints parallel the face of the outcrop and the rapid weathering of the Fayetteville shale. The Fayetteville slumps away from below the Pitkin bluff and the unsupported Pitkin blocks then fall away.

The bluffs near West Fork afford admirable examples of this phenomenon and also show how the Pitkin blocks creep down the Fayetteville shale after they leave the cliff. The Pitkin limestone itself contains less resistant beds which weather out and leave natural shelters within the face of the bluff. Solution cavities are common, generally being located along the major joints. All these features can be seen at the West Fork bluffs. Farther east and back in the mountains the streams are unable to cut through the Pitkin as rapidly as through the other formations, therefore cascades and waterfalls characterize most valleys. Within the Pitkin in the east are several shale beds that are comparatively soft and weather back to form benches, terraces, or reëntrants in the bluff.

The Fayetteville shale is easily weathered and forms a long slope that is steep near the contact with the Pitkin limestone but whose gradient becomes less away from the escarpment and eventually grades into the plains north of the mountains. The Fayetteville shale is not fertile and hence slopes formed upon it can be identified from a distance by the sparse brush it supports. The Wedington sandstone forms a bluff at some places and at others forms rapids or falls in the creeks. When the Pitkin and Wedington are in contact, the two may form the same bluff. The limestone phases of the Fayetteville are not resistant enough to have any noticeable influence upon the topography but they are fairly well defined when seen close at hand by their relatively steep slopes with tabular limestone blocks resting on the surface.

The Batesville sandstone forms a bluff along the White River but is not of much importance topographically in the east and of course is not present in Oklahoma. Its member, the Hindsville limestone, forms low ledges in Madison County and elsewhere, but is also unimportant topographically. The Moorefield shale lies upon the plain near Batesville and generally affords low rolling plains. It is also absent to the west.

The Boone limestone is the cavernous, cherty, thick limestone upon which most of the plain north and west of the Boston Mountains is formed. The residual chert hills provide little opportunity for heavy growths of timber and therefore places where rugged topography obtains are termed "The Barrens" in Arkansas. At some places this relatively uninhabited region is underlain by lower Paleozoic rocks, rather than the Boone limestone. However, the flat plain of Benton

County is developed upon the Boone limestone and is one of the most fertile districts in Arkansas. Caves are common in the Boone and a number are being exploited at this time in northern Arkansas. The St. Joe limestone member of the Boone limestone is a massive crystalline limestone whose most pronounced topographic influence is found in the steep cliffs lining the valley of the Buffalo River in Newton County.

Many outliers of the Boston Mountains stand upon the plain north of the mountains and may be as far as twenty miles from the escarpment proper. These outliers are flat-topped and are generally capped by the Atoka formation, but near Mountain View a few are capped by the Pitkin limestone.

The consequent streams draining the south flank have cut down through the Atoka near Cass, Winslow, Fallsville, Ft. Douglas, and Limestone and have exposed windows in beds of Morrow age. The mountains dip off steeply to the south along the line of these windows and the streams have merely nicked into the upper bend of the monocline. The window at Limestone is orientated east-west, as opposed to the other valleys in the mountains because the streams depart from their typical southerly course to cut down in the zone of the Limestone fault before flowing south again.

The north or escarpment side of the mountains is youthfully dissected by obsequent streams belonging to the drainage system of the subsequent streams north of the mountains. The downdip migration and southward cutting of the tributaries of these subsequent streams maintains the escarpment, whereas the insequent streams dissect out the outliers from the main mass of the mountains.

The Buffalo River and its tributaries in Newton County carry much limestone and sandstone conglomerate which lines one or both sides of the valleys west of Jasper and at other places. These gravel terraces are at varying heights above the streams, though they are nearer the stream beds in the headwaters than in the lower courses. Such non-coördinate levels of the terraces can be explained by the occurrence of natural dams in the courses of the streams. The streams follow a general northerly course which is almost directly up the dip of the rocks, thus when resistant beds were encountered by the streams, a little time was needed for the stream to pierce the stratigraphic barrier and during such times the valleys were widened above the natural dam. When the obstacle was overcome, the upper courses of the stream were rejuvenated and the stream cut down below its former level, leaving the gravel terraces as evidence of its previous elevation. A stratigraphic barrier such as has been suggested to explain these old gravel banks in Newton County is to be seen at Natural Dam in Crawford County.

Caves are common throughout the Boston Mountains, being most common in the cherty Boone limestone. These Boone caves are being exploited in Newton County and Benton County to some extent, but many other caves of monumental proportions are known to the local people.

A few caves also occur in the Pitkin limestone, the most interesting example of which is the Ananias Horton cave in the NE. ¼ NE. ¼, section 5, T. 14 N., R. 16 W., near Bryan School west of Marshall. The cave is in a shatter zone fifty feet south of a fault and is near the base of the Pitkin. There is little or no travertine but the floor of the cave is covered with red dirt. Three large solution cavities in the cave walls are said to have contained skeletons and artifacts of Indians walled up therein.

Another cavern in the Pitkin is on Cave Point, east of Mountain View, in a cherty limestone just below the overlying cap-rock of sandstone. A travertine deposit on the floor of the cave extends out to the edge of the bluff. The cave extends directly back into the mountain and has been formed along a vertical joint in the less resistant cherty limestone.

Springs are abundant in the mountains, generally occurring on the south side of hills because the regional dip is in that general direction. Those issuing from the Boone limestone commonly have the largest volume of water of any of the springs and do not vary much in flow from season to season. Most of the other springs are more or less seasonal and of less volume. Those in the Pitkin generally occur near the base of the formation. One of the largest of the springs in the Pitkin is just east of the road 0.5 mile north of Cane Hill. The springs in the formations above the Pitkin are definitely seasonal and the quality of their water is generally inferior to that of springs in the Pitkin. Sulphur springs are not rare and occasionally salt licks occur, especially in the Atoka formation.

Perched water tables commonly occur where a sandstone is underlain by shale or limestone, with the result that some mountain sides are marked by two or three zones of springs.

GEOLOGY

GENERAL

The formations with which this report is concerned are listed below in a table showing them as tabulated by the early surveys (left) and as the usage is at present (right). The column of older terms is not that of any one writer, but is a composite grouping. It is not within the province of this report to deal with the development of the present-day terminology, hence an elaborate compilation has not been attempted. Extensive tables on the subject can be consulted in various Arkansas Geological Survey and United States Geological Survey reports and folios.

SUMMARY OF THE GENERAL EQUIVALENCY OF FORMATIONS*

Mostly Older Usage			Present-Day Usage		
	Millstone grit (Winslow)	Pennsylvanian	Atoka fm.		
	Shale and Sandstone		Morrow	Bloyd sh.	
Boston Group	Kessler ls.				Kessler ls. lentil
	Coal-bearing sh.				Baldwin coal member
	Pentremital ls.				Brentwood ls. lentil
	Washington sh. and ss.			Hale ss.	
	Archimedes ls.	Mississippian	Chester	U	Pitkin ls.
	Productal ls. Shale and sandstone Marshall sh.			M	Fayetteville sh. Wedington ss. member (Mayes ls. member)
	Wyman ss.			L	Batesville ss. Hindsville ls. member
			Mer.		Moorefield sh.
	Encrinital ls.		Osage		Boone ls. St. Joe ls. member

* Compiled from Arkansas and U. S. Geological Survey publications.

PRE-MIDDLE CHESTER STRATA

The formations from the top of the lower Chester to the base of the Mississippian are not important in interpreting either the stratigraphy or the faunal relations of the Pitkin limestone, hence they are only considered very briefly here. The St. Joe limestone member of the Boone limestone is the cliff-maker along the course of the Buffalo River in and around Newton County. It is frequently referred to as the St. Joe "marble" because of its massive and crystalline nature. The Boone limestone is the thickest Mississippian limestone in northern Arkansas. It occurs to the north of the Boston Mountain escarpment on the rolling plain, but also crops out in some of the mountain valleys, notably in Limestone Valley, Newton County.

The Moorefield shale is very much like the Fayetteville shale in texture, color, and topographic expression. It forms gentle slopes above the Boone limestone in the eastern part of the area.

The Hindsville limestone member of the Batesville sandstone is localized near Madison County, where it forms low bluffs and ledges. The Batesville sandstone is essentially restricted to the eastern part of the mountains, for it thins to the west. It commonly forms a bluff in the Batesville district.

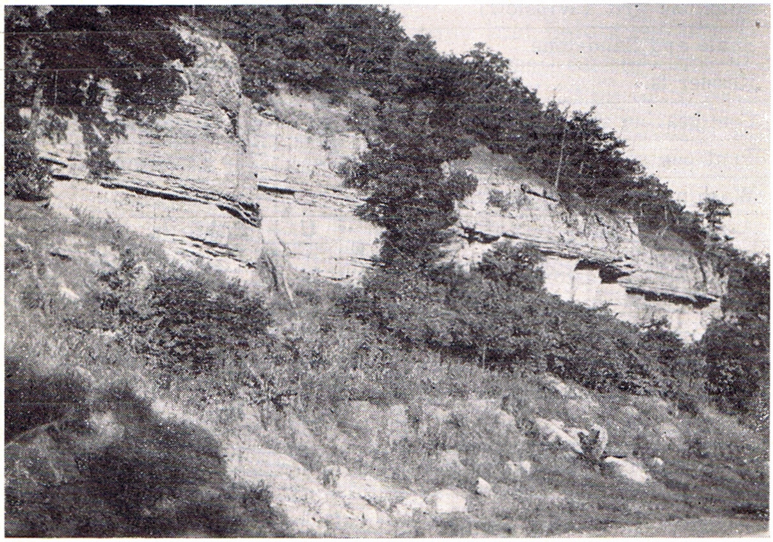


FIG. 2—Bluff of Pitkin limestone 45 ft. high, overlain by shale and sandstone of the Hale and underlain by Fayetteville shale, near West Fork.

FAYETTEVILLE SHALE

Definition. — The Fayetteville shale was named by Simonds[1] in 1891 for beds between the Boone cherty limestone and the Pitkin limestone in northwestern Arkansas, the name being taken from exposures at and near the town of Fayetteville, Arkansas.

Distribution and stratigraphic relations.—The Fayetteville shale crops out along the foot of the Boston Mountain escarpment as well as in the plain north of the mountains. To the east and south of the Batesville district the formation is very prominent because of erosion of the overlying formations. The formation rests upon the Batesville sandstone in the east but because of the westward thinning of the sandstone, the Fayetteville rests upon lower beds and lies upon the Boone limestone in northwest Arkansas.

Character and thickness.—The main body of the Fayetteville consists of brown to black shales. The Wedington sandstone is contained within these shales at about the middle of the formation and the Mayes limestone occurs near the base. An unnamed sequence of black limestone beds separated by thin shale beds commonly is present near the top of the formation. The best exposures of these upper beds are found between Marshall and Batesville. Black limestone has been quarried in a small way at a number of places in the eastern half of the mountains. Near the base of the Fayetteville shale is an horizon of septarian concretions. The thickness of the Fayetteville shale ranges from one hundred fifty to one hundred seventy feet throughout most of the area, but in Searcy County the formation becomes at least three hundred fifty feet thick.

Age.—The upper part of the Fayetteville shale is of late Chester age and the rest is of Middle Chester age, though the recurrent Spring Creek fauna in the Mayes limestone member would indicate Meremacian age for part of it, were the true stratigraphic relationships not understood.

MAYES LIMESTONE

Although no longer recognized as a valid formational name by the United States Geological Survey, the Mayes limestone member of the Fayetteville shale is a recognizable litho-

---

[1] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. 1888, vol. IV, pt. I, pp. 42-49, 1891.

logic unit in Arkansas. The formation consists of thin limestone beds near the base of the Fayetteville shale. These beds commonly crop out near the base of the Boston Mountain escarpment and break down into loose tabular blocks. The Mayes is very thin or absent in the east but increases in thickness westward, attaining its maximum known thickness in Mayes County, Oklahoma. At the foot of the hill along the road leading down from the northeast into Limestone Valley, in Newton County, is an outcrop of limestone here considered to be the Mayes. The age of the Mayes is probably Middle Chester, though a recurrence of the Meremacian Spring Creek fauna in it is confusing.

WEDINGTON SANDSTONE

Definition.—The Wedington sandstone member of the Fayetteville shale was named by Adams[1] in 1904 from exposures of the formation on Wedington Mountain in Washington County, Arkansas.

Distribution and stratigraphic relations.—The Wedington sandstone crops out somewhat below the bluff of the Pitkin limestone on the northwest flank of the Boston Mountains. Commonly the Pitkin limestone rests upon the Fayetteville shale beds, but where the upper shale beds are absent, the Pitkin rests upon the Wedington.

Character and thickness.—The Wedington sandstone is a variable formation, being a fine-grained, hard, buff to brown sandstone at the type locality, but becoming thinner-bedded and more flaggy to the east and west. At some localities the Wedington resembles the Hale sandstone, but the two formations are everywhere separated by intervening shales and limestones. The Wedington is considered to have been deposited in shallow water, for ripple marks are common. The thickness varies from a feather edge to about fifty feet over most of the area, but at the type locality the member displays an exceptional thickness of about one hundred fifty feet.

Age.—The fauna of the Wedington is of Chester age. Moreover, the stratigraphic relations of this formation within other Chester beds establish the age beyond a doubt.

PITKIN LIMESTONE

Definition.—The Pitkin limestone was named by Adams and Ulrich [2] in 1904 from exposures of the formation near Pit-

---

[1] Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, p. 27, 1904.

[2] Op. cit., pp. 27, 109.

kin postoffice in Washington County, Arkansas; although the postoffice is still called Pitkin, the little village has since been renamed Woolsey. This formation is, in part, the "Archimedes limestone" of early writers.

Distribution and stratigraphic relations. — The Pitkin limestone crops out the entire length of the Boston Mountain escarpment in Arkansas and extends into Oklahoma where the mountains are not as prominent. Moore [1] considered the formation in Oklahoma to be divisible into massive, argillaceous, and granular phases, in ascending order. The limestone beds crop out in the outliers north of the Boston Mountains, but usually do not cap these outliers. The best exposures are to be found in the stream valleys dissecting the escarpment. Throughout most of the area the Pitkin rests upon the Fayetteville shale or the members of the Fayetteville. In the west the Wedington sandstone member underlies the Pitkin at some places, but at no place in Arkansas does the Pitkin seem to lie upon beds older than the Wedington. In the east the Pitkin rests upon the upper black limestone beds of the Fayetteville and is difficult to distinguish from these beds where the lithology is similar, for at such places there are not many fossiliferous beds. The upper limit of the Pitkin limestone is well marked in the west by the contact with the overlying Hale sandstone. In the east the upper boundary of the Pitkin is in doubt because the upper members of the limestone sequence may be of Morrow age. The details of this are discussed elsewhere.

Character and thickness.—The Pitkin limestone consists, in the main, of grey or blue-grey, fossiliferous, oölitic limestone. Locally the limestone may contain chert either near the top or bottom of the formation. Beds of shale ranging from partings to aggregates of tens of feet occur in the eastern part of the area. Sandstone is reported from the upper portion of the limestone in the northwestern part of the mountains but at no place does it represent an important lithologic phase. One small lens occurs near the base of the formation in the bluffs near West Fork; the lens is not more than eighteen inches thick and feathers out in a short distance. Conglomerate is not commonly present, but in Washington County many outcrops contain it, usually in thin beds near the north-

---

[1] Moore, C. A., Morrow group of Adair County, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 24, no. 3, pp. 409-434, 1940.

ern limit of the formation. This is an indication that the shore of the Pitkin sea was not far north of the present northern limit of outcrop. Not all the conglomerates in the area are of Pitkin age, however, for some are of Hale age and contain pebbles of Pitkin limestone and reworked Pitkin fossils. The oölitic limestone phases of the Pitkin are present in most sections but this feature is not of sufficient importance to distinguish the Pitkin from the Morrow limestones. Near Cane Hill the cross-bedded oölitic limestones show by their direction of bedding that the currents were from the south. The cherty phases of the formation have not been considered of much importance heretofore, but at several localities some beds may be half chert by volume. The cave at Cave Point is formed in such a cherty limestone. The chert in the lower beds occurs near the Fayetteville-Pitkin contact. Such an occurrence can be seen in the bluff west of Iceledo School, where, as is commonly the case in such phases, there are few fossils. The black Pitkin limestones are also near the base of the formation and hence cause considerable difficulty in differentiating Fayetteville and Pitkin beds in the eastern part of the mountains. Moore[1] studied insoluble residues of the Pitkin in Oklahoma and concluded that they were not distinctive enough for stratigraphic use.

The thickness of the Pitkin limestone ranges from a feather edge to perhaps four hundred feet or more, though the exact maximum thickness is not known. The average thickness ranges from about fifty feet in the west to about two hundred feet in the east. A number of measured sections are given elsewhere.

Age.—The Pitkin limestone has been placed in the Upper Chester. Ulrich [2] was the first to make a careful examination of the fauna and Snider [3] was the first to attempt any extensive correlation of the formation with other Chester formations. Snider considered the Fayetteville and Pitkin to be the equivalent of the Okaw and Menard of the Mississippi valley.

---

[1] Op. cit.

[2] Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, p. 109, 1904.

[3] Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, pt. I, p. 43, 1915.

HALE SANDSTONE

Definition.—The Hale sandstone was named in 1905 by Adams and Ulrich[1] from exposures on Hale Mountain in Washington County, Arkansas.

Distribution and stratigraphic relations.—The Hale sandstone occurs in the western part of the mountains, but has not been identified definitely in the eastern part. The lower sandstone bed typically present in the west thins out and probably is absent in the east. The shaly phases may be present but as yet they have not been certainly recognized and differentiated from the other shales there. The sandstone of the Hale is present at Low Gap in Newton County and is somewhat thinner there than to the west.

Character and thickness.—The basal conglomerate of the Hale, though absent at some places, is usually a well-marked phase, attaining a thickness of about fifteen feet on the mountain south of Henson Branch west of Diamond Cave near Jasper. Moore[2] has recently shown the conglomerate to be phosphatic in Oklahoma, and it is probably phosphatic in Arkansas. In the west the rather massive sandstone phase predominates, but to the east this sandstone thins out and the Hale may be largely represented by sandy shales such as occur in the west with the sandstone. The thickness of the Hale ranges from a feather edge to about three hundred feet on Dierra Mountain in the Eureka Springs quadrangle.

Age.—The Hale sandstone is the oldest of the Pennsylvanian formations in this region. The faunal relations were worked out by Mather[3] and are somewhat similar to those of the Brentwood limestone.

BLOYD SHALE

The Bloyd shale was named in 1907 by Purdue[4] from exposures on Bloyd Mountain in Washington County. The various members and lentils, the Brentwood limestone, Baldwin coal, and Kessler limestone will be discussed in the following paragraphs. These units are commonly within the main mass of the Bloyd shale, but at some places they form either the top or the bottom of the formation.

---

[1] Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), p. 4, 1905.

[2] Op. cit.

[3] Mather, K. F., The fauna of the Morrow group of Arkansas and Oklahoma: Denison Univ. Sci. Lab. Bull., vol. XVIII, art. 3, pp. 65-89, 1915.

[4] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), p. 3, 1907.

BRENTWOOD LIMESTONE

Definition.—The Brentwood limestone lentil of the Bloyd shale was named in 1904 by Adams and Ulrich[1] from exposures of the beds near the station of the same name south of Fayetteville. This name takes the place of the 'Pentremital limestone' of previous usage. The type locality is near the famous *Pentremites* collecting ground, the 'Acorn Cut' of local designation.

Distribution and stratigraphic relations.—The Brentwood is typically exposed in the western Boston Mountains. It may extend to the eastern end of the mountains, but this fact has not been definitely established. Morrow limestone occurs near Campbell in eastern Searcy County where a thick shale bed separates two thick sequences of limestones and at least part of the upper sequence is of Morrow age. The Hale sandstone, however, was not observed at this locality. In Oklahoma the Brentwood lies upon the Pitkin at some places and overlies beds older than the Pitkin to the north of the Tahlequah and Muskogee quadrangles. The Brentwood thins to the east and northeast in Arkansas toward the Harrison quadrangle, but possibly increases in thickness southeast of that area. The most northeasterly exposure in the Harrison quadrangle is in T. 17 N., R. 22 W., near Compton, where irregular distribution of the formation suggests that the basin of deposition had several arm-like extensions over the previously deposited shales.

Character and thickness.—The Brentwood limestone consists of massive beds of blue-grey to brown, fossiliferous, crystalline limestone separated by beds of hard shale and impure limestone of varying thicknesses. In Arkansas, the maximum thickness of about eighty feet is in Washington County, but the formation possibly becomes much thicker to the southwest in Oklahoma. To the east and west in Arkansas the Brentwood thins out and may disappear. Apparently the formation is a lentil in Arkansas. The known thinning of the limestones to the northeast of the type locality is accompanied by an increase in impurities and number of shale beds.

Age.—The Brentwood limestone is pre-Pottsville but post-Mississippian in age, as shown by the faunal analysis of

---

[1] Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, p. 28, 1904.

Mather.[1] Mather wrote that the Morrow group, of which the Brentwood limestone is the most fossiliferous and important unit, represents beds containing proemial Pennsylvanian fossils, but retaining residual elements of the Chester faunas.

BALDWIN COAL

Definition.—The Baldwin coal was named in 1930 by Croneis [2] for exposures of the 'Coal-bearing shales' of earlier writers, the name being chosen from Baldwin, in Washington County, near where the coal seam has been exploited.

Distribution and stratigraphic relations.—The entire outcrop of the Baldwin coal has not been traced, but it is known to occur throughout much of Washington and Madison counties. It lies within shale beds of the Bloyd shale, above the Brentwood and below the Kessler limestone. The Baldwin may be equivalent to one or another of the coal seams that have been located at several places in the mountains. Purdue and Miser [3] say the Baldwin is limited to the area west of the Eureka Springs quadrangle.

Character and thickness.—The Baldwin coal lies within a sequence of highly carbonaceous shales. The carbon ration or percentage of fixed carbon, as computed from data given by Croneis,[4] is 70.76 for thirteen samples. The coal is said by Simonds [5] to be from six to fourteen inches thick.

Age.—The age of the Baldwin can best be determined from its stratigraphic relations with other formations. David White [6] examined the fossil flora and considered it similar to that of the Sewanee group (Pottsville) of Tennessee.

KESSLER LIMESTONE

Definition.—The Kessler limestone lentil of the Bloyd shale was named in 1891 by Simonds [7] from exposures on Kessler Mountain in Washington County.

Distribution and stratigraphic relations.—The Kessler, like most of the formations in the mountains, crops out southward in the stream valleys in western Arkansas and extends

---

[1] Op. cit., pp. 59-284.

[2] Croneis, C. G., Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, p. 82, 1930.

[3] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 15, 1916.

[4] Op. cit., p. 362.

[5] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. 1888, vol. IV, pt. I, p. 93, 1891.

[6] White, C. D., The Pottsville series along New River, West Virginia: Geol. Soc. America Bull., vol. VI, p. 316, 1895.

[7] Op. cit., pp. 103-105.

east as far as the southwest corner of the Eureka Springs quadrangle in the vicinity of Huntsville. Farther east the Kessler has not been recognized, thus, either it was not deposited there, or, if deposited, it has been subsequently eroded. The Kessler typically occurs within the upper shales of the Bloyd.

Character and thickness.—The Kessler is a coarsely crystalline, grey to brown, very fossiliferous limestone. In Washington County it forms a convenient marker as the first limestone below the Atoka formation. It is readily recognized on the outcrop by the chocolate brown color of the weathered surfaces. The limestone is commonly about ten or fifteen feet thick, but because of slumping, it is very difficult to locate at horizons where it is thinner than that. It does not exceed ten feet in thickness near Huntsville and commonly is a single ledge about a foot thick.

Age.—The fauna of the Kessler shows that it is more definitely Pennsylvanian than other members of the Bloyd, according to Croneis.[1] It has been suggested that the Mississippian-Pennsylvanian contact should be placed at the top of the Brentwood. This would place the base of the Pennsylvanian below the Kessler, which might be proper, but the formations of the Morrow group below this hypothetical boundary also contain Pennsylvanian faunal elements, so the splitting of the Morrow group is not advisable, even though it would separate beds with a typical Pennsylvanian fauna from those characterized by a proemial Pennsylvanian assemblage.

ATOKA FORMATION

Definition.—The Atoka formation was named by Taff and Adams[2] in 1900 from exposures near the village of Atoka, Oklahoma.

Distribution and stratigraphic relations.—The Atoka formation occurs throughout the length of the Boston Mountains in Arkansas, everywhere cropping out as the uppermost formation when present. It is the most widely exposed Paleozoic formation in the state, and extends south to the Arkansas River valley like a great blanket. It is overlain by the Hartshorne sandstone in the southwest. It rests upon

---

[1] Op. cit., p. 87.

[2] Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey 21st Ann. Rept., Part II, p. 273, 1900.

the Morrow group of limestones and shales in the west, but it possibly rests upon older beds in the east where subsequent study may show that the Atoka rests upon the Pitkin limestone.

Character and thickness.—The formation consists of shales and sandstones, each varying from a few inches to many feet in thickness, succeeding each other in confusing array. The sandstone tends to predominate in the east. Limestone is not commonly present but there are some beds of calcareous sandstone. The Atoka ranges from nearly white to very dark reddish-brown. Although the formation has a maximum thickness of seven thousand feet, it attains but a fraction of that thickness in the Boston Mountains. It ranges from a feather edge at some places near the escarpment and increases in thickness to the south, not exceeding about fifteen hundred feet in thickness in the Boston Mountains. It is extremely difficult to identify horizons in the Atoka because of thickening and thinning of the various beds and because of the great number of lithologic changes.

Age.—The Atoka is apparently of Pottsville age, although complete floral and faunal analyses of the formation have not been made. The relative age can be ascertained most readily from its stratigraphic relations.

"WINSLOW FORMATION"

The status of the "Winslow" is best given by Wilmarth:

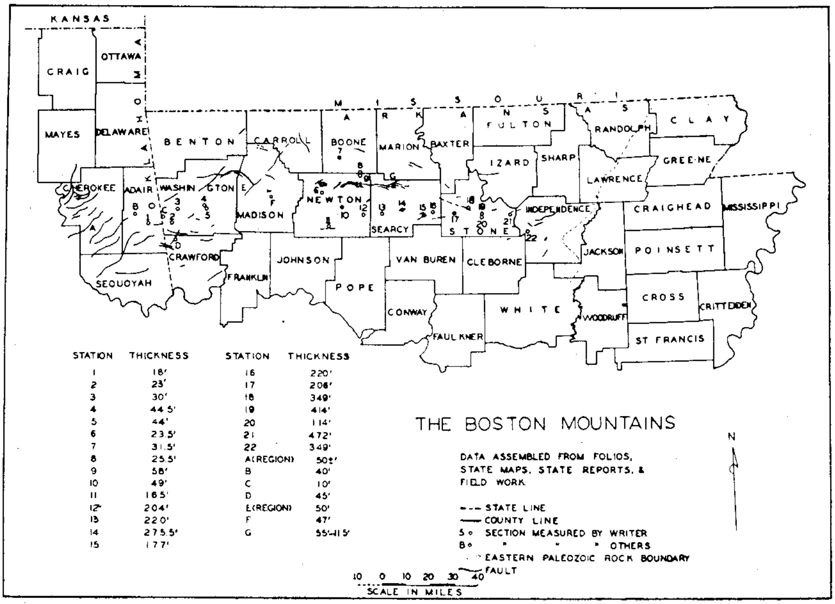
> "The strata included in Winslow fm. are of late Pottsville and early Allegheny age. That it is a blanket term covering rocks susceptible of subdivision into several fms. has long been recognized by J. A. Taff, C. Croneis (Ark. Geol. Surv. Bull. 3, 1930), and other geologists. According to field work of B. Parks and T. A. Hendricks, all of it that is present in Fayetteville quad. is now known to belong to Atoka fm. In Winslow quad. it included Atoka fm., Hartshorne ss., and lower part of McAlester fm.; and as used in some other areas it included, in addition, upper part of McAlester fm., the overlying Savanna ss., and at least the lower part of Boggy sh. This blanket name has therefore been discarded."[1]

---

[1] Wilmarth, M. G., Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, Part 2, p. 2354, 1938.

STRATIGRAPHY OF THE PITKIN LIMESTONE

The following index map of the area of the Boston Mountains shows the known faults and the locations of stations where the thickness of the Pitkin has been recorded. The numbered stations correspond to the numbers of the columnar sections which follow in the text. The lettered stations are those at which the thickness of the formation has been determined by geologists other than the writer. An especial attempt has been made to find localities at which the formation is exposed as fully as possible and at which the upper and lower limits are clearly discernible. Obviously, such a combination is not always obtainable, but the precipitous grades of the streams descending northward from the Boston Mountains do present many cleanly exposed sections or portions thereof. Very few cuts line any of the few roads traversing the region and most of the territory is very heavily forested. In view of these facts, the writer spent most of the field work in the western portion of the area in order to do at least a portion of the work rather thoroughly. Therefore, the eastern portion of the mountains is known in less detail than the western portion. As much of each section as



STATION	THICKNESS	STATION	THICKNESS
1	18'	16	220'
2	23'	17	208'
3	30'	18	349'
4	44.5'	19	414'
5	44'	20	114'
6	23.5'	21	472'
7	31.5'	22	349'
8	25.5'	A(REGION)	50±'
9	58'	B	40'
10	49'	C	10'
11	165'	D	45'
12	204'	E(REGION)	50'
13	220'	F	47'
14	275.5'	G	55'-115'
15	177'		

FIG. 3—INDEX MAP OF THE AREA OF THE BOSTON MOUNTAINS

possible was measured with a steel tape and the rest with a Brunton compass, all work being checked against available topographic sheets.

OKLAHOMA

The Pitkin limestone crops out in the east half of the Muskogee quadrangle along parallel faults. The thickness varies but little from fifty feet in this quadrangle. The character of the limestone is variable, but the granular and oölitic phases are the most typical.

The upper boundary of the Pitkin is hard to distinguish where the Hale is absent, but a shale bed commonly separates the Pitkin from overlying formations. Only a careful study of the fossils will enable the differentiation of Morrow limestones from the Pitkin where the two are in contact. The lower boundary of the Pitkin is readily identified in western Arkansas and eastern Oklahoma because of the change from the Pitkin limestone to the Fayetteville shale (or Wedington sandstone).

In the Tahlequah quadrangle the Pitkin is thinner to the north than to the south, but variations of two to three times the thickness of about 18 feet at locality No. 1 occur north and south of that locality. The maximum thickness in this

FIG. 4—Irregularities in the bedding near the base of the Pitkin limestone, as shown in the road cut south of Mountain View. (Hammer for scale.)

quadrangle is 65 feet, according to C. A. Moore.[1] He believes there is a topographic high near the center of Adair County, and that the formations thin around this high in all directions, the average thickness of the Pitkin for the county being 30 feet. Moore recognizes an upper granular phase, a middle argillaceous phase, and a thick lower massive limestone phase. After studying the insoluble residues of the Pitkin, Moore concludes that they are not uniquely characteristic of the Pitkin, hence could not be used solely in identification of the formation. In Adair County above the Pitkin the Hale everywhere crops out, thus there is little difficulty in differentiating Pitkin and Morrow beds. In this area the most notable feature of the Hale is its phosphate content, which ranges up to about 3% in the basal conglomerate.

Columnar Section No. 1

Section on the west side of the hill one-half mile east of Stillwell, Oklahoma, in the NW. ¼, NE. ¼ section 2, T. 15 N., R. 25 E. (Snider's locality No. 1).

PENNSYLVANIAN
Hale sandstone.
Massive sandstone with *Lepidodendron.*
Coarse-grained, crystalline, red-speckled limestone.

MISSISSIPPIAN	ft.	in.
Pitkin limestone.		
Nodular impure limestone and dark shale		3
Massive, dark grey, fine-grained limestone	1	1
Nodular, dark grey, fine-grained, impure limestone and black shale	1	11
Hard, grey, medium-grained limestone	1	3
Wavy, black shale		1
Buff to grey, coarse-grained, crystalline limestone		5
Wavy black shale with knobby, grey, impure limestone		5
Hard, dark grey, fine-grained, crystalline limestone		4
Covered (shale and limestone in thin bands)	5	11
Hard, light grey, coarse-grained limestone	1	
Medium-grained, grey, brittle limestone		11
Massive, buff to grey, coarse-grained, crystalline limestone	4	2
Total	17	9

Fayetteville shale.
Poorly exposed slope of weathered shale.

At Columnar Section No. 1, where the Pitkin is more thinly bedded than at most localities, a bed of limestone speckled with red calcite crystals occurs between the Pitkin and the Hale sandstone, but actually is of Morrow age. In general, the upper part of the Pitkin is less massive than the lower portion, therefore the strata at Columnar Section No. 1

---

[1] Moore, C. A., Morrow group of Adair County, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 24, no. 3, p. 415, 1940.

are probably upper Pitkin. The lower beds of the formation were not deposited in this area, if the foregoing assumption be true.

In the Pryor quadrangle the Pitkin is overlain by the Brentwood, but the former strata extend only a short distance into the area. The Pitkin is thinner here than to the south and eventually feathers out. The Brentwood continues to crop out to the north beyond the northernmost Pitkin extension.

THE FAYETTEVILLE QUADRANGLE

In most places the Pitkin limestone was deposited in quiet water, but there is a minor amount of cross-bedding and conglomerate. More important is the presence of conglomerate at the base of the Hale sandstone, for this conglomerate contains Pitkin pebbles and waterworn Pitkin fossils. In this quadrangle the Pitkin is disconformable both above and below, the actual angularity of contacts not being enough to be recognized at any single exposure.

The northward thinning of the Pitkin is pronounced in this quadrangle, where one is able to see the effects of the nearshore deposition in the Pitkin sea. The pebbly zone mentioned in the literature is undeniably of Pitkin age at some localities near Fayetteville, but without doubt the basal conglomerate of the Hale sandstone has been confused with this rubble zone at other places.

WINSLOW QUADRANGLE

Columnar Section No. 2

Section on Hale Mountain continuing up the creek from behind the house of Mr. Earl Reed, in the SW. ¼, NE. ¼ section 6, T. 13 N., R. 32 W.

PENNSYLVANIAN

Hale sandstone.

Sandstone and sandy shale with lower part poorly exposed.

MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Massive, grey, coarse-grained, fossiliferous limestone with plates of calcite	5	
Concealed (shale?)	1	6
Dark grey, fossiliferous, crystalline limestone	1	
Dark grey, fossiliferous, crystalline limestone with calcite seams	1	6
Massive, dark grey, medium-grained limestone with crinoid fragments present as calcite plates	1	
Dense, non-fossiliferous, grey, cherty limestone		6
Coarse-grained, fossiliferous grey limestone	1	
Covered	1	
Unevenly bedded oölitic limestone		10

Dense, medium-grained, oölitic limestone	1	2
Covered	1	
Massive, fossiliferous, grey, medium-grained limestone	1	
Black, somewhat concretionary limey shale	1	4
Massive, fossiliferous, grey, cherty limestone	1	
Concealed	2	10
Massive, fossiliferous, dark grey, coarsely crystalline limestone	3	
Total	24	8
Fayetteville shale.		
Grey clay shale.		

This section was previously measured by Giles and Brewster.[1] Some of the details are taken directly from their section but better exposed portions near the base permit more accurate descriptions of some of the beds than could be given ten years ago. The exposure of more beds has also necessitated increasing the thickness of the section slightly.

At Columnar Section No. 2 the Pitkin rests with apparent conformity upon the Fayetteville shale. The contact of the Pitkin with the Hale is not well defined; the base of the Hale at this place is arenaceous and not conglomeratic. The most notable local feature of the Pitkin is its chert content. Chert, however, occurs locally in the basal portions of the formation throughout its outcrop.

Columnar Section No. 3

Section at the rock quarry and fifty yards north of it in SW. ¼, SW. ¼ section 4, T. 14 N., R. 32 W., ½ mile north of Cane Hill (Boonsboro).

PENNSYLVANIAN		
Hale sandstone.		
Coarse sandstone and sandy shale.		
Hale sandstone (?).	ft.	in.
Massive, grey, fine-grained, sandstone with streaks of carbonaceous material; disconformity at top	6	1
Soft black shale; sandy concretions at base		9
Total	6	10
MISSISSIPPIAN		
Pitkin limestone.		
Massive, jointed, brittle, buff limestone	4	10
Dark, coarsely crystalline, crinoidal limestone becoming finer grained near the base	10	
Oily, black, soft shale with Bryozoa and crinoid fragments		½
Dark, fine-grained, dense, brittle limestone with basal bands of pure, hard, denser limestone 2″ thick; less fossiliferous than upper dark bed	4	4
Grey, finely oölitic, fossiliferous limestone	3	8
Fissile, brown to black shale		6
Fine-grained to coarse-grained, grey, fossiliferous limestone	1	4
Fine-grained to medium-grained, grey, fossiliferous limestone	3	6
Black shale parting		½
Coarse, grey, crystalline limestone		8

---

[1] Giles, A. W., and Brewster, E. B., Hale Mountain section in northwest Arkansas: Am. Assoc. Petroleum Geologists Bull., vol. XIV, no. 2, pp. 121-138, 1930.

Black shale		2
Coarse, crystalline limestone with calcite seams	1	6
Total	30	1

At Columnar Section No. 3, the most notable features of the formation are shale partings, massive crystalline limestone beds without thin-bedded upper strata, and the cross-bedded lower oölitic limestone. The cross-bedding in the last-named unit shows the direction of the current to have been from the south. At the top of the road metal quarry at this section is a thin brownish black shale and a sequence of massive carbonaceous sandstones with a gently undulating disconformity at the top. These beds are unfossiliferous and lithologically unlike the Pitkin limestone, yet, are also dissimilar to the Hale. They are placed in the section as Hale strata, however, because they may represent the less coarse deposits swept out farther into the ocean during the time that the Hale conglomerate was being formed along shores to the north. The known Pitkin conglomerates are not dominantly sandy, but the Hale beds commonly are. Sandstone is known to occur within the Pitkin limestone, but at this locality there is even less evidence that this sandstone belongs to the Pitkin than that it may be of Hale age.

Columnar Section No. 4

Section at the vertical bluff on the spur above and west of the West Fork of White River in SE. ¼, NW. ¼ of section 32, T. 15 N., R. 30 W., ½ mile north of West Fork.

PENNSYLVANIAN
  Hale sandstone.
    Sandy paper shale with thin limestone beds.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Massive, dense, light grey, crystalline limestone with a streak of intraformational conglomerate	10	
Thinly bedded, light grey limestone with sandy, shaly, and nodular limestone phases; a zone of stylolites near the base	17	
Thickly bedded, dense, grey, finely crystalline ls	6	6
Black shale, forming deep re-entrant		6
Massive, dense, crystalline, blue-grey limestone	10	6
Total	44	6

Fayetteville shale.
  Black shale.

At Columnar Section No. 4 a nearly vertical bluff of Pitkin limestone is exposed, and the formation is practically all massive limestone beds. The Hale lies upon the Pitkin with apparent conformity and the Fayetteville shale below also seems conformable. One of the rare occurrences of stylolites in the Pitkin may be seen near the base of the 17-foot limestone bed.

Columnar Section No. 5

Section at bluffs, above the West Fork of White River on U. S. Highway No. 71, center of the W. ½, NW. ¼ section 4, T. 14 N., R. 30 W., ¾ mile southeast of West Fork.

PENNSYLVANIAN
Hale sandstone.
Coarse sandstone with fragments of limestone (from the Pitkin, probably) and crinoid stem plates.

MISSISSIPPIAN

Pitkin limestone.	ft.
Massive, crystalline, grey limestone	17
Black, limey shale with limestone nodules and commonly an efflorescence on the surface; fossiliferous	2
Irregularly bedded, grey, crystalline limestone	11
Fine-grained, dark grey massive limestone with irregular bands of crinoid fragments	14
Total	44

Fayetteville shale.
Black shale.

Columnar Section No. 5 is one of the most noteworthy exposures of Pitkin limestone in Arkansas. This is in the region of the type section of the formation. A rock shelter is formed at some places along the bluffs where the lower part of the limestone is more readily weathered. The actual delineation of separate strata within the formation is singularly difficult, even within comparatively short distances, because beds thin out, and are variable in texture, bedding, color, in the number of fossils, and thickness. At some places on the bluff two readily weathered beds can be seen, whereas a short distance away three similar beds occur. This variable character of the Pitkin is pointed out in order to demonstrate that near the type locality, as well as all across the mountains, correlation of individual strata is very difficult except in some special cases. The section discussed above, for instance, does not show a small lenticular body of sandstone which crops out in the bluff just to the south of the measured section. Because this lentil was not observed at other places, it is not considered typical of the Pitkin and hence was not included in the measured section. Some of the finer-grained phases of the limestone at the bluffs show bands of crinoidal fragments which indicate that there was appreciable current during the deposition of the limestone.

EUREKA SPRINGS QUADRANGLE

The outcrop of the Pitkin limestone is roughly restricted to the southernmost tier of townships in this quadrangle. The formation's thickness is about 50 feet in the west, only half that thickness in the east, and it feathers out rapidly to the north. The formation consists of fairly thick beds of somewhat impure limestone which weather into angular blocks and thin plates with unrounded edges. Purdue and Miser [1] found that the Hale conglomerate, which commonly overlies the truncated edges of the Pitkin limestone is 10 feet thick near Kingston and contains pebbles derived from the Pitkin. At Spring Valley the conglomerate is 1 foot thick and contains chert fragments which probably were derived from the Boone limestone farther to the north. The area of outcrop of the Pitkin limestone in this quadrangle has been folded and faulted so that the Pitkin does not line the valley walls as regularly as it does farther east and west. Just south of the bridge over War Eagle Creek in the SE.¼ NW.¼ section 25, T. 16 N., R. 26 W., a narrow band of Pitkin limestone borders both sides of the creek. Many dozens of cup corals appear in weathered sections on the east bank.

SOUTHERN MADISON COUNTY

This area has not as yet been mapped either topographically or geologically. The Pitkin limestone crops out only in a few places, the most extensive exposures being in the valleys of White River and of Richland Creek in T. 15 N., R. 28 W.

The War Eagle Oil and Gas Company's well drilled south of Huntsville in section 13, T. 15 N., R. 26 W., penetrated 47 feet of Pitkin limestone overlain by Hale sandstone and underlain by shale of the Fayetteville, according to Croneis.[2] This well, a few miles south of the Wharton arch and the Reed Creek fault, reached the pre-Cambrian at 2,286 feet, after having started 56 feet above the top of the Pitkin limestone.

HARRISON QUADRANGLE

In the southwest portion of this area the Pitkin is about twenty feet thick, just as is the case in the southeastern part

---

[1] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

[2] Croneis, C. G., Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, pp. 188-189, 1930.

of the Eureka Springs quadrangle to the west, but farther to the east in the Harrison quadrangle, the formation is about twice that thick.

Columnar Section No. 6

Section at the big spring at Low Gap, west of the general store and Post Office, in SW. ¼, NE. ¼ section 33, T. 16 N., R. 22 W.

	ft.	in.
PENNSYLVANIAN		
Hale sandstone.		
Shaly sandstone.		
MISSISSIPPIAN		
Pitkin limestone.		
Cross-bedded, fine-grained, buff limestone	1	
Coarsely crystalline, red-specked limestone	4	
Dense, finely crystalline, grey or buff, laminated limestone, finely oölitic in part	7	
Massive, laminated, coarse-grained limestone with crinoid fragments and more oölitic	2	
Dark grey, dense, fine-grained limestone with a strong odor of hydrocarbons; black oily bands of shale occur also	1	8
Massive, dense, grey, fine- to medium-grained from top to bottom, limestone that weathers into small blocks	7	11
Total	23	7
Fayetteville shale.		
Hard, black, brittle shale.		

At Columnar Section No. 6 the Pitkin forms a low bluff with a large spring flowing from the lower part. Here the formation is not as massive, but consists of thin beds of limestone with numerous thin shale beds. This exposure is of beds typical of the upper portion of the Pitkin limestone where thicker exposures occur, thus the lower beds possibly were not deposited in this area, inasmuch as no evidence of erosion of Pitkin limestone is apparent at this place. In order for the lower beds to be omitted without being eroded subsequent to deposition, there must have been a widespread high in this region during Pitkin time, only the upper beds of the formation having been laid down over the shoal. The contact of the Pitkin and Hale is disconformable, thus some of the uppermost beds of the Pitkin were eroded in pre-Hale time. No conglomerate was seen, the upper Hale consisting of a massive sandstone underlain by thinner sandstones, the whole formation being thinner than to the west or the north. This eastward thinning of the Hale is of great importance, for, if the diminution of thickness persists, the place will be reached where the upper Morrow beds will rest upon the Pitkin, from which they can be distinguished only through detailed faunal comparisons.

Columnar Section No. 7

Section on Gaither Mountain 100 yards north of the beginning of the southward swing of the east slope in the center of section 14, T. 17 N., R. 21 W.

PENNSYLVANIAN
Hale sandstone.
Sandstone above sandy shale.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Dense, fine-grained, grey limestone	3	10
Medium-grained, fossiliferous limestone	2	
Dark grey, knobby, impure, fossiliferous limestone	1	2
Dense, dark grey, unevenly weathered limestone	3	6
Massive, medium-grained, grey to buff, varyingly oölitic limestone	12	4
Fine-grained, dense, grey limestone	2	8
Massive, coarsely crystalline, buff, crinoidal limestone	6	
Covered (Wedington sandstone is 11′10″ below)		
Total	31	6

Fayetteville shale.
Black shale above Wedington sandstone.

At Columnar Section No. 7 the Pitkin is ten feet thicker than at the preceding section. All but perhaps a foot of the formation is exposed, but the omission of a small thickness of the Pitkin from the measured section is not important, for its inclusion would not obscure the fact that within a mile or so to the north, the formation thins out to such an extent that its outcrops are very hard to discover. The formation probably feathers out not far north of the last detected outcrop. At the south end of the mountain where Columnar Section No. 7 was measured, the Pitkin is much more massive than at Columnar Section No. 6, thus perhaps these beds lie on the north bank of the pre-Pitkin topographic high previously hypothecated. The upper, less massive beds, then, would have been eroded in post-Pitkin time.

Columnar Section No. 8

Section about one hundred yards south of the beginning of the northwest swing on the northeast slope of Boat Mountain, on the Boone-Newton County line, in section 20, T. 17 N., R. 19 W.

PENNSYLVANIAN
Hale sandstone.
Shaly sandstone.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Coarse-grained, buff, crinoidal limestone	3	6
Varyingly oölitic, buff, flaggy-weathering, fossiliferous limestone	4	9
Dense, dark grey, coarsely crystalline limestone	1	3
Knotty, impure, easily weathered limestone		8
Grey, dense, coarsely crystalline limestone	3	4
Buff, iron-spotted, coarsely crystalline limestone	1	

Grey, fine-grained, dense limestone from 0″ to	1	2
Buff, coarsely crystalline limestone	3	3
Grey, coarsely crystalline limestone	6	6
Total	25	5

Fayetteville shale.
Brown to black shale.

At Columnar Section No. 8 a nearly complete section of the Pitkin was measured, but here again the foot or so that is covered is not sufficient to obscure the rapid thinning of the formation. In considering this section, it is also necessary to study Columnar Section No. 9, measured at the south end of the same mountain a mile distant. At the latter locality, about twice the thickness of the outcrop at Columnar Section No. 8 occurs. A very striking feature of the sections is that the same strata seem to be represented in each, but the individual thickness of each bed decreases from the south to the north. This, in combination with post-Pitkin erosion of the limestone, causes the northward thinning of the formation. Although similar thinning of each bed has not been observed at many localities, it is probably one of the most important factors in explaining the northward thinning of the formation. Obviously, if all beds thinned as rapidly as the ones exposed on Boat Mountain, the formation would extend only a short distance north of that locality. That it does extend for a considerable distance to the north is explained by the occurrence of many more or less lenticular beds within the formation which thin to the east and west, as well as to the north. It is very difficult to correlate strata within the formation from township to township along the mountain front, because of this thinning. Only the sequences of beds can be correlated, and these not too accurately from sections about six miles apart. As one walks the outcrop, a specific bed may either thin out or undergo a change in texture or composition, yet, when considered with neighboring beds, the gross appearance of the sequence may remain the same.

Columnar Section No. 9

Section on the south end of Boat Mountain about two hundred yards or less east of the hairpin curve of the road to the fire tower, in section 20, T. 17 N., R. 19 W.

PENNSYLVANIAN
Hale sandstone.
Sandy shale and sandstone.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Grey, medium- to coarse-grained limestone	10	6
Medium-grained, buff, oölitic limestone	10	

Dense, grey, fine-grained, brittle, coralline limestone	3	
Dense, massive, mixture of coarsely crystalline crinoidal limestone and massive fine-grained light grey limestone	5	6
Medium-grained, darker grey, poorly bedded limestone	7	
Massive, bedded, grey, medium to coarse-grained, crystalline, limestone with color bands	6	6
Medium-grained, unevenly bedded, buff, limestone	4	
Coarse-grained, massive limestone	8	
Dense, wavy, crystalline limestone	1	
Calcareous, fine-grained, dark grey sandstone that weathers reddish	2	3
Total	57	9
Fayetteville shale.		
Black to brown soft shale.		

The sandstone bed at the base of the Pitkin at Columnar Section No. 9 may have a bearing on the Pitkin-Fayetteville contact. Although, as in the Fayetteville quadrangle, no single exposure was seen to display a definite disconformity between the two formations, it has been considered that the two formations are disconformable because at different localities the Pitkin rests upon different phases of the Fayetteville, the oldest of which is the Wedington sandstone. This lack of conformity seems less important to the south than to the north, so there probably was some erosion of the Fayetteville to the north before Pitkin time. The sandstone bed near the base of Columnar Section No. 9 at Boat Mountain is evidence of erosion. A similar occurrence of sandstone near Columnar Section No. 5 may be more evidence of such erosion, but at Columnar Section No. 5 the sandstone is a lentil within limestone beds. Any erosion that might have occurred was in very early Pitkin time.

NORTHWEST NEWTON COUNTY

The Pitkin limestone crops out along the valley walls of the Buffalo Fork and the Little Buffalo Fork of White River. East of Murray post office, the Pitkin limestone is exposed in the creek bed and on the side of the hill south of the road three-quarters of a mile west of the fork of the Parthenon road in NE.¼ NW.¼ section 24, T. 15 N., R. 22 W. The thickness is about 130 feet, but the outcrop is not clean enough to afford a detailed section. Further mapping work even of a reconnaissance nature cannot be done here until the area has been surveyed topographically.

The Pitkin limestone is exposed fairly well in the SE.¼ SW.¼ section 1, T. 15 N., R. 22 W., along the side of the mountain. It also crops out in the ravine called Hudson Branch which is tributary to Henson Creek, where about 15 feet of Hale conglomerate are exposed. This massive bed of limestone pebbles derived from the Pitkin limestone is indicative of considerable post-Pitkin erosion. The Pitkin is thinner at Low Gap than on Hudson Branch which is five miles to the east. Moreover, massive sandstone rather than Hale conglomerate occurs at the former place. The Pitkin at Low Gap is very likely represented by only the upper phase of the formation; had the area suffered pronounced erosion, the formation probably would have been entirely removed. Although the exact source of the Pitkin pebbles in the Hale conglomerate is not known at this time, it seems reasonable to assume that they did not come from the west.

MT. JUDEA QUADRANGLE

This quadrangle has not been mapped geologically as yet, but at the time the field work for this report was done, advance sheets of the topographic maps were available. The Pitkin limestone was traced up the west fork of Shop Creek, where it crops out on both sides of the valley in low bluffs. A section of Pitkin limestone 2.30 miles south of the post office at Parthenon on Shop Creek in the SW. ¼ NE. ¼ section 29, T. 15 N., R. 21 W., measures 114 feet. It was clearly exposed at the top where the Hale sandstone rests disconformably upon it. The contact with the Fayetteville is fairly well exposed above the Fayetteville shale slope. Some of the black oölitic limestone of the Pitkin is saturated with hydrocarbons.

Columnar Section No. 10

Section along the north side of the Red Rock road and in the gully in the SE. ¼, NW. ¼ section 36, T. 15 N., R. 21 W. 1.3 mi. east of State Highway No. 7, south of Jasper.

PENNSYLVANIAN
Hale sandstone.
Massive sandstone.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Hard, dark-grey, medium-grained, crystalline limestone in 8″-12″ beds which weather knobby	4	4
Platy, dark grey limestone with coarse calcite crystals and fragments of crinoids	1	
Flaggy, grey, oölitic, fine-grained limestone with fragments of crystalline fossils	3	5
Massive, dense, very fine-grained, dark grey, knobby weathering limestone with calcite seams	8	5
Massive, light grey, fine-grained, oölitic limestone weathering		

into vertical prismatic columns	9	7
Massive, dense, fine- to medium-grained limestone with large calcite crystals	3	11
Massive, dense, fine-grained, laminated, hard, dark grey limestone	3	8
Massive, medium-grained, grey-brown limestone	3	2
Flaggy, coarsely crystalline, grey, fossiliferous limestone	1	6
Massive, dark grey, dense, cross-bedded limestone weathering flaggy	9	9
Total	48	9

Fayetteville shale.
Black shale and limestone.

At Columnar Section No. 10 the thickness of the formation is considerably less than a few miles to the east at Columnar Section No. 12. At Section No. 10 the Hale rests disconformably upon the Pitkin, but the subjacent contact with the Fayetteville is not as clearly shown, and large blocks of Pitkin have slumped down below their proper horizon.

Columnar Section No. 11

Section 200 yards up and to the left of the creek at the foot of the hill, E. ½, NW. ¼ section 7, T. 13 N., R. 21 W., in Limestone valley.

PENNSYLVANIAN
Atoka formation.
Coarse sandstones.
Hale sandstone (?).
Medium-grained sandstone.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Fine- to coarse-grained, dark grey, massive, hard, banded, partly oölitic limestone	7	11
Black shale		10
Dense, hard, grey limestone		11
Impure, crinoidal limestone	1	
Massive, brittle, dark grey, medium-grained, flaggy-weathering limestone	10	4
Massive, hard, coarsely crystalline, light brown, crinoidal limestone	5	2
Covered	6	5
Massive, black, dense, hard, fine-grained limestone but with small calcite crystals; many shale partings	14	8
Dense, brittle, black, fine-grained limestone	6	5
Covered	8	1
Massive, medium-grained, light grey limestone	4	
Nodular, dense, black limestone with shale partings		9
Dense, massive, light grey, medium-grained limestone	1	3
Medium-grained, hard, massive, light brown limestone	4	
Dense, black, nodular, fine-grained limestone that weathers flaggy	11	8
Covered	6	
Dense, black, fine-grained, massive limestone	3	9
Covered	2	2
Massive, light grey, partly oolitic limestone	8	10
Dense, fine-grained limestone	1	4
Medium-grained, light grey, partly oolitic limestone	2	
Dense, grey, finely crystalline limestone		6

Light grey nodular limestone		6
Medium-grained, light grey to light brown, partly coarse-grained and partly oölitic limestone	8	8
Impure, nodular limestone with shale partings and two basal and median 6″ dark crystalline limestone layers	3	7
Dark, unevenly bedded, crystalline limestone with black chert	3	10
Dense, fine-grained, black limestone, weathering into flaggs	7	7
Dark, crystalline, soft, unevenly bedded limestone	10	5
Impure, dark, unevenly bedded, medium to coarsely crystalline limestone with shaly layers	11	3
Massive, medium-grained, crystalline, dark grey limestone	5	10
Impure, nodular, limestone and fossiliferous shale	2	
Black, coarsely crystalline, massive, crinoidal limestone	3	4
Total	165	
Fayetteville shale.		
Black shale and fine-grained thin black limestone.		

At Columnar Section No. 11 the Pitkin limestone forms a bluff near the foot of the mountain and is overlain by medium-grained sandstone here assigned to the Hale but which may be of Atoka age. If the strata be in part Atoka, then not only is the Hale very thin, but the Bloyd shale and its members are absent. The complex problem of the upper Pitkin boundary from Columnar Section No. 11 eastward is discussed elsewhere in this report. The section under consideration is notable in the marked thickening shown by the formation south of the preceding section. This is in accordance with the expected down-dip thickening of the beds in the Boston Mountains and here amounts to about ten feet per mile in the Pitkin limestone.

Columnar Section No. 11 contains beds in the lower half which do not appear farther north, and upper beds which have been eroded at Section No. 10 farther north. The thickness of the individual beds varies somewhat, but the lithologic units of Columnar Section No. 10 probably correspond to the fifth to fifteenth beds inclusive from the top of Columnar Section No. 11. This demonstrates that the southward thickening of the formation may well have resulted from overlap of the individual beds of the Pitkin towards the north. In Newton County, therefore, the first notable thickening of the formation so far mentioned in this discussion seems to indicate that a structural high existed to the north, even as strata were deposited in the Pitkin sea to the south. Perhaps this high was submerged, but whether it was or not, the products of any erosion that took place, either subaerially or subaqueously, either were not transported as far south as

Columnar Section No. 11 or else the material transported was derived from shale phases of the Fayetteville and is present now as thin shale beds commonly present in the Pitkin formation.

Columnar Section No. 12

Section in gully south of the school at Iceledo, T. 14 N., R. 19 W.

PENNSYLVANIAN
Atoka formation.
Coarse sandstone with fossil plants, finer sandstone, and sandy shale; all forming ledges and falls.
Hale sandstone (?).
A few feet of sandy paper shales exposed.

MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Coarse- to fine-grained, dark, fossiliferous limestone with some oölitic and conglomerate near the top, all poorly exposed	28	2
Dense, dark, limestone with black calcite crystals but making very poor exposures	28	6
Coarse, oölitic, dark limestone	2	3
Covered	4	10
Massive, dark, oölitic limestone	5	
Dense, dark, brittle, massive, fine- to medium-grained limestone	12	9
Covered	18	
Massive, dark to light grey, medium-grained limestone	5	10
Massive, light grey, fine- to coarse-grained, oölitic limestone weathering flaggy	18	10
Nodular, impure, black, limestone		4
Medium-grained, dark, crystalline limestone		10
Nodular, impure, black limestone		6
Dark, medium-grained, dense, stylolitic limestone		5
Medium-grained, light grey, massive, oölitic limestone	12	6
Nodular, fine-grained, dense limestone	1	8
Medium-grained, dark, hard limestone	1	
Light grey, medium-grained, oölitic limestone	14	4
Dark, mostly fine-grained limestone that weathers flaggy	4	4
Dense, fine-grained, thin-bedded, black cherty limestone	6	3
Massive, hard, coarse-grained, light grey limestone	5	8
Pitkin limestone (?).		
Dense, dark, fine-grained, very cherty (black) limestone in undulating beds 3″-18″ thick; this grades into medium-grained light grey, blocky-weathering limestone at the base	20	4
Dense, dark to black, cherty, crinoidal, coarse- to fine-grained limestone in 6″-12″ beds separated by hard black shale, partings —4″; lower undulating beds with calcite crystals	12	
Total	204	4

Fayetteville shale.
Hard, black shale.

At Columnar Section No. 12 a few miles east of Columnar Section No. 10 is a section of limestone about five times as thick as at the latter place. The upper portion of the section is not well exposed, but no evidence of strata other than

Pitkin was found. The upper boundary of the formation lies below some sandy paper shales that may be of Hale age and above which occur beds of the Atoka formation. The Bloyd shale was not observed. The lower boundary of the Pitkin is difficult to place, because the formation grades into the Fayetteville shale lithologically and both formations are almost unfossiliferous near the contact. The Pitkin is distinguished by the presence of more limestone and chert and less shale than in the Fayetteville. At this locality, if at any place, one would be justified in claiming uninterrupted sedimentation from the Fayetteville into the Pitkin. The section is not far east of the region where the Pitkin begins to thicken very markedly, the increase in thickness between Columnar Sections Nos. 10 and 12 being about 16 feet per mile. Columnar Section No. 12 is not well exposed at the top and thus does not afford a detailed comparison with Columnar Section No. 10. Individual beds at Section No. 12, however, are somewhat more massive than to the west and less massive than those to the east, and the strata deposited are intermediate in character between the characteristic Pitkin of the eastern and western outcrop limits. The contrast between the two regions has been repeated in this paper and will be further elaborated on succeeding pages.

YELLVILLE QUADRANGLE

The Pitkin limestone crops out in the Yellville quadrangle in only three small areas near St. Joe. The first is on St. Joe Mountain, the second on Pilot Mountain, and the third a mile northeast of Pilot Mountain.

The Pitkin is 60 feet thick on the southwest side of St. Joe Mountain, but remarkable thickening was reported by McKnight[1] on Pilot Mountain, where 115 feet were measured on the west end and 55 feet on the east end of the mountain. The present writer measured a section on the southwest side of Pilot Mountain and found the formation to be almost 78 feet thick at that point. Gullies on the north side of St. Joe Mountain (now called Rainbolt Mountain by the local people) have poor exposures of Pitkin that indicate abrupt northward thinning of the formation even in the breadth of the mountain. These gullies have outcrops of Pitkin conglomerate with frag-

---

[1] McKnight, E. T., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Bull. 853, p. 82, 1935.

ments ranging in size from pebbles the size of a pea to pieces 3 by 2 feet. At this locality the conglomerate seems to be within the Pitkin formation and therefore indicates that the Pitkin shore could not have been far removed to the north.

FIG. 5—Pitkin limestone overlying Fayetteville shale and limestone in the mountain saddle south of Marshall.

MARSHALL QUADRANGLE

Columnar Section No. 13

Section at steep bluff in E. ½, NW. ¼ section 13, T. 14 N., R. 18 W., in back of the farm of Mr. Stanley Luke Casey, south of Snowball.

PENNSYLVANIAN
  Atoka formation.
    Coarse buff to brown sandstone.
  Hale sandstone (?).
    Ledges of coarse sandstone and sandy shale with conglomerate.
MISSISSIPPIAN

Pitkin limestone (?).	ft.	in.
Fragments of grey limestone float on gentle slope extending up to first sandstone crop of the Morrow	34	7
Medium-grained, grey to brown, partly oölitic, sparingly fossiliferous limestone, sandy limestone, and shale, poorly		

exposed	82	10
Pitkin limestone.		
Medium-grained, light to dark grey, partly oölitic, fossiliferous, massive limestone occurring in beds about four feet thick	41	5
Nodular, dense, grey limestone with some shale	1	5
Dense, dark grey to light grey limestone in 2"-24" beds	13	3
Medium- to coarse-grained, grey, massive, fossiliferous limestone	13	11
Dark grey, medium-grained, massive, fossiliferous limestone with black chert	30	5
Nodular, dense, black, impure limestone		9
Grey-brown, coarse-grained, fossiliferous limestone	1	6
Total	220	1
Fayetteville shale.		
Black limestone with chert.		

At Columnar Section No. 13 the Pitkin is more massive and somewhat thicker than at Columnar Section No. 12 to the west. The contact with the Hale is not well exposed but the contact with the Fayetteville shows a marked change in lithology from cherty black limestone of the Fayetteville to the typical Pitkin facies of grey limestone. The cherty black limestone near the base of Section No. 12 is not readily separated from the Pitkin limestone, and although it is tentatively placed in the Pitkin, it does not seem to represent the same black limestone and chert exposed at Section No. 13. The strata at the latter place are thinner and more shaly and there is a more definite lithologic break than at the former locality. The upper beds of the Pitkin are very poorly exposed, but the limestone float on the slope closely resembles the Pitkin limestone. Subsequent investigation may prove that the upper portion of this section belongs to the Morrow group, in which case the Hale is absent at this locality.

Columnar Section No. 14

Section in the gulley on the upthrown side of the fault at the Ananias Horton cave, in the NE. ¼, NE. ¼ section 5, T. 14 N., R. 16 W., west of Marshall, near Bryan School.

PENNSYLVANIAN
Atoka formation.
Coarse sandstone.
Hale sandstone.
Sandstone and sandy shale.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Finely oölitic, light grey limestone as the top bed of a series of variable massive limestones	46	4
Light grey, massive, oölitic limestone	40	3
Mostly covered (apparently shale)	35	2
Light grey, sparsely oölitic, massive limestone	16	3
Massive, grey, coarse-grained, fossiliferous limestone	15	5

Massive, fine-grained, dark grey limestone	38	4
Dense, dark grey, 3″-12″ bedded, finely crystalline limestone	5	2
Coarse-grained, grey, massive, fossiliferous limestone	5	1
Fossiliferous chert		3
Dense, black, finely crystalline limestone with uneven shale layers 4″ thick	10	7
Coarse-grained, crystalline, grey, massive, cherty limestone with oölitic and fossiliferous phases	42	5
Fine-grained, dark grey, crystalline, 6″-10″ bedded limestone	5	6
Medium- to coarse-grained, oölitic, grey, massive limestone grading below into dense, dark grey, fine-grained limestone with shale partings	11	11
Grey, medium-grained, oölitic limestone	2	9
Total	275	5

Fayetteville shale.
Cherty limestone.

At Columnar Section No. 14 the Pitkin is thicker than at Columnar Section No. 13 and consists of similar massive beds. The upper contact is marked by sandstone and sandy shales here referred to the Hale sandstone. The lower contact is clearly shown between cherty limestone of the Fayetteville and oölitic limestone of the Pitkin.

Some thin-bedded limestone and shale crops out above Rambo's spring at Watts. The fauna of these beds consists mainly of molluscs. The strata are here referred tentatively to the Pitkin limestone, but subsequent work may show them to be of Pennsylvanian age. About fifteen feet of these beds are overlain by Pennsylvanian sandstone. It may be that sandstone of Hale age is absent and that the fossiliferous beds are remnants of pre-Atoka strata not present farther to the north. Undoubted Pitkin limestone does crop out along the road east of Watts, where massive limestone beds occur.

Columnar Section No. 15

Section in creek upstream from the black marble quarry east of Leslie in E. ½ section 23, T. 14 N., R. 15 W.

PENNSYLVANIAN
Atoka formation.
Coarse reddish brown sandstone and sandy shale.
Hale formation (?).
Sandy shale, shale, sandstone, and limestone exposed for several feet just on top of the Pitkin.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Very wavy beds of sandstone, shale, and cross-bedded limestone with immense crinoid stem plates; beds 2″-18″ thick, marked by mud-cracks in places	16	
Medium- to coarse-grained, crystalline, grey, partly oölitic, fossiliferous limestone	48	4
Shale and fine- to coarse-grained, dense to soft, flaggy, bedded limestone	24	8

Massive, medium-grained, grey limestone, weathering into blocks	15	6
Black, undulating, impure limestone with shale partings	35	10
Black shale with grey, undulating, medium- to coarse-grained limestone	3	
Dark grey, fine- to coarse-grained, massive, partly oölitic limestone with some fragmentary fossils and some chert	33	6
Total	176	10
Fayetteville formation.		
Black limestones and black shales.		

At Columnar Section No. 15 the Pitkin is much more massive but considerably thinner than at Columnar Section No. 14. The upper group of beds in the section is thin-bedded and variable in lithology, but the rest of the section is made up of massive strata which form bench and bluff exposures in the creek bed in which the section was measured. The upper beds are not fossiliferous, but similar beds near the fault at Leslie contain an unique fauna. If these beds are of Bloyd age, then the Hale sandstone is absent, and the overlying beds are all of Atoka age. No evidence of such a condition was observed, but until the stratigraphy of the beds overlying the Pitkin is worked out, the uppermost boundary of the Pitkin cannot be fixed. The lower contact of the Pitkin is well marked by a change lithologically into alternating beds of black limestone and shale of the Fayetteville type.

MOUNTAIN VIEW QUADRANGLE

Columnar Section No. 16

Section on the steep hill along the road from Elberta to Campbell, just south of Campbell in NW. ¼ section 16 and NE. ¼ section 17, T. 14 N., R. 14 W.

PENNSYLVANIAN		
Atoka sandstone.		
Coarse yellow to reddish sandstone.		
Fine sandstone and sandy shale poorly exposed.		
Morrow Group (at least in part).	ft.	in.
Grey limestone, weathering to marly beds and probably containing shales, but all poorly exposed	39	11
MISSISSIPPIAN		
Pitkin limestone.		
Massive, imperfectly exposed beds of light grey to dark grey limestone with fragmentary fossils, coarse- to fine-grained oölitic limestone, and dense crystalline limestone in the latter	35	6
Dense, fine-grained, grey, calcitic limestone with a non-crystalline limestone at the top that is poorly exposed	29	7
Fissile, dark, weak shale forming a bench	44	4
Massive, coarsely oölitic, light grey, fossiliferous limestone above a platy-weathering, massive, grey, fine-grained limestone with calcite	21	7

Coarse-grained, light grey, fossiliferous, oölitic limestone	5	11
Dense, fine-grained, crystalline, nodular, unevenly weathering limestone	2	11
Massive, fine-grained, crystalline, hard, partly oölitic, fossiliferous limestone	7	6
Fine-grained, impure, nodular limestone	3	7
Fine-grained, impure, nodular, crystalline limestone	3	3
Fine-grained, impure, nodular limestone	2	8
Massive, light grey, medium-grained limestone with fragmentary fossils	10	6
Fine-grained to medium-grained, impure, platy, light to dark grey limestone	8	11
Fine-grained, dense, light to dark grey limestone with large crystals in the finely crystalline matrix	4	6
Fine-grained, light grey oölitic limestone	7	3
Grey, fine- to coarse-grained, dense, limestone with black chert	20	4
Covered	5	3
Dense, shelly, black to grey, jointed limestone		8
Medium-grained, light grey, oölitic limestone with fragmentary fossils	5	11
Total	220	2

Fayetteville shale.

Black limestone with chert and shale beds.

At Columnar Section No. 16 two sequences of limestone are separated by a thick series of strata consisting of shales wherever exposed and which form a wide bench. The upper portion is Morrow age, at least in part, but the lower extent of these Morrow beds is not known exactly. They are restricted here to the uppermost beds of the section until additional field work establishes their range more exactly. The Atoka crops out on the hill above the upper limestone sequence. The Hale is absent. As at Columnar Section No. 12, the contact with the Fayetteville is hard to place, but, as at the former locality, the bottom of the Pitkin was placed above the more shaly beds. If the same conditions obtain just to the east and west of this locality in the mountains, then the upper portion of the limestone which crops out in the escarpment is of Morrow age, and sandstone beds of the Hale are lacking. This, then, is the most important stratigraphic problem in the east half of the mountains, to establish the limits of the Morrow group and its individual members. Not until this has been done east of Newton County, will it be known certainly whether or not the Hale and Bloyd crop out across the mountains, or whether all or part of each is locally missing.

FIG. 6—The cave in Cave Point, east of Mountain View.

Columnar Section No. 17

Section in the road cut on the hill south of Timbo (Blue Mountain) through the center of section 13, T. 14 N., R. 13 W.

	ft.	in.
PENNSYLVANIAN		
Hale sandstone (?).		
Shale and sandstone.		
MISSISSIPPIAN		
Pitkin limestone.		
Dark, grey-brown limestone overlying coarse partly crinoidal limestone; all unsatisfactorily exposed, and probably with considerable shale	44	5
Light grey, fine- to medium-grained, partly oölitic, dense to soft limestone	35	6
Poorly exposed, probably mostly shale	16	
Black shale with increasing lime upward with the result an impure, 2″-10″ bedded limestone; all not perfectly exposed, but probably much shale	40	5

Massive, coarse-grained, fossiliferous limestone with upper part oölitic	5	3
Covered (shale ?)	5	1
Massive, light grey, clay-parted 8″ beds of crystalline, medium- to coarse-grained, fossiliferous, hard limestone with oölitic streaks	23	8
Dense, dark to light grey, 2″-16″ bedded limestone resembling marble but with thin shale partings and some fine-grained, fossiliferous limestone in lentils	34	10
Coarse-grained, dark grey, crystalline, fossiliferous limestone	1	
Total	206	2

Fayetteville shale.
Black limestone and shale.

At Columnar Section No. 17 the Pitkin is less massive than at the preceding section and somewhat thinner. The upper limit as in previously considered sections, is not satisfactorily placed. If the upper sequence of beds should prove to be Morrow in age, then the overlying sandstone and shale must be Atoka.

Columnar Section No. 18

Section on the south flank of Cow Mountain 6 miles west of Mountain View, in the steep gully in the SW. ¼, SE. ¼ section 1, T. 14 N., R. 12 W.

PENNSYLVANIAN
Atoka formation.
Reddish brown sandstone.
Hale sandstone (?).
Sandy shale forming gentle slope with sandstone and conglomerate with limestone fragments.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Massive, medium-grained, grey-brown, fossiliferous, partly oölitic banded limestone and weathering to a marl	29	7
Nodular, crinoidal limestone with shale, upper portion mostly covered; ill defined	26	10
Medium- to coarse-grained, light grey, fossiliferous limestone with the upper beds tending to be finer grained, denser, and darker	29	7
Covered (shale ?)	36	8
Dense, grey, fine- to medium-grained, poorly exposed limestone with black chert	33	2
Light grey, fine- to medium-grained, partly oölitic, massive beds of hard limestone only fairly well exposed	112	5
Covered mostly with some light grey limestone	22	2
Light grey, fine- to medium-grained, hard limestone	33	6
Hard, rather massive, fine- to medium-grained, dark grey limestone with black chert	25	2
Total	349	1

Fayetteville shale.
Cherty black limestone and shale.

The first indication of the remarkable thickening of the Pitkin is shown in Columnar Section No. 18, where the Pitkin has increased in thickness over the previous section on the average of twenty feet per mile. Comparison of the two sections indicates that this important change in thickness involves both increase in thickness of individual beds, as well as addition of different beds between previously noted strata. It is significant that many of the strata mentioned above are not added at the base of the formation as in some previous cases, but the addition of beds is more in the nature of an interfingering. The upper contact of the Pitkin seems to be with the Hale sandstone at this locality, although, as has been repeatedly mentioned, such statements are acknowledgedly subject to revision. Post-Pitkin erosion and sedimentation may have been any one of several kinds. The Hale might have been eroded and the Bloyd deposited upon the Pitkin; the Hale may be present as limestone and shale, with or without the Bloyd; both Hale and Bloyd may be absent; if so the Atoka would lie in direct contact with the Pitkin. The writer believes that the first of these possibilities obtains at Section No. 16, but the situation at other localities is not known with as much certainty.

Columnar Section No. 19

Section on the escarpment south of Mountain View along the road in the S. ½ section 11, and NW. ¼ section 14, T. 14 N., R. 11 W.

PENNSYLVANIAN
Atoka formation.
Coarse sandstone.
Hale sandstone (?).
Low slope with sandstone and sandy shale, mostly covered.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Low slopes, mostly covered up to massive, medium-grained, dark to light grey, hard limestone	85	8
Fine-grained, hard, massive, grey limestone weathering flaggy and nodular at the top	9	
Coarse-grained, light grey, fossiliferous, crystalline massive limestone scattered up poorly exposed slope (shale?) with fine-grained limestone	35	
Medium-grained, light grey, massive, hard, oölitic limestone	11	2
Medium-grained, light grey, crystalline, massive, blocks of limestone on (shale?) slope	52	3
Covered (shale and limestone?)	12	
Massive, cross-bedded, dark grey-brown, crystalline limestone	3	8
Yellow to blue-grey clay (weathered shale?)	6	6
Hard, medium-grained, blue-grey, massive limestone weathering rotten	12	4
Coarse-grained, crystalline, fossiliferous, massive, grey, oölitic limestone	11	10
Massive sequence of limestone grading from basal hard, crystalline, fine- to medium-grained limestone into lighter grey, softer limestone and then into hard limestone near the top	124	3
Total	363	8

Pitkin limestone (?)

Dark grey, fine-grained, wavy, 5″-14″ bedded limestone with with 0″-10″ shale beds	26	8
Black, brittle, fine-grained, massive, 0″-12″ bedded, knobby, fossiliferous limestone	23	8
	50	4
	363	8
Total	414	

Fayetteville shale.
Black limestone and shale.

Columnar Section No. 20

Section of the upper portion of the Pitkin limestone 1.1 mi. south of section 19 and hill along the same road in NE. ¼ section 22, T. 14 N., R. 11 W.

PENNSYLVANIAN
Atoka formation.
Coarse sandstone.
Hale sandstone (?).
Sandstone and shale.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Mostly shale with beds of dark grey, hard, crystalline limestone, rotten limestone, and an uppermost bed of coarse-grained, massive, crinoidal limestone	26	6
Rotten limestone and weathered shale slope enclosing an ill-defined 3′ bed of ¼″ bands of coarse- and medium-grained, light grey, crystalline limestone	12	2
Medium- to coarse-grained, crystalline, grey, 1′-3′ bedded limestone with shale and rotten limestone at the base	14	10
Medium-grained, light grey, massive, oölitic limestone	8	10
Medium- to coarse-grained, crystalline, light grey limestone with bands of fossils and grading into a hard, grey, massive, partly oölitic limestone	39	11
Wavy, fine-grained, dense, black limestone with some hard shale bands	11	10
Total	114	1

Black limestone and shale making up the floor of the valley.

The thickness of the Pitkin at Columnar Section No. 19 is greater than at Columnar Section No. 18, the increase being on the order of ten feet to the mile. The upper portion may after subsequent work prove to be younger than Pitkin. The upper portion of this section is poorly exposed, but at Columnar Section No. 20 about one mile south of Columnar Section No. 19 exposures of these upper beds are much cleaner. The measured portion of Columnar Section No. 19 corresponds to the top two measured units of Columnar Section No. 20. The valley bottom below the former section has been excavated in the middle shaly portion of the Pitkin limestone, although the first impression is that it has been eroded in the

Fayetteville shale. The upper part of the section is thicker than the corresponding beds to the north because post-Pitkin erosion has removed part of the strata at section.

BATESVILLE QUADRANGLE

Columnar Section No. 21

Section on Blue Mountain, in southeastern Stone County, in the small creek bed in the center of the N. ½ section 13, T. 13 N., R. 9 W., near St. James.

PENNSYLVANIAN
  Atoka formation.
    Sandstone.
  Hale sandstone (?).
    Sandy paper shales and fine sandstones.
MISSISSIPPIAN

Pitkin limestone.	ft.	in.
Poorly exposed beds on a bench and in bluffs	88	9
Dark grey, medium-grained, dense, 12" bedded limestone.		
Shale.		
Crinoidal limestone.		
Grey-brown, crystalline, fossiliferous limestone.		
Medium-grained, fossiliferous, grey, massive, oölitic limestone forming great bluff	76	11
Medium-grained, crystalline, light to dark grey and brown limestone	65	1
Ill-defined series of limestone and shale grading one into the other	82	10
Medium-grained limestone without chert.		
Black cherty limestone with shale partings.		
Fine-grained, crystalline, 4"-14" bedded, dark limestone with black chert near the top and some shale.		
Black shale.		
Mostly covered, but with scattered limestone beds and an upper undulating, dark grey, hard, crystalline, medium-grained limestone	64	5
Total	378	
Pitkin limestone (?)		
Mostly covered but with limestone float	47	4
Fine- to medium-grained, massive, grey, crystalline, limestone with nodular, platy, dark, dense bed at the base	47	4
	94	8
	378	
Total	472	8

  Fayetteville shale.
    Black shale and black limestone.

The thickest Pitkin ever noted is at Columnar Section No. 21. The increase from Columnar Section No. 19 is about four feet per mile. A bench and bluff topography occurs at Columnar Section No. 21, and because the section was measured in a creek bed, numerous waterfalls and cascades correspond with the more resistant strata of the formation. The problem of whether or not all of the section is of Pitkin age is again present here.

Columnar Section No. 22

Section at the saddle, starting 2.78 mi. west of Locust Grove post office in the gully on the south side of the road, up the road cut, in the quarry, back across to the road to the top of the saddle, and up the southwest portion of Deane Mountain, in S. ½ NW. ¼ section 30, T. 13 N., R. 7 W.

PENNSYLVANIAN
  Atoka formation.
    Sandstone.
  Hale sandstone (?).
    Sandstone and shale.
MISSISSIPPIAN
  Pitkin limestone.

	ft.	in.
Mostly covered slope with the upper ledge of massive, medium-grained, grey, arenaceous, banded limestone	112	5
Medium-grained, massive, light grey, oolitic limestone	23	8
Covered, with dense limestone as float	29	7
Impure, nodular, dense limestone and calcareous shale	8	
Gradational series of limestones	74	10
Black, medium-grained, 1′-3′ bedded limestones with shale streaks.		
Grey, massive, hard, medium-grained limestone.		
Beds of dense and fine-grained limestone with coarser crinoidal and coralline beds.		
Series of gradational beds from top of quarry to base of section	100	7
Undulating, nodular, dark grey, fine-grained, dense limestone interbedded with shale above and below.		
Hard, grey, medium-grained, crystalline, massive limestone.		
Impure, dark limestone like Fayetteville 'marble' and with 2″-4″ shale beds.		
Undulating, nodular on weathering, grey, medium-grained, crystalline limestone.		
Dark, 10″-18″ bedded, crystalline limestone.		
Total	349	1

  Fayetteville shale.
    Black shale in gully.

Columnar Section No. 22 represents the easternmost Pitkin exposure measured. It is interesting because it shows a decrease in thickness of the great limestone bluffs in the escarpment of the Boston Mountain plateau. The eastward thinning from Section No. 21 is about three feet per mile. Taken as a unit, the Pitkin is less massive at Section No. 22 than to the west in the mountains, but it should be noted that some individual beds or sequences of similar strata in the east may be thicker than complete thicknesses of the formation in western Arkansas. The thinning of the formation at Columnar Section No. 22, as contrasted with the thickening just to the west, however, suggests that the maximum thickness lies to the west of this section and that the formation may continue to become thinner to the east.

The eastern end of the Boston Mountain plateau has been stripped of beds down to and including portions of the Pitkin limestone, so data concerning the thickness of the formation are incomplete there.

A notable feature of the Pitkin limestone occurs on Highway No. 11 about 1.6 miles south of the crossing of Highways Nos. 110 and 111, where a thick conglomerate crops out on the north side of a fault exposed in the road cut. The large limestone pebbles and boulders in the conglomerate probably were derived from erosion of the Pitkin limestone, but the matrix of the conglomerate also resembles the Pitkin limestone. Therefore this conglomerate may be intraformational, and similar to the conglomeratic Pitkin beds noted in the railroad cut at Fayetteville. The conglomerate on Highway No. 11 consists of limestone fragments ranging from 2 to 10 inches in diameter. Bands of shale in with the conglomerate may have been squeezed into their present position during the faulting at this locality for the shale bands are highly contorted. More conglomerate lies *in situ* in the ditch west of the road. The strata overlying and underlying the conglomerate are not exposed, so the exact stratigraphic position of the bed is not known.

In the SE. ¼ section 35, T. 12 N., R. 6 W., the Pitkin is exposed as several ledges along the east side of the road. It could not be determined if the whole formation is exposed there, but if it is exposed, it is thinner than at Columnar Section No. 22.

The appended chart of the columnar sections of the Pitkin limestone illustrates graphically several hitherto unknown features of the stratigraphy of the Pitkin limestone more clearly than will the lithologic descriptions. Especial note should be made of the relations between Columnar Sections Nos. 6 and 11, the latter being located almost directly down-dip from the former. Equivalents of the several beds of Section No. 6 are contained within the top of Section No. 11, therefore, most of the strata at No. 11 were deposited before those of No. 6. Likewise, even thicker sections farther to the east from Section No. 11 also contain in the uppermost portions the equivalents of the thin exposure of the formation to the west. This being the case, it must follow that the Pitkin sea encroached upon western Arkansas and northeastern Oklahoma from the south and east.

Another relationship to be observed from the chart of columnar sections is that the upper and lower sequences of limestone are separated by shale and shaly limestone strata within the body of the Pitkin. The section at No. 5 is representative of the type locality, and because these strata are contained within the upper beds of the formation in eastern Arkansas, the underlying and hitherto undescribed portions of the Pitkin have not been recognized as definitely older than the strata at the type locality. The thick sections of the Pitkin actually contain sequences of shale and shaly limestone of about the same thickness of the limestone at the type locality. Moreover, even thicker sequences of limestone above and below the shale have not been adequately considered hitherto. By definition, the Pitkin limestone "overlies Fayetteville shale and unconformably underlies Morrow group (Pennsylvanian),"[1] hence, strata older than those at the type section are necessarily included within the confines of the Pitkin limestone. In view of the diverse lithologic character of the Pitkin, as shown by this study, the writer proposes that the name "Pitkin *formation*" (rather than Pitkin *limestone*) be applied to the strata between the Fayetteville shale and the Morrow group. Furthermore, it will prove convenient for the Pitkin formation to be divided on lithologic grounds into a "lower limestone member," a "middle shale and limestone member," and an "upper limestone member." The relations of these three members are most clearly shown from Section 14 eastwardly. Perhaps the best exposures and contacts of the three members are shown at Section No. 16. The shale and limestone member is not exposed at Sections Nos. 11 and 12, but may be represented in the "covered" portions midway in the sections. It would be considered feasible by many to describe these members as formations in their own right; however, the writer has been unable to demonstrate the separation of the three units faunally.

Correlations of lithologic facies are shown within the formation. These correlations demonstrate quite clearly the wedging and interfingering of the strata.

---

[1] Wilmarth, Grace, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, Part 2, p. 1672, 1938.

GEOLOGIC STRUCTURE

The major part of the structure of the district under consideration has been studied by previous workers, from whose works the details have been freely abstracted. The newly discovered structural features are either specified as such or are accompanied by detailed descriptions.

OKLAHOMA

The structure of the Boston Mountains in Oklahoma is discussed in the Tahlequah[1] and Muskogee[2] folios, hence those areas are not considered in detail in this report, which deals most particularly with Arkansas. In the eastern half of the Muskogee quadrangle a system of parallel faults, whose strikes trend essentially northeast-southwest, is associated with two kinds of folding aligned parallel with the faults. The major folds comprise broad basin-like structures whose southern borders are faulted down with relation to the next fold to the south. Some of these folds extend beyond the faults which partially delimit them. It is not known whether or not the folding and faulting were contemporaneous. The other system of folds comprises structures smaller than those of the major type, and they probably were formed at the same time as the faulting.

In discussing the structure of the Boston Mountains of Arkansas, the quadrangles will be treated as units in so far as this is possible. Where quadrangles have not been mapped, the discussion will center on appropriate portions of counties.

FAYETTEVILLE QUADRANGLE[3]

The Price Mountain syncline, with a trend toward the northeast, lies in the southeast corner of the quadrangle. It is not of notable size, but its strike is roughly parallel with those of other structures in the region.

The most important faults lies in the southeast corner of the quadrangle. One of these, the Price Mountain Fault, extends about N. 40° E. and has a maximum displacement of about three hundred feet with the displacement on the southeast side. Near Fayetteville, the rocks bordering the fault all dip toward the fault and hence constitute a syncline there.

---

[1] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (no. 122), 1905.

[2] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Muskogee folio (no. 132), 1906.

[3] Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), 1905.

The White River faults have a trend about east-west and lie in the southeast corner of the quadrangle, where the main fault crosses the Price Mountain fault.

WINSLOW QUADRANGLE [1]

The outcrop of the Pitkin limestone in this quadrangle is terminated on the southwest by the Mountain Fork faults. The northernmost of these faults has a displacement of about five hundred feet and the southern one a displacement of about one hundred feet. An elongate east-west graben between them parallels the faults.

The Evansville Creek fault is also an east-west fault which follows the axis of a syncline in its western portion but shifts to the south limb of the syncline toward the east. The downthrow is on the north and is not more than one hundred feet. This fault is in line with a smaller faulted fold called the Frisco fault and monocline lying east of the Evansville Creek fault. The downthrow here is on the south. A continuation of the structure occurs north of Porter. Associated with the last two mentioned faults is a monoclinal fold in the east which branches in the west to form two monoclinal folds. The present writer believes that this monoclinal structure persists eastwardly along the Boston Mountains, as will be pointed out later on.

The Mulberry fault, which extends northeast-southwest, in the southeast corner of the quadrangle may have a displacement of as much as three hundred feet, the downthrow being to the southeast. Other northeast-southwest faults are the Price Mountain fault, which extends into this quadrangle from the Fayetteville quadrangle, and the White River fault, which crosses the northwest corner of this quadrangle and passes from the Fayetteville quadrangle into Oklahoma. Other smaller faults have been described but are not as important as the foregoing ones. The writer has observed additional faults discussed below.

In the creek in the N. ½ section 1, T. 11 N., R. 33 W., is a fault whose trace is N. 83° E. The fault plane shows a dip of 74° S. and the downthrow side is on the south. The fault scarp forms a cascade in the Brentwood (?) limestone. The total displacement could not be measured, but it is not less than fifty feet and is probably considerably more. Drag

---

[1] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), 1907.

folds south of the fault show dips up to 23° S., but do not extend far from the fault. Many minor faults occur throughout the Mountain Fork region northwest of Natural Dam and make this a relatively complex structural area. The natural dam mentioned above is formed by a resistant bed of Atoka sandstone which dips 3° upstream (north).

At the north end of the railroad tunnel at Winslow is a fault, the plane of which has a dip of 37° to 40° S. and a strike of N. 70° W. The displacement is seen within the Atoka formation. The uniform nature of the Atoka prevents accurate measurement, but an estimate of the displacement here is twenty feet, with the south side thrust-faulted over the north. A set of small drag folds indicates a small amount of relaxation of forces after the thrust had formed larger drag folds. The strata as distant as one-half mile to the north show a slight northward dip, whereas the regional dip is 2° to 3° S. Several small faults north of the main fault show displacements of a few inches. Their most notable feature is that in all cases observed, the south side is downthrown. This is in opposition to the conditions at the main fault, where the north side is downthrown. The small faults just mentioned, therefore, must have been formed during the time of tension after the major disturbance. The main fault is also visible in the road cut on the hill northeast of the north end of the railroad tunnel.

EUREKA SPRINGS QUADRANGLE[1]

The Price Mountain fault and syncline also extend into this quadrangle on the west half from the Fayetteville quadrangle. The total length of the structure is fifty-five miles.

The Clifty Creek faults near the center of the quadrangle extend east-west for a few miles, with the downthrow of the north fault on the north side and the downthrow of the south fault on the south side, thus there is a horst between the two faults. Both the Price Mountain and the Clifty Creek faults occur north of the Boston Mountains. South of the latter faults is a small dome.

The White River faults extend from the Fayetteville quadrangle and curve somewhat to the southeast to termi-

---

[1] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

nate in the Drakes Creek fault. A graben lies between the two faults and the strata in this graben either dip to the north or are synclinal. The displacement of the faults at their eastern ends is about one hundred feet. The faults extend for about twenty-five miles to the west of the Drakes Creek fault.

The Drakes Creek fault extends northeast-southwest through the south-central half of the quadrangle and continues beyond its southern boundary an unknown distance. The northeastern half of the fault does not affect the Boston Mountains. The disturbance sometimes is merely monoclinal, but the faulted portion has a maximum displacement of about four hundred feet, this being near the southern edge of the quadrangle. This is one of the longest structures in north Arkansas, its known extent being twenty-seven miles.

The Reed Creek fault north of Huntsville extends northwest-southeast parallel the eastern end of the White River faults and terminating at the west at the Drakes Creek fault. The downthrow side is to the southwest and the displacement has brought the Bloyd shale and the Boone limestone in contact.

The most important fold in the region is the Osage anticline, extending across the northeast corner of the quadrangle and into the Harrison quadrangle from the northwest to the southeast, but not occurring within the Boston Mountains.

SOUTHERN MADISON COUNTY

The following discussion concerns the unmapped area south of the Eureka Springs quadrangle.

The Drakes Creek fault enters the region in the northwest corner of T. 15 N., R. 27 W. and continues southwest an unknown distance.

In the NE¼ NW¼ section 25, T. 16 N., R. 26 W., approximately 0.20 mile north of the bridge over War Eagle Creek, is a fault with an estimated displacement of about forty feet. The south block is downthrown. The trend of the fault is about N. 80° E. but the actual plane of the fault is obscured and the highway covers the top of the Pitkin, so the dip of the fault plane and the actual displacement cannot be measured. This fault probably was formed at the same time as the other smaller faults in the immediate vicinity. One of the latter is located in the bed of Withrow Branch one hundred yards upstream from the small bridge in the extreme northwest corner of section 25. The displacement there is only eighteen inches, the dip of the fault plane is 67° NE., and the strike of the fault is N. 56° W. Just above the Pitkin a bed of Hale shale about two feet thick is overlain by sandstone. The shale is stretched up over the fault, but the Hale sandstone strata are cleanly faulted. The Atoka formation in the Pettigrew district is locally much distorted but the disturbance probably centered south of these contorted beds. Evidence for a more southern location of the major disturbance is found in the presence of much larger faults and monoclinal folds along the same east-west line some distance south of Pettigrew.

HARRISON QUADRANGLE [1]

The Osage anticline extending about northwest-southeast lies in the west half of this quadrangle north of the Boston Mountains escarpment. The closure of the dome is about eight hundred feet in the Boone limestone. On the east flank of this anticline is the Green Forest fault, with a maximum displacement of three hundred feet and the downthrow on the northeast. Roughly parallel with it but in the north-central part of the quadrangle is the Long Creek fault with only a small displacement and with the downthrow on the southwest side. East of Harrison is the small Crooked Creek fault with the displacement on the northeast side. Only part of the Osage anticline and the Green Forest fault extend into the Boston Mountains.

The Buffalo faults trend about northeast-southwest in the southern part of the quadrangle. Several individual faults occur, the general downthrow being on the south side of the group and the maximum displacement being about three hundred feet.

The other faults in the southern part of the quadrangle trend about east-west. The Osage fault is the westernmost of these and has a displacement of about one hundred feet with the downthrow on the south. The Compton fault has

---

[1] Op. cit.

a displacement of about three hundred feet and the downthrow is on the southeast. The structure continues to the southwest as a monocline. Just north of the fault is the Sneeds Creek dome, which lies parallel with it and has a closure of about four hundred feet. Southeast of the Compton fault lie the Sneeds Creek faults. Four of these faults lie in one unit of very complex structure with two of the faults delimiting a graben which contains the other two faults. Other small faults of the Sneeds Creek group are represented by two which also border another graben. The small Ponca faults lie south of the Sneeds Creek faults and trend north-south. Northeast of the Buffalo faults lie the Yardelle faults, which enclose a graben, the block having sunk about three hundred feet. The Hurricane faults, similar to the preceding two structures, partially delimit a graben which has been down faulted about two hundred feet.

The Carrollton dome, which lies in the center of the quadrangle, has a closure of about four hundred feet and is one of the largest domes in northern Arkansas. Aside from the previously described structures, the writer observed additional evidence of folding in the region. There is a small anticlinal hill in the E½ section 8, T. 17 N., R. 20 W., just east of Gaither Mountain and the Carrollton dome. The axis of the anticline trends N. 10° E. and small faults within the anticline trend in the same direction. The surface rock is the Batesville sandstone. East of the bridge four miles to the north on the Jasper-Harrison road is another folded area but the type of structure could not be determined because only one set of dips was observed. As can be seen, the Harrison quadrangle is much more faulted and folded than the other quadrangles.

NORTHWEST NEWTON COUNTY

The western part of Newton County south of Jasper has not been surveyed topographically. This discussion concerns the unmapped quadrangle west of the Mt. Judea quadrangle.

At the ford and suspension foot-bridge across Buffalo River north of Murray post office is a low bluff of Boone limestone. Just west of the suspension bridge is a tension fold in the Boone, east of which the strata have dips as great as 3½° to the east. There undoubtedly is a fault to the east but the actual fault trace is obscured in the creek bed and floodplain. The beds in the Boone bluff still farther east are essentially horizontal.

On Henson Creek one-quarter mile upstream from Hudson Branch in the northeast corner of T. 15 N., R. 22 W. is a faulted anticline. The St. Joe and Chattanooga are exposed in the bluff on the south side of the creek and the Sylamore sandstone crops out in the creek bed. The axis of the anticline trends N. 40° W. and the strata show dips up to 4° to the east on the east limb of the anticline in the drag-folded zone. The dip of the fault plane is 69° southwest and the strike is N. 65° W. The estimated displacement is thirty feet, the downthrow side being on the northeast. This faulted anticline is probably a continuation of one of the Buffalo faults north of Jasper. The fault created a gouge zone two and one-half to three feet thick in which there is a small cave. The shale below the St. Joe is highly contorted through adjustment movements, yet does not show some of the small faults visible in the massive beds between which it is contained. Pronounced horizontal movement in the upper few feet of shale beds has been responsible for drag folds, intersecting faults, and isolated limestone fragments in the shale.

MT. JUDEA QUADRANGLE

The mining activities in the Cave Creek district centered around the Confederate fault in the northeast corner of the quadrangle. This fault trends northeast-southwest, the downthrown south side being two hundred seventy-five feet lower than the north side. The Pitkin and Boone abut at the fault.

One of the largest faults in the Boston Mountains lies in the extreme southwest corner of the quadrangle. The east-west valley at Limestone has been cut in the weak zone of a fault which dropped the Atoka on the south to the level of the Boone limestone. The Mineral Survey of Arkansas calculated the displacement to be four hundred eighty feet. The actual plane of the fault was not located, as it is obscured under talus on the mountain sides and under residual material in the valley, but it may be presumed that the fault follows the valley trend more or less closely. An examination of aerial photographs of the region does not help locate the fault trace any more exactly than field work did, but the lack of correspondence between beds on the north and south sides of the valley is striking. Other aerial photographs of this quadrangle show resistant strata clearly, but the few indications of faults observed do not warrant comment here.

YELLVILLE QUADRANGLE [1]

The structure of this quadrangle is complex in the extreme southern portion, where most of the faults trend east-west. A number of important faults occur north of the Boston Mountains, hence they are only mentioned briefly here. The Crooked Creek fault extends into this quadrangle from the Harrison quadrangle for a short distance. Although this fault and the Pine Hollow fault farther southeast are in line, they probably are not connected. Farther east and parallel with the Pine Hollow fault lie the Rush Creek, Climax, and Silver Hollow faults. Some grabens and folds are associated with these faults. Near the center of the quadrangle are the Georges Creek and Sugarloaf faults, whose trends are nearly east-west with the downthrow on the north in both cases.

The Hurricane faults, mentioned in the Harrison quadrangle discussion, extend into the Yellville quadrangle, where they are termed the Mill Creek fault and the St. Joe fault for the south and north structures, respectively. Between these east-west trending and nearly parallel faults, lies the Mill Creek graben. The north rim of the graben is about two hundred feet high and the south rim about half that height.

A short distance north and extending east from St. Joe is the Tomahawk fault complex. The Tomahawk fault limits the complex to the north but to the south the Pilot Mountain and the South Tomahawk faults extend away from the first mentioned structure and limit several separate variously elevated blocks, including the Tomahawk graben. Other small faults to the southeast increase the complexity of the region.

The important Pilot Knob dome occurs in the northwest corner of the quadrangle and many smaller domes and basins

---

[1] McKnight, E. T., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Bull. 853, 1935.

lie entirely or partially within its boundaries, the most strongly folded structures being in the southeast corner of the quadrangle between the Rush Creek and the Tomahawk faults. The Rock Creek, Panther Creek, and Water Creek basins and the De Soto dome are notable examples in this district.

A line of northeast-southwest structures lies just west of the St. Joe region. The southernmost of these structures is the St. Joe monocline, followed to the north by the St. Joe syncline, some small faults, and, finally, by the Water Creek monocline.

MARSHALL QUADRANGLE

Faulting and folding have taken place along the road between Leslie and Watts. A dip of 12°, N. 35° E. was observed one-quarter mile west of the junction of this road with the main highway at Leslie. This steep dip is structually related to the faulting just to the south.

A fault occurs in the bed of Cove Creek seventy-five feet north of the ford on the Sulphur Springs Schoolhouse road. The dip of the fault plane is 52° south, the strike is N. 82° E.,

FIG. 7—Normal fault and shatter zone in the Pitkin limestone in the road cut on the hill 0.52 mi. east of the post office at Leslie. The total displacement is about 80 ft. and the downthrow is on the right. (Hammer for scale.)

and the downthrown side is to the south. The Batesville (?) sandstone here is upthrown against the Fayetteville shale but the amount of displacement could not be measured. Less than one mile south folding has brought the Hindsville limestone up in the creek bed where the strata dip as much as 9° to the northwest. The Batesville sandstone crops out in the railroad cut north of the creek.

On the hill 0.52 mile east of the Leslie post office a fault shows clearly in the road cut. The fault plane shows a dip of 68° to the north and a strike of N. 71° E. The displacement is sixty feet and the downthrow is on the north side of the fault. The beds on the upthrown side are of Pitkin age but the age of the beds on the downthrown side is in doubt. The beds are tentatively referred to the Pitkin limestone, but they may prove to be of Morrow age. This fault will be referred to as the Leslie fault.

A fault is indicated one hundred fifty feet south of the Anderson and McMein quarry near Leslie but the fault trace is obscured by dirt and travertine. The displacement is ten feet and the downthrow is on the south side. The fault plane has a dip of about 50° to 60° S. and a strike of a little north of east.

At the Ananias Horton cave near Bryan Schoolhouse is a fault of about ten feet with the dip of the fault plane inclined 52° to the south and the strike trending N. 84° E. The downthrow is to the south. A wide shatter zone occurs south of the fault and the cave is in this zone. An associated fault north of the one previously mentioned has a displacement of about eight feet and is merely an adjustment fracture.

North of Leslie the presence of many folds and faults weakened the rocks, thus permitting the several streams to cut down to their present levels relatively rapidly. The maturity of these streams in a region topographically youthful or submature probably has been effected by their having more time than the other streams to widen their valleys since this rapid cutting down ceased.

At the upper Cave Creek district the Confederate fault has a trend of N. 43° E. and the Pitkin abuts against the Boone to the north. The structural details of this area are given by McKnight.[1]

MOUNTAIN VIEW QUADRANGLE

Hopkins[2] mentions several folds and faults but gives neither accurate locations nor satisfactory details about them. In section 17, T. 15 N., R. 14 W. he mentions the southward dip of the St. Clair marble beds, which are at the level of Big Creek at that place, yet are four hundred feet above the level of the creek where it joins Long Creek. Either faulting or folding is presumed to have taken place there. Another fault in the centers of sections 16 and 17, T. 16 N., R. 13 W. that carries the St. Clair below the level of Spring Creek north of Big Flat is directed about east-west. A third fault is in the N½ section 7, T. 15 N., R. 12 W. The fault trends about east-west, the downthrown side being on the south and the displacement amounting to about one hundred feet. Finally, a fault was traced from the center of the W½ section 12, T. 15 N., R. 14 W. southeast to the SE¼ SE¼ section 33, T. 15 N., R. 12 W.

The most important folds are the anticline in section 17, T. 15 N., R. 12 W. and the folds northwest of the Roasting Ear Creek fault mentioned above as occurring in section 7, T. 15 N., R. 12 W. The former anticline trends northeast-southwest and has a closure of about one hundred feet.

The writer has observed other structures in this quadrangle. South of state Highway No. 66 a distance of 0.22 mile on Meadow Creek in the NW¼ section 19, T. 14 N., R. 13 W. is a much contorted and faulted zone, here termed the Meadow Creek disturbance. Numerous faults exist in the creek bed north of the extremely folded and mashed Hale (?) sandstone, but the displacement at any one single fault cannot be measured. The Arkansas Mineral Survey calculated the displacement between beds in the valley bottom and on the mountain to the south to be about two hundred fifty feet. A creek courses east-west about midway through the length of the structural zone parallel the mountain front. The general trend of the fault is about N. 80° E.

---

[1] Op. cit., pp. 164-168.

[2] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. 1890, vol. IV, pp. 245, 249, 1893.

Just south of Cow Mountain west of Mountain View in the NW¼ NE¼ section 12, T. 14 N., R. 12 W. the Moorefield shale on the north abuts the St. Joe. The fault plane exposed in the creek shows a dip of 65° N. and a strike of N. 77° W. Drag-folded beds just north of the fault have a dip of 23° N. but in a short distance they level out. The total displacement at this place is one hundred eighty-five feet. This fault lines up with the fault mapped by Hopkins to the northwest. The former structure is herein referred to as the Cow Mountain fault.

A fault of about eight feet shows in the gully on the south flank of Cow Mountain. This is probably an adjustment fracture associated with the Cow Mountain fault.

East of Mountain View 7.7 miles on the highway in the SW¼ SE¼ section 1, T. 14 N., R. 10 W. a fault of forty-eight feet brings the Batesville and Fayetteville formations in contact, as shown in the ditch at the side of the road at the stone culvert. A small fracture which seems to be parallel with the line of the fault has a dip of 65° S. and a strike of N. 76° E. The main fault plane is covered. Both the larger and the smaller faults are downthrown on the south side. They are here designated the Mountain Township faults.

BATESVILLE QUADRANGLE

A small fault with all the displacement within the Batesville sandstone is present in T. 13 N., R. 8 W. on the state road 2.68 miles west of the Independence County line. The dip is 57° S., the strike is N. 86° E., and the south side is downthrown. This fault possibly is connected structurally with the pair of faults north of Batesville.

A fault occurs 5.0 miles north of Pleasant Plains on the east side of the road in the Atoka formation. The fault plane is about vertical, the fault trace trends about N. 40° E., the north side is downthrown, and the estimated displacement is thirty feet. Low folds and minor faults occur in the immediate vicinity. One low angle thrust fault with the south side downthrown occurs 0.09 mile north of the vertical fault previously mentioned. The dip of the fault plane is 15° N., the trace is N. 82° E., and the displacement is at least fifty feet. This structural group is here termed the Salado Creek faults.

FIG. 8—Fayetteville shale (right) thrust over the coarse Pitkin conglomerate (left) in the road cut of Highway No. 11, halfway between Pleasant Plains and Batesville. (Hammer for scale.)

A thrust fault on the north flank of the hill 1.6 miles south of the crossing of state roads Nos. 110 and 111 has brought into contact the top of the Fayetteville shale and a massive conglomerate tentatively assigned to the Pitkin limestone. The dip of the fault plane is 16° S., the trace of the plane is N. 37° E., and the south side is thrust over the north side. The displacement is about equal to the thickness of the Pitkin limestone, provided that the conglomerate is in the upper part of the Pitkin, for Pitkin limestone crops out above the shale a few yards east of the road cut on the hill. Other outcrops of the conglomerate lie to the west of the road. Across the creek 0.2 mile to the north the Batesville sandstone crops out at about the level of the Fayetteville-conglomerate contact at the fault described above. In order to bring the Batesville up this high, there must be a fault with a displacement at least equal to the thickness of the Fayetteville shale just south of the Batesville outcrop, but the wide floodplain of the creek hides all direct evidence of its presence.

GENERAL STRUCTURAL AND STRATIGRAPHIC CONSIDERATIONS

The Boston Mountains comprise a plateau with a regional dip of about 2 degrees, which is to the south and southwest in the west and to the south and southeast in the east. In addition to this dip, the whole plateau is arched in the middle so that strata in the east and west sides slope away from the center. Many minor folds occur in the plateau, but the major structural element by far is the great Boston Mountain monocline. South of the escarpment the regional dip of 2 degrees prevails until the axis of the monocline is reached, south of which the dip increases markedly. The northern structural boundary of the Arkansas valley is located at the monoclinal axis. The slope of the summit of the mountains is less than the regional dip, thus the Atoka becomes increasingly thick to the south and attains a maximum thickness of about fifteen hundred feet in the Boston Mountains proper. But south of the Arkansas River the thickness of the formation further increases to a maximum of nine thousand four hundred feet.

Croneis [1] and Purdue [2] discuss how the streams cut down through the Atoka and expose beds of Morrow age in their valleys. Purdue thought these "windows" were the result of minor folds and Croneis considered them to be caused by headward cutting of the streams on the south slope of the mountains. This writer agrees in part with both these views but wishes to point out that the windows for the most part lie along the monoclinal axis. Therefore, the streams, cutting headward over the lower limb of the fold, are excavating only in the Atoka, but without notable change in gradient, they cut into the Morrow beds at the monoclinal axis, upstream from which they continue with the same gradient into the Atoka again. These windows are confined to the western half of the mountains, hence, either the monocline is more pronounced there or the streams have not cut down far enough in the eastern half to expose the Morrow beds. Of course, there is a possibility that the windows are present but have not as yet been found. Very likely the eastern

---

[1] Croneis, C. G., Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, p. 170, 1930.

[2] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), p. 3, 1907.

portion of the mountains, which, as pointed out above, is lower than the central portion, has not undergone the same amount of erosion as the more elevated portion of the mountains where the gradients of the streams are greater.

The trend of one of the Morrow windows suggested that some additional influence other than a monoclinal fold was responsible for its east-west trend. This valley is at Limestone, Newton County, and is interesting because of its orientation perpendicular to the direction of the other major valleys in the mountains. Field work shows that a fault of about four hundred eighty feet (measured by the Arkansas Mineral Survey) has thrown the Atoka down on the south side to the level of the top of the Boone limestone. The fault plane was not located, so that further details about the structure are lacking.

The window at Cass, Franklin County, may subsequently prove to have been formed in the same way as the one at Limestone.

Several faults more or less aligned with the disturbance at Limestone have been found and are discussed in the section on structure of the quadrangles. The general trend of faulting is east-west and extends across the mountains at about T. 13 N. but east of Searcy County it swings a little north of east. The faults are shown on the accompanying map. It is important to note that the faults mapped in the various folios form a zone extending across the state just north of the Boston Mountain escarpment. The zone of faulting north of the escarpment and the zone along the monocline are the two most valuable aids in deciphering the geologic structure and history of the Boston Mountains. The southern set represents faulting of the monocline contemporaneous with the major uplift of the mountains. The northern set of east-west faults are the result of adjustment which was probably contemporaneous with the elevation and tilting which caused the faulting to the south. The general or collective downthrow is to the south, therefore, the Boston Mountain block subsided somewhat at the north, even though a regional dip to the south is maintained in this region.

The southern set of faults, although not as striking as the northern set, probably were formed by relative elevation of the plateau above the synclinal valley of the Arkansas River. Were this the case, the downthrow should be on the south side of the faults, as it actually is in most instances. The forming of the monocline, therefore, marks the time of differentiation of the Boston Mountain and Arkansas valley provinces. The attitude of the fault planes indicates the faults to be of the tensional type for the most part. It has been pointed out that the beds south of the monocline are much thicker than north of it, hence, although the actual load of the deposits in the valley may not have been sufficient to have caused the actual folding, it might have been adequate to act as a trigger to initiate the subsequent faulting.

The diastrophism in the Boston Mountains occurred at more than one time. As was shown in the stratigraphic discussion, the Pitkin limestone becomes increasingly thick down-dip, hence, there must have been a basin to the south as early as Pitkin time. There may have been a definite southward regional slope after Fayetteville time because increasingly younger beds of the Pitkin rest upon strata of the former formation at different places from south to north. Non-deposition of certain phases of the Fayetteville, however, would explain the condition as well as tilting of the basin would. Whether or not there was pre-Pitkin diastrophism along the line of the present monocline is not known. Some low folds and domes were formed before Pitkin time in certain parts of the mountains, as is shown by thinning of the Pitkin at some localities, notably in the Eureka Springs-Harrison quadrangles. After Pitkin and before Hale time the region was elevated because the northern extension of the Pitkin has been beveled off. The Hale sandstone was deposited on beveled Pitkin strata and then more gentle folding occurred, for the Bloyd shale thins out upon the limbs of certain of these structures, notably the Sneeds Creek dome. Deposition of the Atoka may have been preceded by some erosion, as there is evidence in the eastern part of the mountains that Morrow beds were deposited but are now absent in part at some places. The initiation of the monoclinal folding occurred at least before Atoka time, for the Atoka beds thicken markedly south of the monocline. After Atoka time the monoclinal structure became more pronounced and eventually not only was the monocline faulted, but the Sneeds Creek dome and other folds were also faulted. This is evident because the Atoka on these folds is arched up. It is not known whether or not the faulting of all structures was contemporaneous. The time of the major diastrophism probably was contemporaneous with the Ouachita folding, namely, near the close of the Carboniferous.

A few wells have been drilled to the pre-Cambrian crystalline rocks in northern Arkansas, and offer some very interesting data. The four wells have been discussed by Croneis.[1]

Well No. I. A well drilled by the Arkansas Publicity Bureau 5 miles southwest of Bentonville in the NE¼ SE¼ section 5, T. 19 N., R. 31 W. The well started at the top of the Boone and reached the pre-Cambrian at 2,365 feet, provided that "syenite" reported at that depth in the driller's log is the pre-Cambrian. The fact that traces of oil were reported just below the "syenite" throws doubt on the value of the log.

Well No. II. Croneis describes another well in the NE¼ SW¼ section 30, T. 15 N., R. 31 W., 1.5 miles south of Prairie Grove. This well started 21 feet above the base of the Fayetteville shale and reached the pre-Cambrian at 2,485 feet.

Well No. III. The Independent Oil and Gas Company's H. Banks Well No. 1, in the SE¼ NE¼ section 6, T. 16 N., R. 27 W., also reached the pre-Cambrian. The well started 310 feet above the base of the Boone and reached the pre-Cambrian at 2,397 feet.

Well No. IV. The War Eagle Oil and Gas Company well in section 13, T. 15 N., R. 26 W., near Witter, started 56 feet above the base of the Hale and reached the pre-Cambrian at 2,286 feet. This well is 13 miles southeast of the preceding well.

Well No. II was started 21 feet above the top of the Boone and Well No. I was started very close to the top of the Boone. The elevation above sea level of the casing head, as computed from topographic maps, is 1,275 feet for Well No. I and 1,175 feet for Well No. II. The interval between

---

[1] Op. cit., pp. 171-193.

the top of the Boone and the pre-Cambrian in Well No. I is about 2,365 feet and the same interval in Well No. II is 2,464 feet, hence Well No. II is about 100 feet higher stratigraphically than Well No. I. The top of the Boone at Well No. I, however, is about 122 feet higher than that at Well No. II, so the pre-Cambrian is at least 222 feet farther below sea level at Well No. II than at Well No. I, taking both topography and stratigraphy into account.

Well No. III, located 25 miles east of Well No. II, started 310 feet above the base of the Boone, has a casing-head elevation of about 1,425 feet. The interval between the case of the Boone and the pre-Cambrian is 2,087 feet at this well, and 2,155 feet at Well No. II which has a casing-head elevation of 1,175 feet. Hence the latter well is 242 feet higher stratigraphically than the former. The elevation of the base of the Boone at Well No. III, however, is 270 feet higher than that at Well No. II. Thus the pre-Cambrian is about the same distance below sea level at the two places.

The distance below sea level of the pre-Cambrian at Well No. IV cannot be calculated at this time because the casing-head elevation is not known, nor are there any topographic maps from which it can be estimated. Croneis[1] studied the stratigraphy as shown in the well logs of Nos. III and IV, however, and he points out that the early Paleozoic rocks near Witter are somewhat thinner than those to the west. This probably means that there is a notable high in the pre-Cambrian near Witter.

As was pointed out in the discussion of the Pitkin limestone, the formation is much thicker in the eastern part of the mountains than near their western termination. The thickening is achieved by the introduction of additional beds in the lower portion of the formation, as well as by the thickening of individual and continuous beds. The phenomenon of addition of beds between continuous strata was not observed to be as prominent to the east in the thickened sections as it was on the south or down-dip side of the mountains.

The Pitkin sea in Arkansas, as conceived by the writer, consisted of a wide and relatively deep basin located where the eastern half of the mountains stands today, plus a shallow

---

[1] Op. cit., pp. 193, 194.

portion of the sea at the west. Early Pitkin sedimentation predominated in the deeper portion of the sea, but subsequently there was increasingly active deposition over the shallow region to the west. The only places that afford complete sections of the Pitkin are along the escarpment, so data from which the outline of the sea could be reconstructed are lacking, except in an east-west line across the state. Judging from the general configuration of the structural features of the region, however, the sea probably was deepest to the east and south of the mountains and was broadly elongate in the former region from the northwest to the southeast. The northern limit of the sea was not far north of the present northern extent of the formation in the west, as is shown by the coarse material contained within the formation there. Throughout the central and most of the eastern portions of the region, the coarse material is absent, thus the outcrops there must be considerably removed from the northern limits of the sea. South of Batesville the formation contains more shale and a conglomerate previously noted may belong to the Pitkin, thus there is some evidence that these outcrops are close to the former border of the sea. The shale and chert in the formation are interpreted as representing times of erosion near the Pitkin sea in the first instance and times of relatively quiet water and little erosion in the latter instance.

South and east of Batesville the strata of the Boston Mountains slope to the east and south and the prominent escarpment gives way to low hills and ridges. The extreme eastern extension of the Paleozoic rocks in the mountains southwest of Newport is covered by unconsolidated rocks of Eocene age and younger in the Mississippi embayment. It is noteworthy that this blanket of Tertiary rocks laps up over the Paleozoic material and extends above the level of the embayment. Either the mountains have been uplifted since the deposition of the overlapping formations, or the sediments in the embayment have settled by compaction, the thinner portions of them lying on the low plateau of the Boston Mountains. This ridge is traceable as a low linear hill extending into the embayment for a few miles.

CORRELATIONS

In the appended correlation chart the writer has shown the relationship of the Pitkin to some other formations, some of which have been correlated with the Pitkin by certain writers but are considered differently today; others are undoubtedly correlatives in part; and still others of Chester age are included to show their relation to the Pitkin. Because some correlations have not been referred to specific formations within the standard section of Illinois, it is difficult to place all groups in precise juxtaposition, however, this correlation chart will illuminate certain correlations of interest in the study of the Pitkin, as well as in the correlation of other Chester formations.

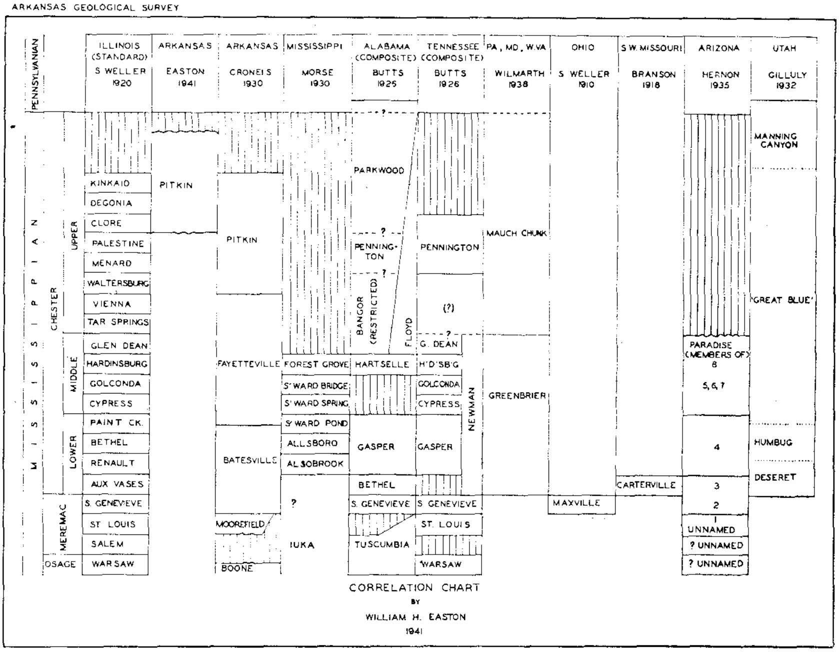


FIG. 9—CORRELATION CHART SHOWING THE RELATION OF THE PITKIN LIMESTONE TO OTHER FORMATIONS

The left side of the chart gives the key for dividing the Mississippian then the first column is the Standard Section as offered by Stuart Weller[1] for the Illinois basin. The Ste. Genevieve is placed in the Meremacian according to the present usage of the U. S. Geological Survey.

---

[1] Weller, Stuart, "The Geology of Hardin County," *Geol. Surv. of Ill., Bull.*, No. 41 (1920), Table 1, p. 80.

The writer considers the Pitkin to be younger in part than the Kinkaid and younger as a whole than it has been heretofore considered to be. The physical evidence leading to this conclusion is presented in this report but the faunal study will be presented in a subsequent publication.

Croneis[1] presented a correlation chart with the formations arranged as shown in the third column. It is noteworthy that Croneis considered the Batesville to be of about Cypress age in part. Girty[2] believed there was very little evidence which he considered trenchant for placing the top of the Batesville at the top of the Cypress, yet he provisionally followed Stuart Weller[3] and Ulrich[4] [5] [6] and made the Batesville equivalent to the interval including the Cypress and Ste. Genevieve.

The formations of northeastern Mississippi described by Morse[7] are included to show their relation to the nearby Arkansas Chester beds. If post-Forest Grove sediments were ever deposited in Mississippi, they have since been eroded. There is no positive evidence that the Pitkin seas ever did cover this region and there is no evidence that the seas that deposited these formations of Mississippi ever laid down deposits in Arkansas.

The composite sections in Tennessee and Alabama from Butts[8] show much of the Parkwood of Alabama and the upper part of the Pennington of Tennessee to contain Pitkin equivalents, provided that the relationships continue to be considered as shown in this chart. The Parkwood apparently offers an instance of uninterrupted sedimentation from the Mississippian into the Pennsylvanian.

The Mauch Chunk and Greenbrier of Pennsylvania, Maryland, and West Virginia are shown in their relative strati-

---

[1] Op. cit., p. 20, 1930.

[2] Girty, G. H., The fauna of the Batesville sandstone of northern Arkansas: U. S. Geol. Survey Bull. 593, p. 20, 1915.

[3] Weller, Stuart, The Batesville sandstone of Arkansas: New York Acad. Sci. Trans., vol. 16, p. 20, 1897.

[4] Ulrich, E. O., Determination and correlation of formations of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, p. 104, 1904.

[5] Ulrich, E. O., and Smith, W. S. T., The lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36, p. 39, 1905.

[6] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull. 22, pl. 29, 1911.

[7] Morse, W. C., Paleozoic rocks of Mississippi: Mississippi Geol. Survey Bull. 23, p. 19, 1930.

[8] Butts, Charles, The Paleozoic rocks: Alabama Geol. Survey Special Rept. No. 14, pl. opposite p. 80, 1926.

graphic positions as given by Wilmarth.[1] The Mauch Chunk probably is in part equivalent to the Pitkin. Reger[2] correlated the subdivisions of the Mauch Chunk and suggests that the top of the Talcott shale is equivalent to the upper boundary of the Chester of Illinois and that, therefore, 3,075 feet of Mauch Chunk sediments are younger than the Kinkaid of Illinois. Reger placed the base of the Mauch Chunk at the top of the Glen Dean.

Snider[3] considered the Maxville limestone of Ohio to be equivalent to the Pitkin and quoted Stuart Weller[4] for the correlation. The correlation as previously presented by Weller was with the Ste. Genevieve. Also, Morse[5] thought the evidence for the correlation of the Maxville to be equally divided between the Fredonia and the Ohara members of the Ste. Genevieve limestone and that the preponderance of evidence indicated Ohara age. Snider also considered the Carterville to be the only possible equivalent (if any be present) of the Pitkin in southwestern Missouri but Branson[6] later considered the Carterville to be equivalent to the Aux Vases.

The members of the Paradise formation of Arizona as correlated by Hernon[7] are given in the chart. Finally, the uppermost Mississippian formations of Utah are given in the chart not according to their correlation with other Chester formations but according to the relative thickness of the four formations. These strata represent about seven thousand feet of sediments, far more than are involved in the other areas of Chester sedimentation. It is worth pointing out that the Manning Canyon shale is part Pennsylvanian and part Mississippian, according to Gilluly.[8] Pitkin correlatives may be represented in the Manning Canyon shale.

---

[1] Wilmarth, Grace, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pt. I, pp. 866-867, 1938.

[2] Reger, D. B., Mercer, Monroe and Summers counties: West Virginia Geol. Survey County Rept., pt. II, Geology, p. 313, 1926.

[3] Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, pt. I, p. 43, 1915.

[4] Weller, Stuart, Correlation of the middle and upper Devonian and the Mississippian faunas of North America: in outlines of geologic history with especial reference to North America, by Baily Willis and R. D. Salisbury, Univ. Chicago Press, pp. 115-116, 1910.

[5] Morse, W. C., The Maxville limestone: Ohio Geol. Survey Bull. 13, Fourth Series, p. 108, 1910.

[6] Branson, E. B., Geology of Missouri: Missouri Univ. Bull. 19, no. 15, p. 71, 1918.

[7] Hernon, R. M., The Paradise formation and its fauna: Jour. Paleontology, vol. IX, no. 8, p. 667, 1935.

[8] Gilluly, James, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, p. 7, 1932.

PALEOGEOGRAPHY

The paleogeographic map has been drawn from data compiled largely through the researches of other writers but modified to apply to the details in this paper. Miser [1] [2] has done considerable work in the general region and his studies have been supplemented by those of Jenny,[3] who made a magnetic

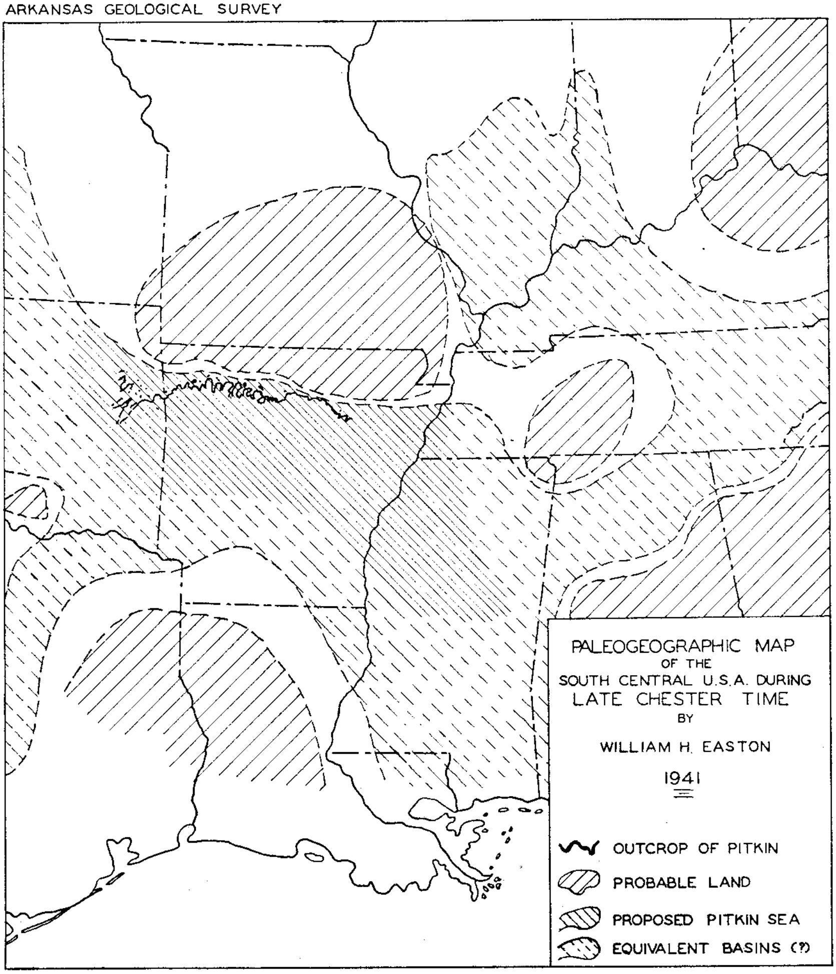


FIG. 10—PALEOGEOGRAPHIC MAP OF SOUTH CENTRAL UNITED STATES DURING THE LATE CHESTER TIME

---

[1] Miser, H. D., Relation of Ouachita belt of Paleozoic rocks to oil and gas fields of Mid-Continent region: Am. Assoc. Petroleum Geologists Bull., vol. XVIII, no. 8, pp. 1059-1077, 1934.

[2] Miser, H. D., Carboniferous rocks of Ouachita Mountains: Am. Assoc. Petroleum Geologists Bull., vol. XVIII, no. 8, pp. 971-1009, 1934.

[3] Jenny, W. P., Magnetic vector study of regional and local geologic structure in principal oil states: Am. Assoc. Petroleum Geologists Bull., vol. XVI, no. 12, p. 1201, fig. 10, 1932.

vector study of parts of the region shown on the map. This map shows how the writer considers the general relations of land and sea to have been at about Pitkin time. It has been presumed herein that magnetic ''lows'' indicate places where there may have been troughs or basins, and that magnetic ''highs'' possibly indicate potential lands. The principal error in interpreting magnetic anomalies with relation to past conditions is that the magnetic picture is of features which may not have existed in remote times.

Sedimentation in Arkansas during Pitkin time occurred in a more or less restricted embayment of a larger sea which the writer believes lay to the south and southeast from the present outcrops and parallel with the northern arc of the Ouachita trough, overlapping the edges of that trough, however, to extend as an increasingly shallow body of water some distance northwest from its deepest portions. In fact, it seems incontrovertible that the outcrop of the Pitkin is very close to the northern limit of sedimentation. This is borne out by the notable down-dip thickening to the south and east and by the presence of intraformational limestone conglomerate within the Pitkin formation.

Faunal studies show the basis of the Pitkin fauna to be composed of more commonly recurring Chester species which are not peculiar to any individual formation of the Illinois basin, but which were still flourishing in Pitkin seas after connection with the Illinois basin had been severed in pre-Pitkin times. It is, indeed, true that earlier Chester seas were connected from Illinois through Kentucky, Tennessee, and Mississippi, but deposits of these seas are lacking in Arkansas in so far as is known, just as are Pitkin deposits lacking in the foregoing areas. Undoubtedly there were connections between the Pitkin sea and other contemporaneous seas whose deposits are recognized today, but the lack of adequate faunal correlation seems to indicate that the several different areas of sedimentation were connected by circuitous straits.

The other boundaries of the sea are known only from comparison with neighboring formations and from a study of the structure of the region. The eastward extension of the Pitkin sea is in doubt because if it ever extended across northeastern Alabama above lower Chester deposits it has since been removed by erosion. The sea probably extended farther into Oklahoma than the outcrops do today, but studies show no Pitkin in that area.

McClellan[1] quotes Roth for the identification of four hundred feet of Chester limestone in Clark County, Kansas, and adjacent areas of northwestern Oklahoma. This region is far from the outcrops of Pitkin, but offers interesting speculation on how the distribution of this thick limestone sequence is related to the problem of connection of late Chester seas.

Should these four hundred feet of Chester limestones prove to be in any part equivalent to the Pitkin, then drawing the extent of the sea into Clark County, Kansas, and adjacent northwestern Oklahoma would be justified. The southern extension of the sea can be proved only by well borings through the Pennsylvanian sediments, which, to date, have not given the answer to the problem. It is obvious that there was some outlet to the Pitkin sea, but it is not known whether this outlet was across Mississippi, Texas, or both.

After studying the faunal and lithologic characters of the Pitkin, the writer concludes that there was no connection with the late Chester sea of the Illinois basin across the "saddle" between the Ozark region and the Nashville dome.

It seems equally as possible that the connection between the Illinois basin and the main ocean at that time was through southwestern Kentucky and the Appalachian geosyncline as across the "saddle." It should be pointed out, however, that the range of marine faunas may be restricted by ecologic barriers, just as effectively as by physical barriers. That is, differences in temperature, velocity of currents, depth, salinity, and amount of suspended material in a body of water have profound effects upon the living things occupying any marine environment, hence, any shallow water connection between two adjacent seas may prevent certain species from negotiating their transfer from one locality to another.

As pointed out by Buchanan,[2] it seems reasonable that there may have been a connection through the Ouachita

---

[1] McClellan, H. W., Subsurface distribution of pre-Mississippian rocks of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. XIV, no. 12, pp. 1542-1543, map, 1930.

[2] Buchanan, G. S., Distribution and correlation of the Mississippian of Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. XI, no. 12, pp. 1318-1320, 1927.

trough with some southwestern body of water. Indeed, it may well have been through such a strait that the unique coral fauna entered the Pitkin seas overspreading Arkansas. Certainly there is no evidence that this fauna came from any northern part of the continent. On the other hand, the main connection of the Pitkin sea with the parent body of water may have been from the south between the hypothetical land Llanoria and the eastern highlands and thence westward to a Cordilleran sea. The northwestern extent of the seas into Oklahoma probably was in the form of a lobe rather than as a main connection with another sea. The reason for this statement is that the Pitkin thins to the west and north.

It seems probable that the regions of the Cincinnati Arch, the Ozark and Nashville domes, the Appalachian highland, and possibly Llanoria, the Arbuckles, and the Wichitas were land masses. Unshaded areas might have been either land or water, but most portions were probably land.

Buchanan[1] mentions the occurrence of sand grains of probable Simpson origin from the Arbuckle and Wichita mountains of the southwest, hence, there must have been land in that region. Furthermore, it is quite likely that most of the shale within the Pitkin is reworked Fayetteville shale from northern and western Arkansas and northeastern Oklahoma where the Fayetteville was probably exposed during part of Pitkin time. Other origins of sediments are unknown for the formation.

The writer believes Pitkin sedimentation began to the south or southeast of Arkansas and progressed to about central northern Arkansas, where deposits, mainly of limestone, were continually laid down. The bordering land was then probably elevated slightly following the limestone deposition, for the middle shale and shaly limestone member of the formation was deposited above the lower limestones. Sedimentation next occurred farther to the west and northwest, where portions of the upper limestone member are the only Pitkin sediments present today.

Pitkin time closed with the withdrawal of the sea, probably towards the southeast in the direction from whence it came. The evidence for this is that in Searcy County (see Columnar Section 15) the Pitkin grades up into thin-bedded

---

[1] Ibid.

impure limestones, shales, and sandstones exhibiting mudcracks and ripple marks. Ensuing elevation of the region with subsequent erosion has not yet effected the removal of these strata with their characters of shallow water sediments.

The presence of thick sediments of limestone precludes the possibility of any noteworthy current diastrophism in a region. Because it lies at the top of the Mississippian in its area of known occurrence, writers discussing diastrophism and complex stratigraphic relations of sediments of about Pitkin age in the region must consider the importance of the Pitkin limestone. The Pitkin adds complexity to the problem because it indicates a rather long time of comparatively stable lands and of mostly clear seas immediately prior to ensuing local movements of the earth's crust and deposition of clastic sediments.

FAUNAL LIST

FORAMINIFERA
  Endothyra sp.
PORIFERA
  Cliona sp.
ANTHOZOA
  Amplexus sp.
  Aulopora cf. A. gracilis Thomson
  Cup coral n. gen. et n. sp.
  Koninckophyllum n. sp.
  Lonsdaleia n. sp.
  Lonsdaleia n. sp.
  Micrelinia eugenae White
  Michelinia meekana Girty
  Syringopora sp.
  Triplophyllum spinulosum (Edwards & Haime)
BLASTOIDEA
  Pentremites sp.
  Pentremites n. sp.
  Pentremites cf. P. platybasis Weller
CRINOIDEA
  Agassizocrinus sp. 1
  Agassizorcinus sp. 2
  Agassizocrinus sp. 3
  Carcinocrinus stevensi Laudon
  Catillocrinus sp.
  Cosmetocrinus, sp.
  Cromyocrinus sp.
  Cyathocrinus sp.
  Delocrinus sp.
  Hydreionocrinus sp.
  Linocrinus floweri Laudon
  Pachylocrinus sp.
  Pelecocrinus stereosoma Laudon
  Phanocrinus cooksoni Laudon
  Phanocrinus cf. P. cooksoni Laudon
  Poteriocrinus ? sp.
  Pterotocrinus sp.
  Scytalocrinus sp. 1
  Scytalocrinus sp. 2
  Scytalocrinus braggsi Laudon
  Scytalocrinus dunlapi Laudon
  Scytalocrinus garfieldi Laudon
  Crinoid unidentified
STELLEROIDEA
  Agenester n. sp.
  Schoenaster ? sp.
ECHINOIDEA
  Archaeocidaris sp.
VERMES
  Spirorbis sp.
BRYOZOA
  Anisotrypa solida Ulrich
  Archimedipora sp.
  Archimedipora communis (Ulrich)
  Archimedipora distans (Ulrich)
  Archimedipora intermedia (Ulrich)
  Archimedipora invaginata (Ulrich)
  Archimedipora proutana (Ulrich)
  Archimedipora swallovana (Ulrich)
  Batostomella sp.
  Chilotrypa n. sp.
  Dichotrypa n. sp.

- Dyscritella ? sp.
- Fenestella (Fenestrellina) sp.
- Fistulipora n. sp.
- Glyptopora michelinia (Prout)
- Glyptopora n. sp.
- Lyropora n. sp.
- Meekopora n. sp.
- Meekopora n. sp.
- Polypora sp.
- Polypora cf. P. whitei Ulrich
- Rhombopora sp.
- Septopora cestdiensis Prout
- Septopora subquadrans Ulrich
- Tabulipora cestriensis (Ulrich)
- Tabulipora n. sp.
- Tabulipora n. sp.
- Tabulipora n. sp.
- Tabulipora n. sp.

BRACHIPODA

- Athyris cestriensis Snider
- Buxtonia arkansana (Girty)
- Camarophoria explanata (McChesney)
- Chonetes oklahomensis Snider
- Chonetes sericeus Girty
- Chonetes n. sp.
- Cliothyridina sublamellosa (Hall)
- Composita subquadrata (Hall)
- Composita trinuclea (Hall)
- Composita sp.
- Crania n. sp.
- Diapharagmus ? sp.
- Dielasma ? sp.
- Dielasma arkansanum Weller
- Dielasma formosum (Hall)
- Dielasma illinoisensis Weller
- Dielasma shumardanum (Miller)
- Dielasma whitfieldi Girty
- Echinoconchus alternatuc (Norwood) & Pratten)
- Echinoconchus ? sp.
- Eumetria costata (Hall)
- Eumetria pitkinensis Snider
- Eumetria vera (Hall)
- Girtyella indianensis (Girty)
- Hustedia sp.
- Hustedia multicostata Girty
- Krotavia n. sp.
- Linkula sp.
- Lingulidiscina newberryi var. moorefieldana Girty
- Lingulidiscina newberryl var. ovata
- Linouroductus pileiformis (McChesney)
- Martinia sp.
- Orthotetes kaskaskiensis (McChesney)
- Orthotetes kaskahkiensis var. ?
- Orthotetes subglobosus var. protensa Girty
- Orthotetes suspectum (Girty)
- Productus cestriensis Worthen
- Productus fasciculatus McChesney
- Pustula ? sp.
- Reticularia setigera (Hall)
- Spirifer leidyl Norwood & Pratten
- Spirifer pellaensis Weller
- Spiriferina spinosa (Norwood & Pratten)
- Streptorhynchus ? sp.
- Syringothyris n. sp.
- Tetracamera sp. [T. neogenes]
- Tetracamera neogenes Girty

PELECYPODA

- Allorisma walkeri Weller
- Astartella sp.
- Aviculopecten batesvillensis Weller
- Aviculopecten eurekensis Walcott
- Aviculopecten keoughensis Snider
- Aviculopecten morrowensis Girty
- Aviculopecten multilineatus Girty
- Aviculopecten pitkenensis Girty
- Conocardium sp.
- Conocardium peculiare Girty
- Cypricardella sp.
- Cypricardinia sp.
- Edmondia crassa Girty
- Edmondia pitkinensis Snider
- Leda sp.
- Leda vaseyana (McChesney)
- Leiopteria ? sp.
- Leptadesma ? sp.
- Myalina sp.
- Myalina compressa Snider
- Myalina longicardinalis Snider
- Nucula illinoisensis Worthen
- Parallelodon sp.
- Pteronites sp.
- Schizodus sp. 1
- Schizodus sp. 2
- Schizodus arkansanus (Weller)
- Schizodus chesterensis Meek & Worthen
- Schizodus depressus Worthen
- Schizodus insignis Drake
- Solenomya ? sp.
- Spenotus cherokeense Snider
- Spenotus quadriplicatum Snider
- Spenotus gibsonense Snider

SCAPHODA

- Laevidentalium sp.

GASTROPODA

- Bellerephon sp. 1
- Bellerephon sp. 2
- Bellerephan pitkinensis Snider
- Bucanella ? sp.

Colpites ? sp.
Euphemites n. sp.
Glabrocingulum sp.
Gosseletina ? sp. 1
Gosseletina ? sp. 2
Helcionopsis ? n. sp.
Hemizyga sp.
Holopea newtonensis Whitfield
Latischisma ? sp.
Leptoptygma sp.
Leptoptyma ? sp.
Microptychis sp.
Mourlonia n. sp.
Naticopsis sp.
Neilsonia sp.
Phanerotrema sp.
Platyceras subrotundum Snider
Platyschisma sp.
Pseudozygopleura ? sp.
Sphaerodoma subcorpulenta (Whitfield)
Stegocoelia sp.
Straparolus n. sp.
Strobeus sp.
Strobeus ? sp.
Strophostylus sp.
Conularia sp.

CEPHALOPODA
Coloceras (Leuroceras ?) sp. 1
Coloceras sp. 2
Cravenoceras cf. C. hesperium Miller & Furnish
Cycloceras randolphensis (Worthen)
Cycloceras sequoyahensis Snider
Dolorthoceras ? eurekensis (Walcott) ?
Dolorthoceras ? sp.
Eoasianites n. sp.
Mooreoceras sp.

TRILOBITA
Griffithides sp.
Griffithides pustulosis Snider
Kaskia chesterensis J. M. Weller
Paladin muchonatus (Girty)

OSTRACODA
Glyptopleura inoptina Girty
Paraparchites sp.
Primitia fayettevillensis Girty

VERTEBRATA
Cladochonus sp.
Cladodus sp.
Deltodus sp.
Petalodus sp.

PLANTAE
Encrusting alga

BIBLIOGRAPHY

PUBLICATIONS

Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, 1904.

——————————, U. S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), 1905.

Branson, E. B., Geology of Missouri: Missouri Univ. Bull. 19, no. 15, 1918.

Buchanan, G. S., Distribution and correlation of the Mississippian of Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 11, no. 12, 1927.

Butts, Charles, The Paleozoic rocks: Alabama Geol. Survey Sp. Rept. 14, 1926.

Croneis, C. G., Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, 1930.

Fenneman, N. M., Physiography of eastern United States: 1st ed., McGraw Hill Book Company, New York, 1938.

Giles, A. W., and Brewster, E. B., Hale Mountain section in northwest Arkansas: Am. Assoc. Petroleum Geologists Bull., vol. XIV, no. 2, 1930.

Gilluly, James, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, 1932.

Girty, G. H., The fauna of the Batesville sandstone of northern Arkansas: U. S. Geol. Survey Bull. 593, 1915.

Hernon, R. M., The Paradise formation and its fauna: Jour. Paleontology, vol. IX, no. 8, 1935.

Hershey, O. H., Peneplain of the Ozark highland: Am. Geologist, vol. XXVII, 1901.

——————, Boston Mountain physiography: Jour. Geology, vol. X, no. 2, 1902.

Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. 1890, vol. IV, 1893.

Jenny, W. P., Magnetic vector study of regional and local geologic structure in principal oil states: Am. Assoc. Petroleum Geologists Bull., vol. XVI, no. 12, 1932.

Johnson, Clayton, and Hoagland, A. D., Mineral resources of Benton, Carroll, Madison, and Washington counties: Arkansas Geol. Survey County Mineral Report 2, 1940.

Laudon, L. R., New Crinoid fauna from the Pitkin limestone of northeastern Oklahoma: Jour. Paleontology, vol. XV, no. 4, 1941.

Mather, K. F., The fauna of the Morrow group of Arkansas and Oklahoma: Denison Univ. Sci. Lab. Bull., vol. XVIII, art. 3, 1915.

McClellan, H. W., Subsurface distribution of pre-Mississippian rocks of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. XIV, no. 12, 1930.

McKnight, E. T., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Bull. 853, 1935.

Miser, H. D., Carboniferous rocks of Ouachita Mountains: Am. Assoc. Petroleum Geologists Bull. vol. XVIII, no. 8, 1934.

——————, Relation of Ouachita belt of Paleozoic rocks to oil and gas fields of Mid-Continent region: Am. Assoc. Petroleum Geologists Bull. vol. XVIII, no. 8, 1934.

Moore, C. A., Morrow group of Adair County, Oklahoma: Am. Assoc. Petroleum Geologists Bull. vol. 24, no. 3, 1940.

Morse, W. C., Paleozoic rocks of Mississippi: Mississippi Geol. Survey Bull. 23, 1930.

————————, The Maxville limestone: Ohio Geol. Survey Bull. 13, Fourth Series, 1910.

Owen, D. D., First report of a geological reconnoissance of the northern counties of Arkansas, made during the year 1857 and 1858, 1858.

Parks, Bryan, Black marbles of northern Arkansas: Arkansas Geol. Survey Inf. Circ. 3, 1932.

Purdue, A. H., Physiography of the Boston Mountains, Arkansas: Jour. Geology, vol. IX, no. 8, 1901.

————————, U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), 1907.

Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

Reger, D. B., Mercer, Monroe, and Summers counties: West Virginia Geol. Survey County Rept. pt. II, Geology, 1926.

Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Report 1888, vol. IV, pt. I, 1891.

Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, pt. I, 1915.

Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (no. 122), 1905.

————————, U. S. Geol. Survey Geol. Atlas, Muskogee folio (no. 132), 1906.

Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey 21st Ann. Rept., pt. II, 1900.

Ulrich, E. O., Determination and correlation of formations of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, 1904.

————————, Revision of the Paleozoic systems: Geol. Soc. America Bull. 22, 1911.

Ulrich, E. O., and Smith, W. S. T., The lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36, 1905.

Weller, Stuart, The Batesville sandstone of Arkansas: New York Acad. Sci. Trans., vol. 16, 1897.

————————, Correlation of the middle and upper Devonian and the Mississippian faunas of North America: In Outlines of geologic history with especial reference to North America, by Bailey Willis and R. D. Salisbury, Univ. Chicago Press, 1910.

————————, The geology of Hardin County: Illinois Geol. Survey Bull. 41, 1920.

White, C. D., The Pottsville series along New River, West Virginia: Geol. Soc. America Bull., vol. VI, 1895.

Wilmarth, Grace, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pts., 1 and 2, 1938.

MAPS

United States Geological Survey, Folios:

No. 119:	Fayetteville Folio, Arkansas-Missouri, 1905.
No. 122:	Tahlequah Folio, Oklahoma-Arkansas, 1905.
No. 132:	Muskogee Folio, Oklahoma, 1906.
No. 154:	Winslow Folio, Arkansas-Oklahoma, 1907.
No. 202:	Eureka Springs-Harrison Folio, Arkansas-Missouri, 1916.

United States Geological Survey, Topographic Maps:

Batesville Quadrangle, Arkansas, 1891 (reprint 1921).
Eureka Springs Quadrangle, Arkansas-Missouri, 1901 (reprint 1916).
Fayetteville Quadrangle, Arkansas-Missouri, 1904.
Harrison Quadrangle, Arkansas-Missouri, 1905 (reprint 1928).
Marshall Quadrangle, Arkansas, 1901 (reprint 1936).

Mountain View Quadrangle, Arkansas, 1894 (reprint 1932).
Muskogee Quadrangle, Oklahoma, 1901 (reprint 1929).
Mt. Judea Quadrangle, Arkansas, (advance sheet).
Pryor Quadrangle, Oklahoma, 1901 (reprint 1930).
Tahlequah Quadrangle, Oklahoma-Arkansas, 1901 (reprint 1927).
Winslow Quadrangle, Arkansas-Oklahoma, 1901 (reprint 1927).

"Geologic Map of Arkansas," *Arkansas Geological Survey,* G. C. Branner, State Geologist (1929), scale 1:500,000.

"Geologic Map of Oklahoma," *Oklahoma Geological Survey,* C. E. Decker, Custodian (1926), scale 1:500,000.

Arkansas State Highway Commission, General Highway and Transportation Maps, 1936:

Crawford County
Independence County
Madison County
Newton County
Searcy County
Stone County
Washington County

PLATE I

Figs. 1, 2. *Triplophyllum spinulosum* (E. & H.). 1, corallite, 1X, UC 48264; 2, polished transverse surface, 1X, UC 48261.

Fig. 3. *Syringopora* sp. Corallum, 1X, UC 48324.

Fig. 4. *Michelinia eugeneae* White. Corallum, 2X, UC 48283.

Figs. 5. 6. *Amplexus* sp. 5, corallite, 1X; 2, transverse section, 1X; both UC 48277.

Fig. 7. *Aulopora* cf. *A. gracilis* Thomson. Portion of corallum encrusting large cup coral, 5X, UC 48276.

Fig. 8. *Archimedipora intermedia* (Ulrich). Transverse section of an axis, 1X, from Chester series at Chester, Ill. (from Ulrich).

Fig. 9. *Archimedipora communis* (Ulrich). An axis, 1X, from Chester series at Sloan's Valley, Ky. (from Ulrich).

Fig. 10. *Archimedipora proutana* (Ulrich). An axis, 1X, from Chester series at Sloan's Valley, Ky. (from Ulrich).

Fig. 11. *Archimedipora distans* (Ulrich). An axis, 1X, from Chester series at Sloan's Valley, Ky. (from Ulrich).

Fig. 12. *Archimedipora invaginata* (Ulrich). An axis, 1X, from Chester series at Chester, Ill. (from Ulrich).

Fig. 13. *Archimedipora swallovana* (Hall). An axis, 1X, from Chester series at Chester, Ill. (from Ulrich).

Fig. 14. *Fenestella* sp. Portion of a frond, 2X, UC 47205.

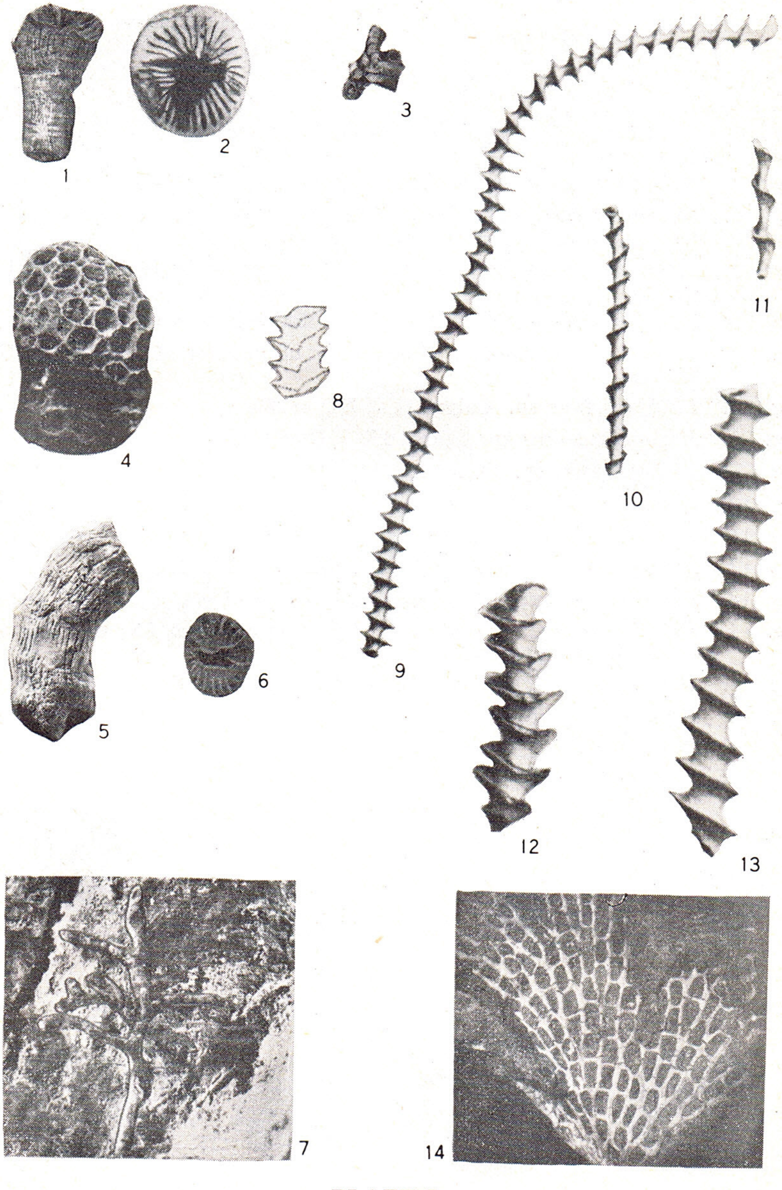


PLATE I

PLATE II

Fig. 1. *Septopora subquadrans* Ulrich. Surface, 10X, UC 47206.

Fig. 2. *Septopora cestriensis* Prout. Surface, 10X, from Chester series at Chester, Ill. (from Ulrich).

Figs. 3, 4. *Archaeocidaris* sp. 3, spine, 1X; 4, spine base, 1X; both UC 48305.

Fig. 5. *Pentremites* sp. Calyx, 2X, U. S. National Museum specimen.

Fig. 6. Crinoid undetermined. Basal view of portion of calyx, 2X, UC 48287.

Fig. 7. *Pachylocrinus* sp. Calyx, ½X, UC 48289.

Fig. 8. *Hydreionocrinus* sp. Spine, 1X, UC 48266.

Fig. 9. *Pterotocrinus* sp. Spine, 1X, UC 48269.

Fig. 10. *Agassizocrinus* sp. Fused basals, 1X, UC 48345.

Fig. 11. *Agassizocrinus* sp. Fused basals, 1X, UC 48268.

Fig. 12. *Agassizocrinus* sp. Fused basals, 1X, UC 48344.

Fig. 13. *Cromyocrinus* sp. Basal view of portion of calyx, 2X, UC 48286.

Fig. 14. *Poteriocrinus* sp. Basal view of portion of calyx, 2X, UC, S. National Museum specimen.

Fig. 15. *Delocrinus* sp. Basal view of portion of calyx, 1X, UC 48267.

Fig. 16. *Phanocrinus* cf. *P. cooksoni* Laudon. Basal view of portion of calyx, 2X, UC 48288.

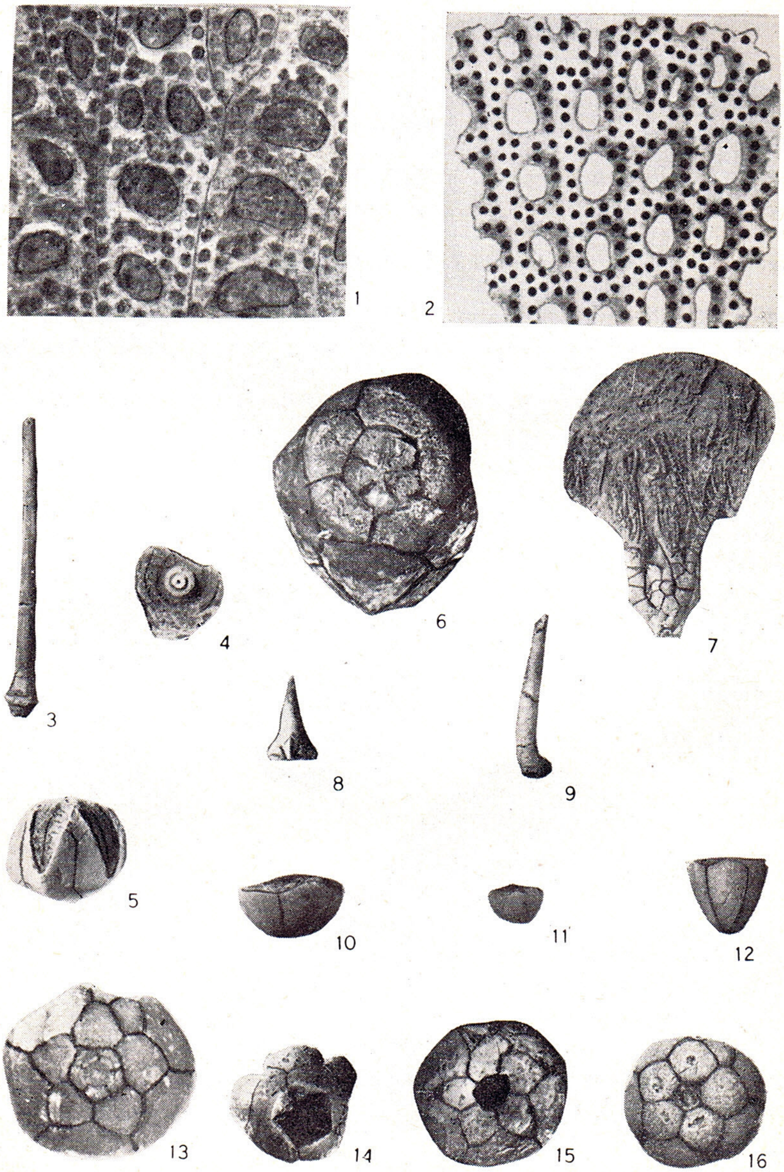


PLATE II

PLATE III

Fig. 1. *Scytalocrinus* sp. Calyx, 2+X, U. Tulsa J-510, (from Laudon).

Fig. 2. *Linocrinus floweri* Laudon. Calyx, 1+X, U. Tulsa, J-503, holotype, (from Laudon).

Fig. 3. *Scytalocrinus dunlapi* Laudon. Calyx, ½+X, U. Tulsa J-505, holotype, (from Laudon).

Fig. 4. *Catillocrinus* sp. Calyx, 2+X, U. Tulsa J-515, (from Laudon).

Fig. 5. *Carcinocrinus stevensi* Laudon. Calyx, ½+, U. Tulsa J-514, holotype, (from Laudon).

Fig. 6. *Cosmetocrinus* sp. Calyx, 2+X, U. Tulsa J-502, (from Laudon).

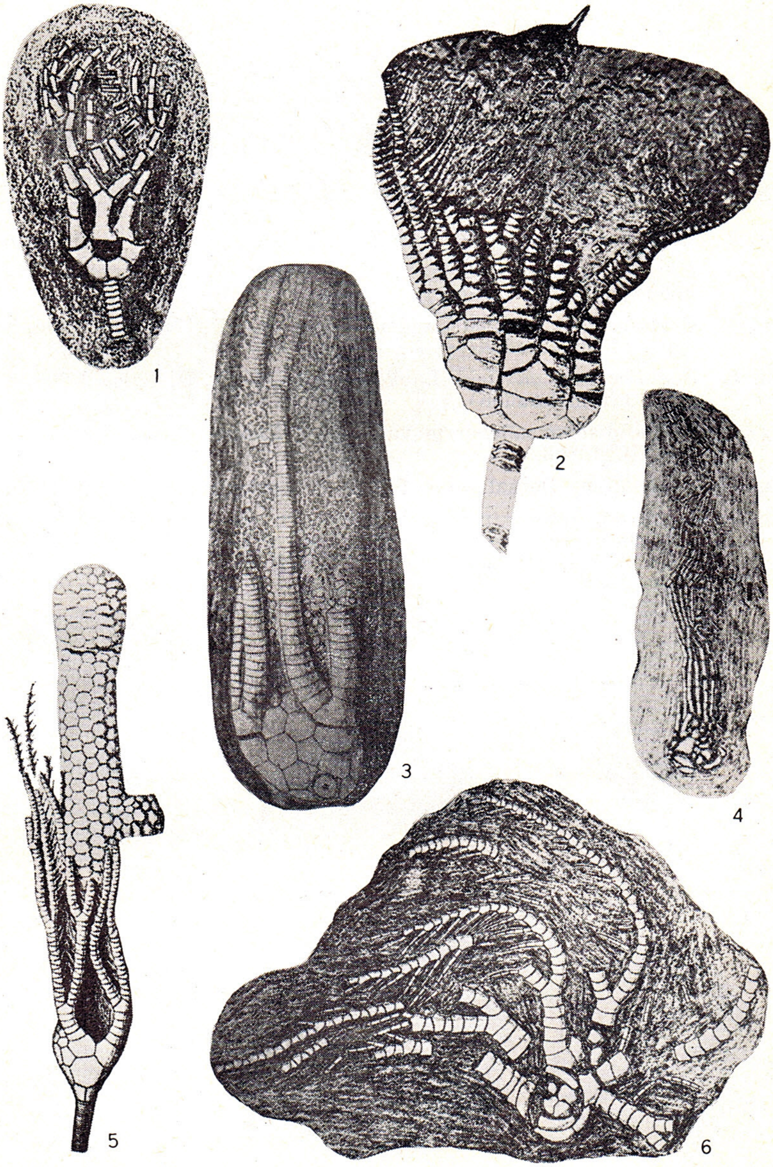


PLATE III

PLATE IV

Fig. 1. *Phanocrinus cooksoni* Laudon. Calyx, 1+X, U. Tulsa J-511, holotype, (from Laudon).

Fig. 2. *Scytalocrinus* sp. Calyx, 1+X, U. Tulsa J-509, (from Laudon).

Fig. 3. *Pelecocrinus stereosoma* Laudon. Calyx, ½+X, U. Tulsa J-500, holotype, (from Laudon).

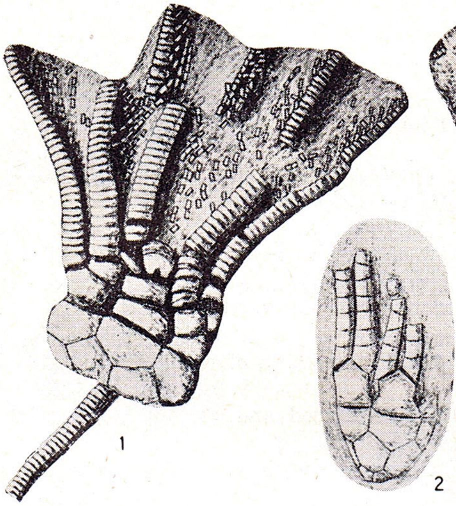
Fig. 4. *Scytalocrinus braggsi* Laudon. Calyx, ½+X, U. Tulsa J-506, holotype, (from Laudon).

Fig. 5. *Scytalocrinus garfieldi* Laudon. Calyx, 1+X, U. Tulsa J-508, holotype, (from Laudon).

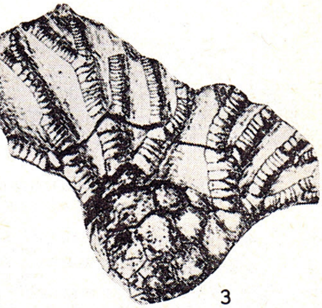
Fig. 6. *Lingulidiscina newberryi* var. *moorefieldana Girty.* Dorsal valve, 2X, UC 16808.

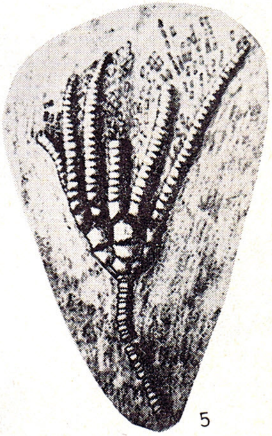
Fig. 7. *Lingula* sp. Dorsal valve, 5X, U. S. Geological Survey specimen.

Figs. 8-10. *Productus cestriensis* Worthen. 8, side view of pedicle valve, 2X; 9, ventral view of pedicle valve, 2X; both UC 47207; 10, interior of brachial valve, 2X, UC 47208.

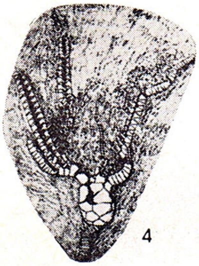

1

2


3


5


6


4


8


7

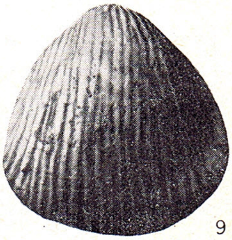

9

PLATE IV

PLATE V

Figs. 1, 2. *Buxtonia arkansana* (Girty). 1, side view of pedicle valve, 1X; 2, ventral view of pedicle valve, 1X; both UC 16888.

Figs. 3, 4. *Linoproductus pileiformis* (McChesney). 3, side view of pedicle valve, 1X; 4, dorsal view of pedicle valve, 1X; both UC 47209.

Figs. 5, 6. *Orthotetes suspectum* (Girty). 5, anterior view of pedicle valve, 1X, UC 47210; 6, exterior of brachial valve, 1X, UC 47211.

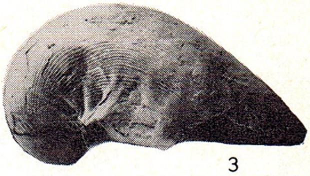
Figs. 7, 8. *Orthotetes subglobosus* var. *protensa* Girty. 7, exterior of pedicle valve, 1X, UC 47212; 8, portion of cardinal area, 2X, UC 47213.

Fig. 9. *Echinoconchus alternatus* (Norwood and Pratten). Exterior of pedicle valve, 1X, UC 16934.

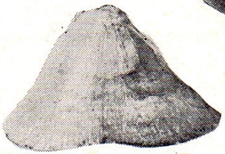
Fig. 10. *Streptorhynchus* sp. Exterior of pedicle valve, 1X, UC 48328.

Fig. 11. *Echinoconchus alternatus* (Norwood and Pratten). Interior of brachial valve, 1X, UC 47214.

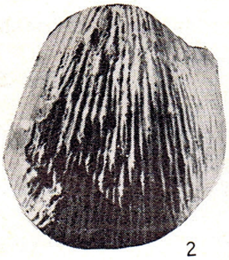
1



3

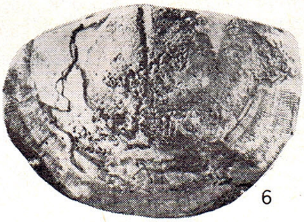


5

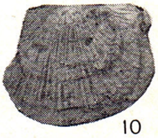


2

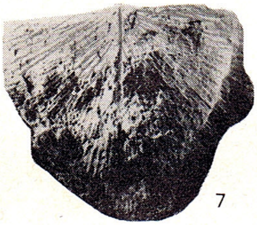
4



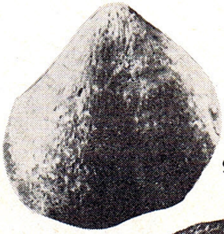
6



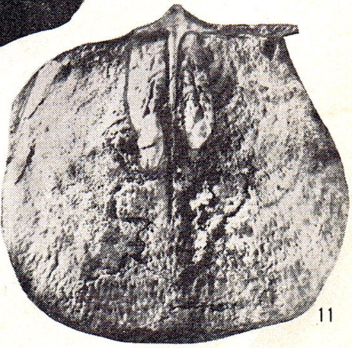
10



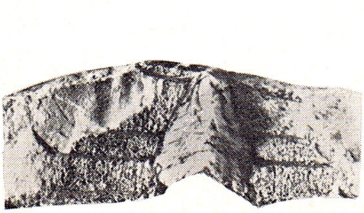
7



9



11



8

PLATE V

PLATE VI

Fig. 1. *Dielasma* ? sp. Interior mold of brachial valve, 1X, U. S. National Museum specimen.

Figs. 2-4. *Dielasma illinoisensis* Weller. 2, side view, 2X; 3, anterior view, 2X; 4, dorsal view, 2X; all UC 47215.

Fig. 5. *Dielasma formosum* (Hall). Surface of internal mold of brachial valve, 2X, UC 47216.

Figs. 6, 7. *Dielasma whitfieldi* Girty. 6, exterior of brachial valve, 2X, UC 47217; 7, exterior of pedicle valve, 2X, UC 47218.

Figs. 8-10. *Camarophoria cestriensis* Snider. 8, dorsal view, 2X; 9, side view, 2X; 10, anterior view, 2X; all UC 47219.

Fig. 11. *Girtyella indianensis* (Girty). Dorsal view, 5X, U. S. Geological Survey specimen.

Figs. 12, 13. *Tetracamera neogenes* Girty. 12, anterior view, 2X; 13, exterior of brachial valve, 2X; both UC 47220.

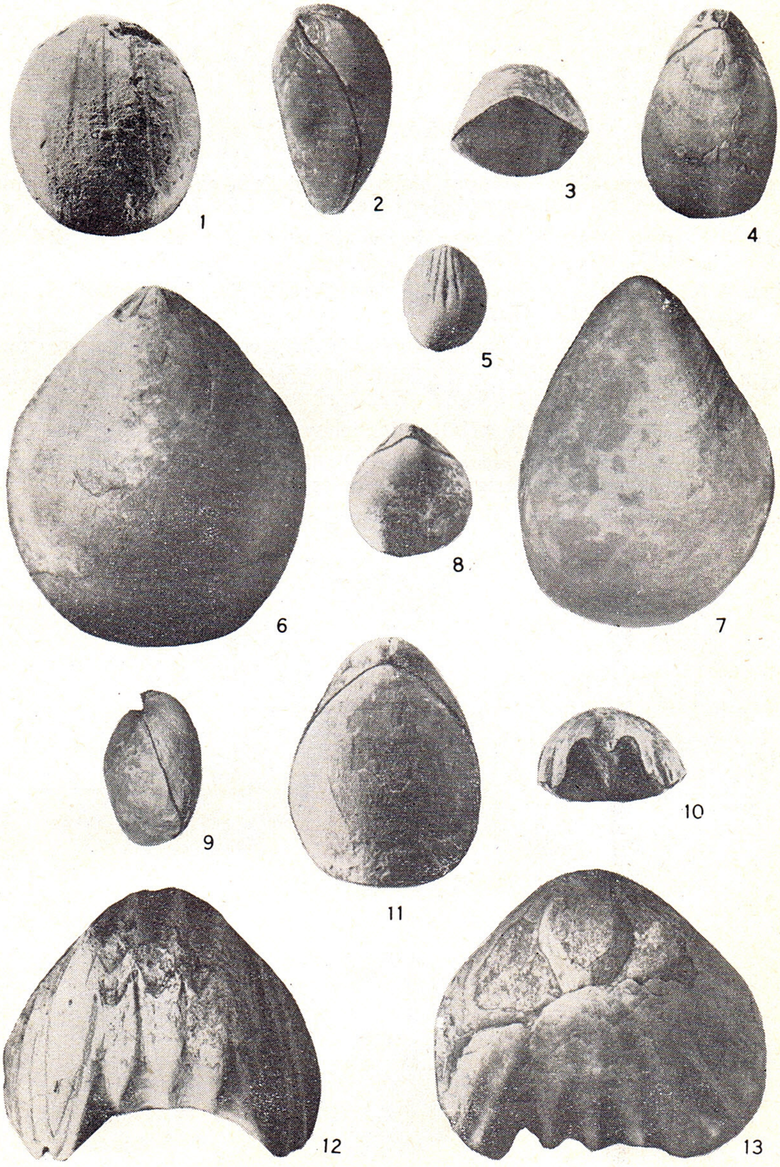


PLATE VI

PLATE VII

Figs. 1, 2. *Spiriferina spinosa* (Norwood and Pratten). 1, brachial valve, 2X, UC 47221; 2, pedicle valve, 2X, UC 16995.

Fig. 3. *Spirifer leidyi* Norwood and Pratten. Pedicle valve, 2X, UC 47222.

Figs. 4, 5. *Spirifer pellaensis* Weller. 4, dorsal view, 2X; 5, pedicle valve, 2X; both UC 47223.

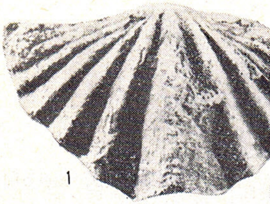
Fig. 6. *Martinia* sp. Pedicle valve, 2X, U. S. Geological Survey specimen.

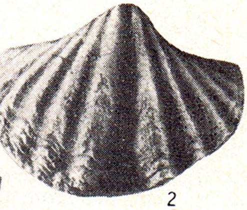
Figs. 7, 8. *Reticularia setigera* (Hall). 7, brachial valve, 2X, UC 47224; 8, pedicle valve, 2X, UC 47225.

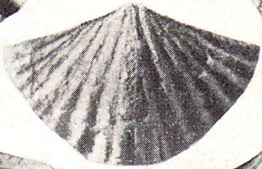
Fig. 9. *Eumetria costata* (Hall). Pedicle valve, 2X, UC 16943.

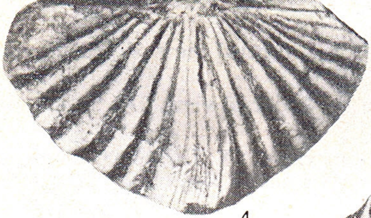
Fig. 10. *Eumetria pitkinensis* Snider. Pedicle valve, 2X, UC 16209, this specimen here designated the holotype.

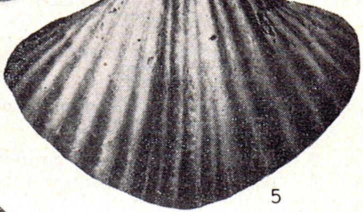
Fig. 11. *Eumetria vera* Hall. Brachial valve, 2X, UC 47226.


1

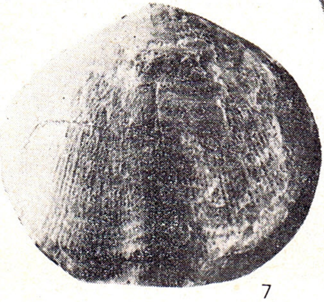

2

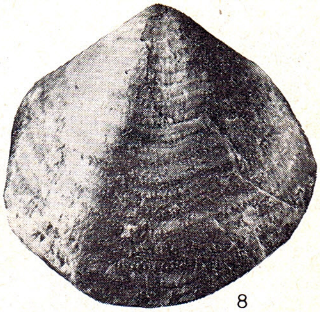

3


4


5


6


7


8


9


10

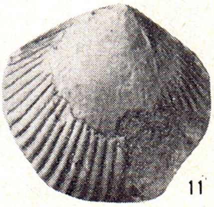

11

PLATE VII

PLATE VIII

Fig. 1. *Athyris cestriensis* Snider. Dorsal view, 2X, UC 16210, one of the cotypes from the Fayetteville shale.

Fig. 2. *Hustedia* sp. Pedicle valve, 2X, UC 47227.

Fig. 3. *Hustedia multicostata* Girty. Dorsal view, 2X, UC 16207.

Figs. 4, 5. *Composita trinuclea* (Hall). 4, dorsal view, 2X; 5, side view, 2X; both UC 17082.

Fig. 6. *Cliothyridina sublamellosa* (Hall). Ventral view of pedicle valve, 2X, UC 47228.

Figs. 7, 8. *Composita subquadrata* (Hall). 7, dorsal view, 2X; 8, side view, 2X; both UC 48729.

Fig. 9. *Myalina compressa* Snider. Right valve, 2X, UC 16220, this specimen, from the Mayes formation (Snider's locality M. 16) is here designated the holotype.

Fig. 10. *Myalina* sp. Left valve, 2X, UC 47230.

Fig. 11. *Myalina longicardinalis* Snider. Left valve, 1X, UC 16219, holotype.

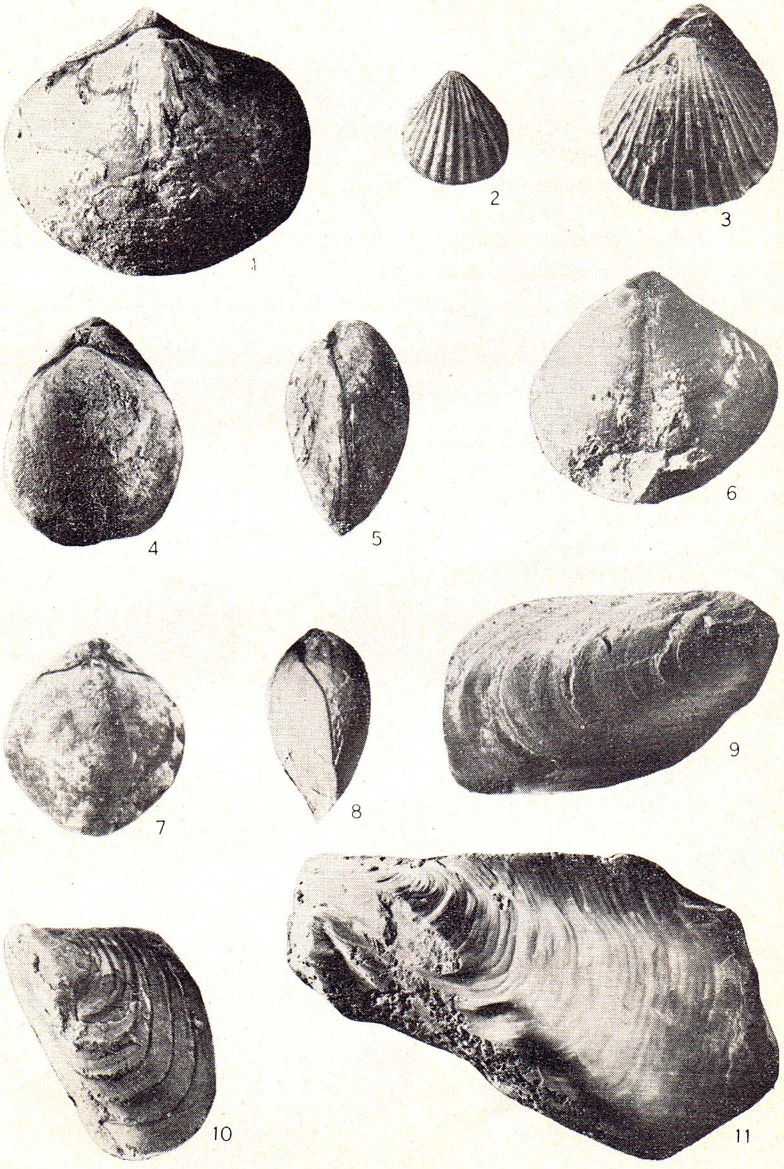


PLATE VIII

PLATE IX

Fig. 1. *Sphenotus quadriplicatum* Snider. Left valve, 2X, UC 16215, holotype.

Fig. 2. *Sphenotus gibsonense* Snider. Right valve, 1X, UC 16216, holotype.

Fig. 3. *Sphenotus* sp. Right valve, 2X, UC 47231.

Fig. 4. *Schizodus chesterensis* Meek and Worthen. Left valve, 2X, UC 17180.

Fig. 5. *Edmondia pitkinensis* Snider. Right valve, 2X, UC 16218, a cotype.

Fig. 6. *Sphenotus cherokeense* Snider. Right valve, 2X, UC 16213, holotype.

Fig. 7. *Cypricardinia* sp. Right valve, 2X, U. S. National Museum specimen.

Fig. 8. *Schizodus insignis* Drake. Left valve, 1X, UC 17178.

Fig. 9. *Leiopteria* ? sp. Left valve, 2X, UC 17168.

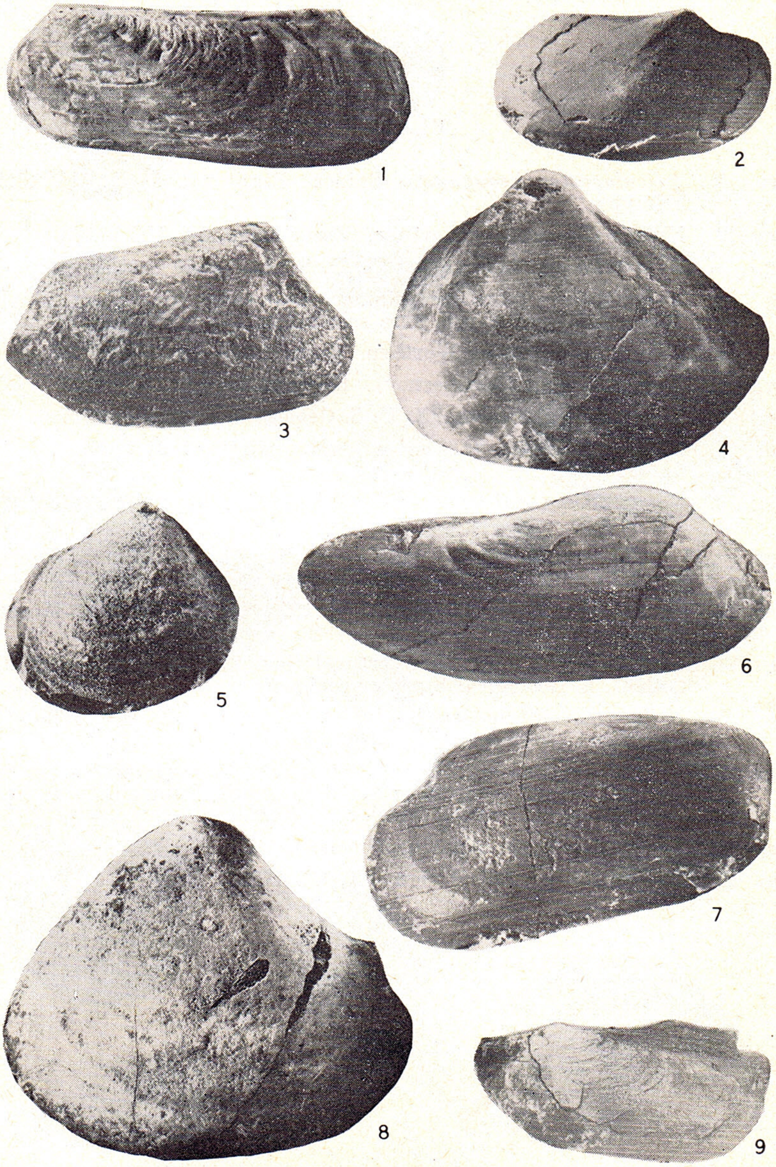


PLATE IX

PLATE X

Fig. 1. *Aviculopecten keoughensis* Snider. Right valve, 1X, UC 16223, holotype.

Fig. 2. *Nucula illinoisensis* Worthen. Right valve, 2X, UC 17163.

Fig. 3. *Astartella* sp. Left valve, 2X, U. S. Geological Survey specimen.

Fig. 4. *Aviculopecten pitkinensis* Snider. Left valve (probably), 2X, UC 16225, this specimen is here selected as the holotype.

Fig. 5. *Schizodus depressus* Worthen. Right valve, 2X, UC 17188.

Fig. 6. *Leda vaseyana* (McChesney). Right valve, 2X, UC 17150.

Fig. 7. *Leda* sp. Right valve, 2X, U. S. Geological Survey specimen.

Fig. 8. *Edmondia crassa* var. *suborbiculata* Girty. Left valve, 2X, UC 17145.

Fig. 9. *Sphaerodoma subcorpulenta* (Whitfield). Apertural view, 2X, UC 17208.

Figs. 10, 11. *Euphemites* sp. 10, side view, 2X; 11, dorsal view showing slit, 2X; both U. S. Geological Survey specimen.

Fig. 12. *Gosseletina* ? sp. Dorsal view, 10X, U. S. National Museum specimen.

Figs. 13, 14. *Gosseletina* ? sp. 13, apertural view, 2X; 14, apical view, 2X; both U. S. Geological Survey specimen.

Fig. 15. *Bellerephon pitkinensis* Snider. Dorsal view, 2X, UC 16228; this specimen is here selected as the holotype.

Figs. 16, 17. *Platyschisma* sp. 16, basal view, 2X; 17, apertural view, 2X; both UC 17202, heretofore listed in Pitkin faunal lists as *Straparollus planidorsatus* (Meek and Worthen).

Fig. 18. *Strophostylus* sp. Apertural view, 1X, UC 17207.

Fig. 19. *Naticopsis* sp. Apical view, 1X, UC 47232.

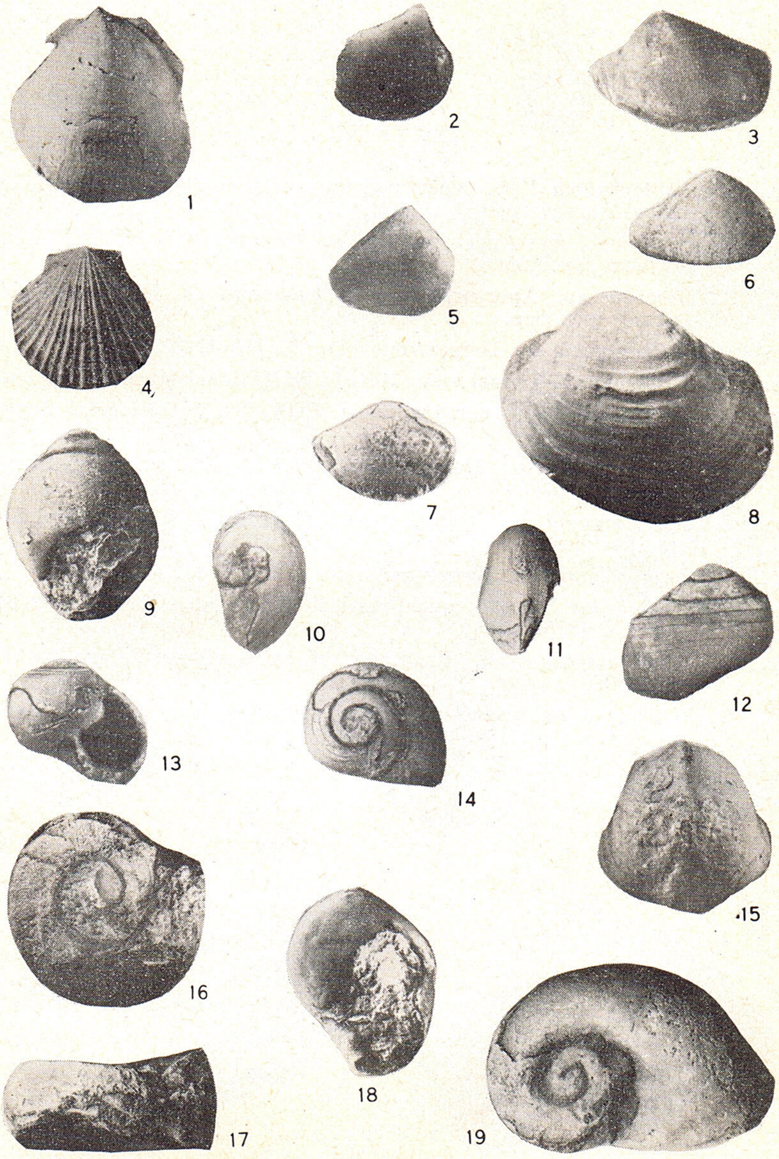


PLATE X

PLATE XI

Fig. 1. *Leptoptygma* ? sp. Apertural view of juvenile, 10X, U. S. Geological Survey specimen.

Fig. 2. *Strobeus* ? sp. Apertural view of juvenile, 10X, U. S. National Museum specimen.

Fig. 3. *Strobeus* sp. Apertural view of fragment, 2X, U. S. Geological Survey specimen.

Fig. 4. *Microptychis* sp. Dorsal view (?), 2X, UC 47233.

Fig. 5. *Neilsonia* sp. Dorsal view, 10X, U. S. National Museum specimen.

Fig. 6. *Stegocoelia* sp. Apertural view, LOX, U. S. Geological Survey specimen.

Fig. 7. *Bucanella* ? sp. Dorsal view, 2X, U. S. Geological Survey specimen.

Fig. 8. *Pseudozygopleura* ? sp. Dorsal view, 10X, U. S. Geological Survey specimen.

Fig. 9. *Leptoptygma* sp. Apertural view, 10X, UC 47234.

Figs. 10, 11. *Colpites* ? sp. 10, apical view, 2/3X; 11, apertural view, 2/3X; both UC 48252.

Fig. 12. *Glabrocingulum* sp. Fragment of spire viewed laterally, 10X, UC 48302.

Fig. 13. *Platyceras subrotundum* Snider. Apical view, 2X, UC 16230, holotype.

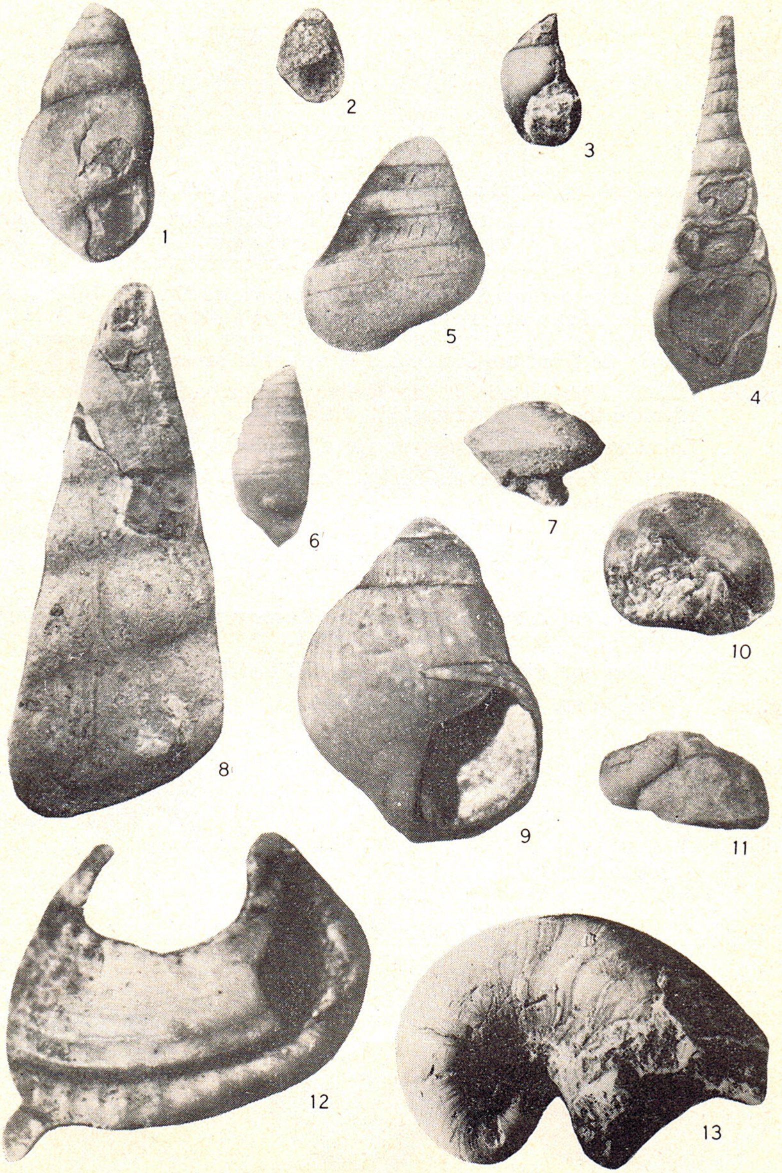


PLATE XI

PLATE XII

Fig. 1. *Conularia* sp. Portion of two sides, 2X, UC 48290.

Figs. 2-4. *Cravenoceras* cf. *C. hesperium* Miller and Furnish. 2, apertural view, 1X; 3, ventral view, 1X; 4, side view, 1X; all U. S. Geological Survey specimen; all figures by courtesy of A. K. Miller.

Fig. 5. *Cycloceras sequoyahensis* Snider. Side view, 2X, UC 16232; this specimen from the Fayetteville shale (Snider's locality F. 2) is here selected as the holotype. The other of Snider's original cotypes is from the Pitkin but is less well preserved.

Fig. 6. *Kaskia chesterensis* J. M. Weller. Cephalon and parts of two enrolled thoracic segments, 2X, UC 48316.

Fig. 7. *Laevidentalium* sp. Side view of a fragment, 1X, UC 48301.

Fig. 8. *Primitia fayettevillensis* Girty. Valve, 25X, U. S. Geological Survey specimen.

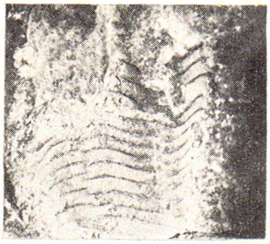
Fig. 9. *Paraparchites* sp. Valve, 10X, U. S. Geological Survey specimen.

Fig. 10. *Glyptopleura inoptina* Girty. Valve, 25X, U. S. National Museum specimen.

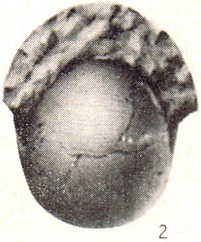
Fig. 11. *Cladodus* sp. A specimen from the Morrow used to show the shape of teeth of this genus, 1X, UC 48331.

Fig. 12. *Deltodus* sp. Plate-like tooth, 1X, UC 48335.

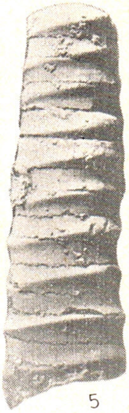
Fig. 13. *Petalodus* sp. Tooth, 1X, UC 48334.



1

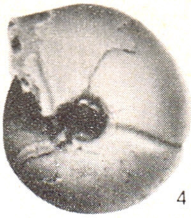


2

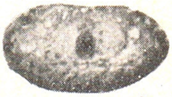


5

3

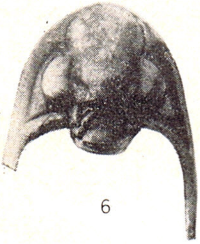


4



8

7

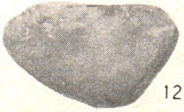


6

9

11

13



12

10

PLATE XII

INDEX

BULLETINS OF THE ARKANSAS GEOLOGICAL SURVEY

1. Upper Cretaceous Formations of Southwestern Arkansas by Carle H. Dane. Cloth bound, price \$1.85, postage 10¢, total \$1.95. Paper bound, price \$1.60, postage 10¢, total \$1.70.

2. Oil and Gas Geology of the Gulf Coastal Plain in Arkansas, by W. C. Spooner. (Out of print.)
   Reprint from Bulletin 2: Upper Cretaceous Ostracoda of Arkansas, by Merle C. Israelsky. Paper bound, price 20¢, postage 3¢, total 23¢.

3. The Geology of the Arkansas Paleozoic Area with Especial Reference to Oil and Gas Possibilities, by Carey Croneis. Cloth bound, price \$2.95, postage and container 25¢, total \$3.20.

4. St. Peter and Older Ordovician Sandstones of Northern Arkansas, by Albert W. Giles. Cloth bound, price \$1.80, postage and container 15¢, total \$1.95.

5. A Geomagnetic Survey of the Bauxite Region in Central Arkansas, by Noel H. Stearn. Paper bound, with map in pocket, price 75¢, postage 5¢, total 80¢.

6. Mineral Resources of Arkansas, by George C. Branner. Paper bound, price 30¢, postage 5¢, total 35¢.

7. Kaolin Deposits of Southern Pike County, Arkansas, by Paul G. Herold and George R. Heyl. Paper bound, price 25¢, postage 5¢, total 30¢.

8. Pitkin Limestone of Northern Arkansas, by William H. Easton. Paper bound, price 60¢, postage 10¢, total 70¢.