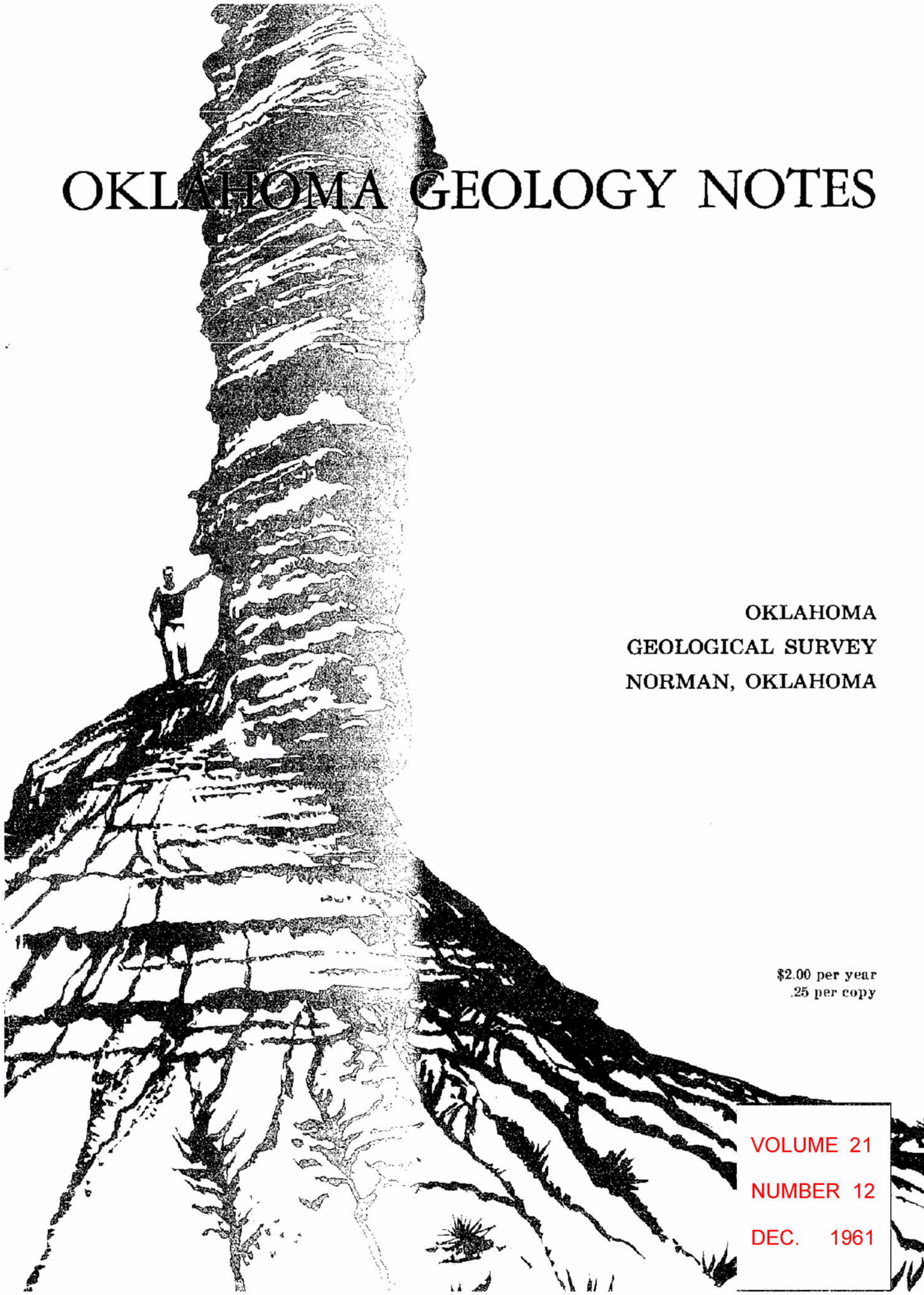
OKLAHOMA GEOLOGY NOTES



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Travertine Formation Associated with Mosses at Turner Falls and Prices Falls, Oklahoma

L. R. Wilson and M. E. Guest

Pleistocene travertine deposits occur widely in southern Oklahoma, and those forming Turner Falls (fig. 1) on Honey Creek and Prices Falls on Falls Creek in the Arbuckle Mountains of Murray County have been of scenic interest for many years. These deposits and the role of plants in the formation of the travertine were described by Emig in 1917, 1918, and 1921. The source of the calcium carbonate is the Cambrian and Ordovician limestones which crop out in the mountains.

The age of the travertine is considered to be Pleistocene, for insoluble residues of the oldest examined deposits contain pine and oak pollen. These pollen represent the Pleistocene flora of the Arbuckle Mountains, but the association of the fossil pollen with a particular part of the Pleistocene is not possible with present knowledge of Oklahoma's floristic history.

Emig (1917) stated that there were three periods of travertine formation, including the present, separated by two periods of erosion, the last about 1850, and that these periods were associated with physiographic conditions. That greater travertine deposition occurred in the past than is occurring today seems apparent, and that there was erosional destruction of these deposits is obvious where the travertine at the falls has been eroded to the limestone bedrock.

At present, travertine is forming on the crests of riffles, on cascades, and on the falls where vegetational debris has accumulated and where mosses and algae thrive. It is not the object of this note to discuss the chemistry and history of the travertine formation but to record the occurrence of certain travertine structures and an abundance of diatoms associated with the moss species *Philonotis fontana* (L.) Brid. and *Didymodon tophaceus* (Brid.) Jur.

Three species of mosses, *Philonotis calcarea* (B. and S.) Schimper, *Didymodon tophaceus* (Brid.) Jur., and *Fissidens julianus* (Savi.) Schimp. were reported by Emig (1917, p. 65) as active agents in the formation of the travertine at Turner Falls and at Prices Falls. The species *P. calcarea* reported by Emig is probably *P. fontana,* for the occurrence of the former in North America is doubtful (Flowers, 1935, p. 179). Specimens from Turner Falls examined by L. R. Wilson agree with Flowers' *P. fontana* f. *occidentalis. D. tophaceus* grows in dense tufts in shaded places on the falls, and *P. fontana* grows where greater sunlight is present. Bright-green tufts of *P. fontana* are common on the crests of most of the cascades.

The role of these mosses in the formation of travertine and in the older deposits at Turner Falls and Prices Falls was recognized by Emig (1921), but the association of diatoms with travertine apparently was not observed. In April 1960, the writers visited Turner Falls and collected a series of living moss specimens in various stages of travertine incrustment and of older travertine structures (phytoliths) similar in growth form to those currently developing on the mosses. These latter

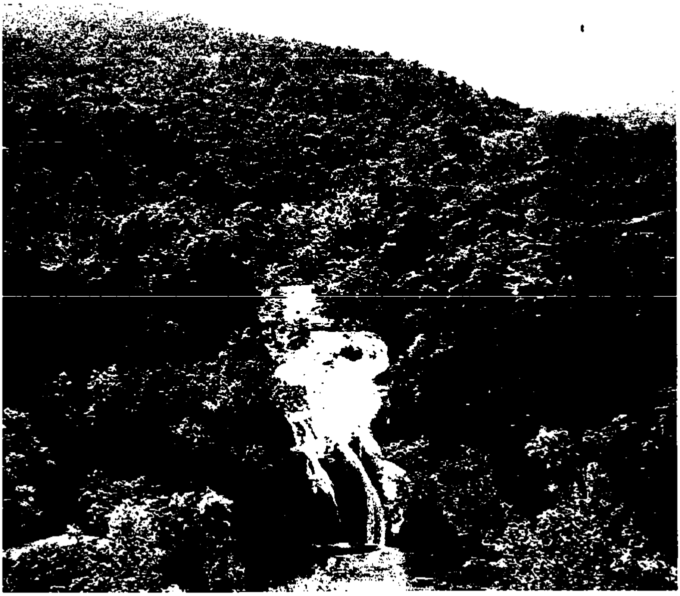

Figure 1. Turner Falls from Lookout Station on State Highway 77. Honey Creek has eroded through the travertine deposit near the crest of the falls leaving cliffs on each side. A series of cascades formed by travertine is shown higher up the valley and a detail of one is in figure 2.

structures were formed early in the history of the two falls. This series is illustrated on plate I.

Incrustment of travertine about mosses has been reported elsewhere, probably the first record being in Robert Townsson's *Travels in Hungary,* published in London in 1797. Boros (1925) reported and illustrated tufa phytoliths of *Didymodon tophaceus* and *Encladium verticillatum* from Tata in central Hungary that are similar to those occurring in Oklahoma. Boros referred to these fossils as bryoliths and, in particular, as *Didymodontolith* and Eucladoliths. He stated, "It is not clear just how the deposit is formed but it is surely due to some specific quality of the plant."

Emig (1917) was more certain about the processes involved in the mosses' role of travertine formation. He described it as follows:

> There are three or more general physiological processes by means of which these mosses assist in the mechanism of travertine development. The water which contains calcium bicarbonate is taken up as a mineral nutrient solution by these plants, either through the rhizoids or from the surfaces of the leaves. **Didymodon** and **Philonotis** are only partly submerged; but the upper leaves and the growing tips are kept moist with seepage, the tufts retaining water like a saturated sponge. Water evaporates from the leaf surface, and

Figure 2. A cascade in Honey Creek above the crest of Turner Falls showing manner of travertine development. Algae occur in the channels and mosses at the water's edge where they are constantly receiving spray or are often submerged during high water.

at the same time the calcium salts concentrate in the cells and in the moist film surrounding the leaves. During the process of photosynthesis, carbon dioxide is removed from the bicarbonate contained in the moist film about the leaves and from the bicarbonate in the cell. This reaction assists in the precipitation of calcium carbonate in the outer layers of the cell walls and on the outer surface of the leaves. A part of the calcium salts absorbed, unite with oxalic acid and other harmful by-products that are formed during the process of metabolism. Briefly stated, calcium bicarbonate and other calcium salts in the water enter the cells in various ways and there concentrate; a part of these salts unite with oxalic acid and hurtful by-products formed during metabolism, which are changed into harmless or useful substances; a part of the bicarbonate is precipitated as the normal carbonate in the outer layers of the cell walls and on the outer surface of the leaves and stems during photosynthesis. The travertine first formed represents a direct precipitation of the calcium salts contained in the mineral water, or it is derived principally by evaporation and to a much less degree as a transformation product from various salts contained in the cells. While Chara deposits the calcium carbonate within its own cells, the mosses precipitate the mineral as an inorganic incrustation outside their leaves and stems. It appears to arise first from the decomposition of the dissolved carbon dioxide and bicarbonates by the living plants and it proceeds along their growing parts. Subsequent evaporation and loss of carbon dioxide causes the calcium carbonate to be precipitated over the tufts of mosses and algous tissue until the substance becomes a soft crystalline limestone.

Figure 3. A travertine-incrusted moss polster at the edge of the cascade (shown in fig. 2). During the spring this polster was submerged. Photograph taken October 8, 1961.

In Emig's later discussion of this travertine formation (1921) he modified his explanation and noted the presence of similar structures in the older deposits.

> These moss tufts absorb water like a sponge and the calcareous water evaporates from the leaves and stems, carbon dioxide escapes and calcium carbonate deposits on the outer surfaces of the plants as a white crystalline covering. Naturally the older and submerged portions of the plants gradually decay. The incrustation increases and the resulting soft and brittle formation has very much the appearance of an aggregate of delicate corals. As this travertine becomes older, it hardens into a compact limestone. . . . These rocks show two kinds of incrustations that were formed about water mosses as nuclei.
>
> Travertine of the first type, develops about tufts of **Didymodon** growing erect on the surface of water falls. The gradual transitions from living mosses to incrusted plants and finally to the compact limestone is a slow development. A second type of travertine, appearing in the form of small overlapping calcareous beds in three approximate rows for each moss stem—arranged like the leaves of cedar or arbor vitae—is so different that one would suspect it to have been formed about mosses of another species. Such is not the case, but instead, the same species of mosses are incrusted with calcium carbonate but in a slightly different manner. If the mosses, instead of growing in erect tufts on the margin of the falls, grow in the more rapid water and appear on the lower ledges of the falls,

the plants are more scattered and bend downward because of the water constantly passing over them. As the calcareous water evaporates, the incrustation slowly thickens about the leaves and stems, keeping pace with development of the plants to within one or two millimeters of the apex. The deposits about the leaves accumulate into little calcareous beads that are finally cemented into a soft mass of travertine.

In his report to the Oklahoma Academy of Science, Emig (1921) stated that photographs were included in the original manuscript. Unfortunately they were not published.

During the examination of the specimens collected in April 1960, some doubt was experienced in accepting the total explanation of travertine formation on the mosses as given above by Emig (1917). The development of travertine on the mosses may begin as Emig suggested, and his belief that evaporation of the lime bearing water further contributes to the growth of the deposits may be correct also. That the biological functions of the mosses have anything to do with the later development of the bead-like and crustous layers which smother all but a few uppermost leaves of the growing plants is questionable. It appears more reasonable that the moss plants function as a framework upon which the travertine accumulates, and the bead-like structures are arranged according to the phyllotaxy of the mosses. This is also essentially the conclusion of Emig in his 1921 paper. Stages in the development of travertine on *Didymodon* and *Philonotis* are shown in figures 1 to 4 of plate I.

When the fresh travertine on the mosses was examined, it was noted that in many cases more than one-eighth inch of travertine incrusted the leaves and stems; and, concentrated upon the surface of the bead-like and crustose deposits, myriads of chlorophyll-bearing algae were seen. The presence of the algae must have more effect on the travertine formation than the physiology of the buried leaves and stems of the moss plant. In order to determine what algae were present on the surface of the travertine, the largest of the seven moss plants shown in figure 3 of plate I was dissolved in dilute hydrochloric acid and the

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Explanation of Plate I

Figure 1. Living moss polster of Philonotis fontana from Honey Creek showing travertine deposit at base of growing plants, also a leaf of sycamore (Platanus occidentalis) incrusted with travertine.

Figure 2. Living plants of Philonotis fontana incrusted with travertine. A number of the plants are entirely covered with calcium carbonate and prevented from further growth.

Figure 3. Seven plants of Philonotis fontana separated from polster to show the bead-like travertine deposits formed on the leaves and their spiral arrangement resulting from the moss-leaf phyllotaxy.

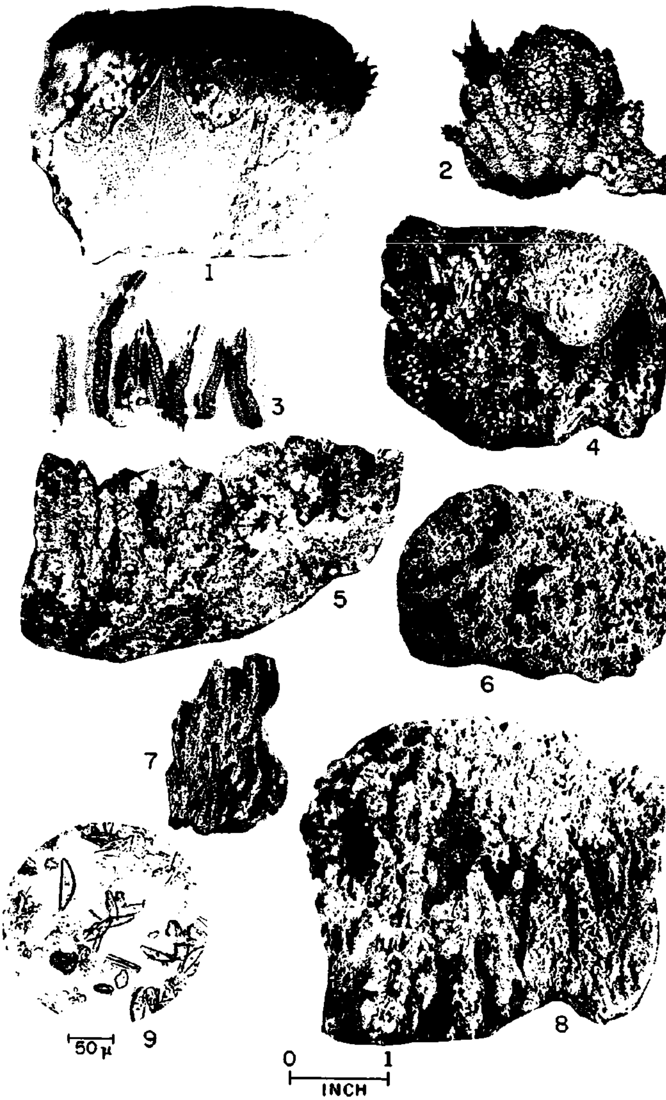
Figure 4. Growing plants of Philonotis fontana with calcium carbonate forming on the leaf edges and early stages of bead-like structure.

Figure 5. Fragment from oldest exposed part of the Turner Falls travertine deposit showing the growth form of moss plant structure.

Figures 6-8. Similar to figure 5 but from somewhat younger parts of the deposit.

Figure 9. Diatom frustules in residue from travertine of the largest moss plant shown in figure 3.

Plate I



insoluble residue concentrated for microscopic study. This residue contained fragments of the moss stem and leaves, and thousands of diatoms and *Chroococcus*-like algae. A small assemblage of the diatoms is illustrated in figure 9 of plate I. Approximately a dozen species were present in the preparation. They belong to the following genera: *Navicula, Gomphonema, Cymbella,* and *Fragilaria.*

That diatoms should be associated with travertine deposition was a surprise for they had not been seen in the older travertine deposit residues prepared for palynological studies. In order to recheck the possibility that diatoms had been overlooked in the palynological preparations, a portion of the old travertine specimen illustrated in figure 7 of plate I was dissolved in dilute hydrochloric acid and the insoluble residue examined with the microscope. No diatoms were found in this and in other preparations that were made subsequently. An explanation for the absence of diatoms in the older travertine deposits may be that the siliceous frustules are dissolved during the early diagenesis of the travertine.

References Cited

Boros, Adam, 1925, Two fossil species of mosses from diluvial lime tufa of Hungary: The Bryologist, vol. 28, p. 29-32

Emig, W. H., 1917, Travertine deposits of Oklahoma: Okla. Geol. Survey, Bull. 29, 76 p.

———— 1918, The travertine deposits of the Arbuckle Mountains, Oklahoma: Science, new ser., vol. 47, p. 468.

———— 1921, Mosses as rock builders: Okla. Acad. Science, Proc. 1910-1920, vol. 1, p. 38-40.

Flowers, Seville, 1935, Family Bartramiaceae, in Moss flora of North America north of Mexico, volume II, part 3: Newfane, Vt., A. J. Grout, p. 152-180.

Townsson, Robert, 1797, Travels in Hungary: London. (Not seen but referred to in Boros, 1925).

Geologic Index Maps Issued

The *Index to geologic mapping in Oklahoma* was issued by the Survey on November 16, 1961. The index consists of five maps on which are outlined the areas of 164 surface geologic maps, published, unpublished, and in progress, and the areas of 218 published and unpublished surface maps. The index maps are printed at a scale of 16 miles to the inch and each has a bibliographic index. The maps are:

Map I. Surface mapping, 1901-1960, compiled by Carl C. Branson
Map II. Subsurface mapping, 1940-1950, compiled by Louise Jordan
Map III. Subsurface mapping, 1951-1956, compiled by Louise Jordan
Map IV. Subsurface mapping, 1957-1958, compiled by Louise Jordan
Map V. Subsurface mapping, 1959-1960, compiled by Louise Jordan

The set of five maps is packaged in a sturdy manila envelope and it may be purchased at the Survey office for $2.00 per set.

Code of Stratigraphic Nomenclature

Carl C. Branson

The American Commission on Stratigraphic Nomenclature has, after years of hard work, agreed on a code, and it was published in May. The primary advantage of the code is that it offers an opportunity for uniformity between publishing organizations. The Oklahoma Geological Survey now officially adopts the code as its guide in stratigraphic nomenclature.

The complexity of the code in differentiating several types of units will neccessitate care in using these and experience in their use before they become familiar. This article is written in order to clarify the rules by citing examples, from Oklahoma in all possible instances.

Article 4. "A rock-stratigraphic unit is a subdivision of the rocks in the Earth's crust distinguished and delimited on the basis of lithologic characteristics."

Example: Sylvan Shale (Upper Ordovician), a greenish shale unit delimited by "Fernvale" Limestone below and Chimneyhill Limestone above. Occurs throughout the Arbuckle Mountain region and locally in the Oklahoma Ozarks.

Each article is bolstered by "remarks." Remark (b) states that a type section should be designated. Actually, in order to establish a unit firmly such a type section must be designated. The type section of the Bluejacket Sandstone Member of the Boggy Formation of Ohern was designated by Howe (1951). The Bluejacket Sandstone is discontinuous, but homotaxial occurrences permit its recognition from southern Oklahoma into Missouri.

The Caney Shale was named without designation of type locality or of type section. A type section was designated fifty years later at a point some 50 miles distant from the place where it was named.

Remark (c) is a rejection of guide fossils or inferred geologic history as criteria for delineating rock-stratigraphic units. On this basis the Haragan and Henryhouse Marlstones cannot be considered as rock-stratigraphic units.

Remark (d) concerns independence of time concepts. Time spans are not considered in defining rock-stratigraphic units. The Postoak Conglomerate is the body of limestone cobbles, granite pebbles, and other coarse clastics in the Wichita Mountain area. That its time span differs from place to place is inconsequential.

Remark (e) applies to surficial deposits. That a unit is a terrace deposit 90 feet above stream level is a subordinate fact to the fact that the unit is a red silt.

Remark (f). Aquifers, oil sands, coal beds, and quarry layers are informal units even though properly named. Secor coal, Oswego lime, Red Fork sand are informal names.

Remark (h) concerns cyclothems, which, even though properly named, are not considered rock-stratigraphic units. None is named in Oklahoma, but the Seminole Formation of the platform is a cyclothem as well as a rock-stratigraphic unit.

Article 5. Boundaries, both vertical and lateral, are placed by lithologic criteria but may be arbitrarily placed in gradational sequences.

Remark (a), concerning gradational boundaries, is illustrated by the Chickasha-Blaine relationship. The Blaine is a sequence of gypsum beds with thin subjacent dolomites and intervening red shales. Laterally its stratigraphic position is occupied by the deltaic Chickasha Formation. The lateral contact between the two is arbitrarily drawn. The Wewoka Formation is distinguished from the Wetumka Shale merely by placing the contact at the base of the first sandstone.

Remark (b) concerns use of key beds. The Upper Relay Creek Dolomite Bed is used as the contact between the Marlow and Rush Springs Formations. The name with Upper is improper and the name will be changed.

Remark (c). Mechanically defined boundaries. Several beds and members can be recognized by high radioactivity, e.g., the Heebner Shale and the Excello Shale. Concerning the deeply weathered area north of Tulsa, R. H. Dott stated that mapping in the rainy season was done by mapping Seminole where the car rolled along, Checkerboard where the field party were out and pushing the car.

Remark (d) concerns unconformities unmarked by lithologic change. Again, this idea would reject the differentiation of the Henryhouse and Haragan Marlstones.

Article 6 defines formation as a lithologic and mappable unit. The Wewoka Formation consists of a sandstone-shale sequence contrasting with a shale below, a predominantly shale unit above. The Chickachoc Chert is a spiculite. The Stratford Formation is a clastic unit composed of coarse material from the Arbuckle and Wichita orogenic masses.

Mappability at a scale of 1:25,000 or smaller is said to be the test of a formation. We cannot agree. Formations exposed in a vertical cliff would be unmappable at that scale. The Glen Park Formation of Missouri is thin and is in cliffs. The Welden Formation can be shown on maps only by exaggerating its outcrop width. Thickness is not a factor (excepting as mappability is affected). The present trend toward 1:24,000 maps, as in Kentucky, makes the choice of 1:25,000 as the cut-off point especially bad.

Article 7 defines a member as part of a formation. Members may be lentils or tongues. The Doe Creek and Verden Members of the Marlow Formation are lentils, although they are long and narrow. A member need not be mappable nor, if mappable, need it be raised in rank to formation. The Bluejacket Sandstone Member of the Boggy Formation is mappable. A member may extend from one formation into another: the Dodds Creek Sandstone Member of the Galesburg Shale Formation legitimately becomes the Dodds Creek Sandstone Member of the Coffeyville Formation. Members may contain beds but not members or submembers.

Article 8. "A bed is the smallest rock stratigraphic unit recognized in classification." The Doneley Limestone is a bed in the Savanna Formation. Many of the Kansas members are beds.

Article 9. A group is a unit consisting of two or more associated formations. A group may consist of unnamed formations, as do the Hoxbar and Deese Groups. It is here contended that a group may consist of but one formation. For instance, the Morrow Group consists of the Hale and Bloyd Formations at places, but of the Wapanucka Formation or the Golf Course Formation at others.

The formations of a group are not everywhere the same. The El Reno Group consists of the Duncan Sandstone and Chickasha Formation in the southeastern part of the Anadarko syncline; of the Flowerpot, Blaine, and Dog Creek Formations elsewhere.

Remark (c) calls for retaining the group name as a formation name where components wedge out. This situation prevails where the Cabaniss Group is represented only by the Senora Formation. Conversely the Vanoss Formation becomes 9 formations in Pawnee County, 13 formations in Kansas (Branson, 1956).

Remark (d) provides for subgroups.

Remark (e) provides for supergroups of two or more groups or of one or more groups and formations. The Des Moines is a supergroup in Oklahoma.

Remark (f) calls attention to the misuse of the term "series," which is a time-stratigraphic term.

Article 10 states that the name of a rock-stratigraphic unit consists of a geographic name with a lithologic term or rank term. It is recommended that all of the component parts of a formal rock-stratigraphic name carry capitalized initial letters. This method is here considered confusing and unwise, but will be adhered to by this survey in the interest of uniformity.

Remark (a) deals with the source of a geographic name. The geographic name "should be the name of a natural or artificial feature at or near" which the unit is typically developed. The statement is loaded with difficulty. What is "near"? The Rancheria Formation is named for Rancheria Peak (which was misidentified), but the type section is 60 miles away. The Caney Shale was named in a bungling way and was restored as a useful name by designating a type section 50 miles from "Caney" Creek. Is that near?

The suggestion is made that names of formations or higher-ranking units be derived from names of geographic features which appear on standard maps. If the name does not appear, a precise location and description should be given. These suggestions are unrealistic. The Bigheart Sandstone was named for a town which later changed its name to Barnsdall. The name Bigheart was then given to another town in the same county. The Checkerboard Limestone was originally named for its jointed appearance. A creek was given the name Checkerboard Creek, and the name was validated as of that date.

Subsurface units are allowed more scope. Why?

Remark (c) recommends against unusual lithologic names, such as Glauconitic Limestone, Black Shale, Siliceous Shale. In Oklahoma this will cause temporary trouble in the Stanley and Jackfork.

Group names should not have lithologic terms. This statement excludes Pontotoc Conglomerate Group, Stanley Shale Group, Arkansas Novaculite Group.

Formation names consist of a geographic name and a lithologic term or the word "Formation." Examples: Boggy Formation, Pawhuska Limestone, Spavinaw Granite.

Member names may, in cases in which a lithologic term is meaningful, include a lithologic term. Examples: Blackjack Creek Limestone Member of the Fort Scott Limestone, Perry Farm Shale Member of the Lenapah Limestone.

Remark (g). In geographic names applied to informal units the unit term should not be capitalized. Capitalization does not imply formalization. This statement corrects an unfortunate rule from the preceding code.

Remark (h). Identical geographic names applied to two or more units in the same sequence are considered informal. The Lake Ardmore Formation cannot have a "Lake Ardmore Sandstone Member."

Article 11 states that the rule of priority should be observed. Presumably the article should be modified by the statement "other considerations being essentially equal." Few early stratigraphers defined their units accurately and even fewer designated type sections. In 60 years geologists have not succeeded in finding a meaningful type section for the Atoka Formation. The Tobucksy Sandstone of Chance (1890) is precisely the unit called Hartshorne Formation by present Arkansas geologists.

Remark (b) states that a well-established name should not be dropped solely on the grounds of priority. Verdigris Limestone is retained for Oklahoma although the possibly equivalent Ardmore Limestone has the older name. The name Emporia Limestone has been adopted because it is an older name for the formation long-called Stonebreaker.

"Duplication of names should be avoided throughout North America." Exception is made for places where alternative names are lacking if the geographic and stratigraphic separation is such as to "preclude" confusion. On this basis the name Byram Granite Gneiss of New Jersey and Pennsylvania must be replaced as conflicting with the older name Byram Marl. The name Cooper Marl of South Carolina antedates the name Cooper Limestone of Missouri, but it is unlikely that a change will be made.

Article 12 provides that "the geographic component of an established rock-stratigraphic name should not be changed." The change from Polk County Ash Bed to Hatton Tuff Lentil, because a county name was considered inappropriate for a minor unit, is sensible but violates the code.

Remarks provide that a repeatedly published name need not be changed although it differs from that of its geographic source. The spelling Exeter Sandstone would be preserved although the town's name was spelled Exter. The change of Standley to Stanley is not clearly ruled against nor that of Wetumpka to Wetumka. No provision is made for such changes as Dry Wood to Drywood, Lance Creek to Lance, Joins Ranch to Joins, but it is here contended that such simplification should be encouraged.

Stratigraphic names are not to be changed because the name of the geographic source has been changed. Bigheart does not become Barnsdall; Standley should not have become Stanley.

Names are not to be replaced because the geographic source no longer exists. If they were, Oklahoma would lose Hunton, Simpson, Viola, Thurman, and Bigheart.

Article 13 sets up the procedure for establishing a new formal rock-stratigraphic unit. It rules out publication in abstracts or guidebooks. Examples are Union Valley Sandstone and Suwannee Limestone, as well as the even less fortunate Oklahoma names, Falls Creek, Criner, Nebo, McKenzie Hill, Chapman Ranch.

Article 14 cautions that a redefinition of a rock stratigraphic unit should call for as much justification as called for in establishing a new unit. For instance, the recognition of and inclusion of the Van Vacter Gypsum in the Blaine Formation required as much evidence as did the establishment of the Blaine. Actually it was vastly better documented.

Remark (b) suggests that the name of a larger unit should not be restricted to a smaller unit. This is here regarded as an unwarranted suggestion. Restriction of units is natural and, in many cases, necessary.

Article 15 provides that a change in the lithologic term does not require a new geographic term. The Blaine Formation can be Blaine Gypsum or Blaine Shale.

Article 16 states that change in rank of a rock-stratigraphic unit does not require redefinition of its boundaries nor alteration of the geographic part of its name. The Hoxbar Formation has (somewhat illegitimately) become the Hoxbar Group. The Admire Group in Kansas is the Admire Formation in Oklahoma.

Article 17 provides that an abandoned name may be used for another unit if it was introduced casually, or if it has been used but once and is not in current use. The names Vinita, Claremore, Garvin, Criner, and others are thus available (Branson, 1957).

Article 18 provides for names of soil-stratigraphic units. Articles 19 to 25 concern biostratigraphic units. Articles 26 to 35 are rules about names of time-stratigraphic units, which are defined as subdivisions based solely upon intervals of geologic time.

Geologic Units, Arranged Approximately in Order of Magnitude

ROCK-STRATIGRAPHIC	TIME-STRATIGRAPHIC	GEOCHRONOLOGIC
		eon
		era
	system	period
group	series	epoch
subgroup	stage	age
formation		
member		
bed		

Names of systems have no particular ending excepting that all are in adjectival form. No standard rule for series names is proposed and they may have the *-an* ending (Morrowan), the *-ian* ending (Meramecian), the period name preceded by Lower, Middle, or Upper (Lower Cretaceous), or no special ending (Des Moines Series). Most names of stages are derived from the names of corresponding rock-stratigraphic units but ideally should have independent nomenclature. In the future names of newly proposed time-stratigraphic units should be independent and distinct from those of rock-stratigraphic units.

References Cited

American Commission on Stratigraphic Nomenclature, 1961, Code of stratigraphic nomenclature: Amer. Assoc. Petroleum Geologists, Bull., vol. 45, p. 645-665.

Branson, C. C., 1956, Cyclic formations or mappable units: Okla. Geol. Survey, Okla. Geology Notes, vol. 16, p. 122-126.

Branson, C. C., 1957, Old stratigraphic names made available: Okla. Geol. Survey, Okla. Geology Notes, vol. 17, p. 99-103.

Chance, H. M., 1890, Geology of the Choctaw coal-field: Amer. Inst. Mining Engineers, Trans., vol. 18, p. 653-661.

Howe, W. B., 1951, Bluejacket sandstone of Kansas and Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 35, p. 2087-2093.

New Theses Added to O. U. Geology Library

The following Master of Science theses were added to The University of Oklahoma Geology Library during the month of October 1961:

Subsurface study of Morrowan rocks in central and southern Beaver County, Oklahoma, by Lynn W. Barrett, II.

Subsurface geology of Pawnee County, Oklahoma, by Patrick H. Clare.

Palynology of the Secor coal (Pennsylvanian) of Oklahoma, by Robert T. Clarke.

Subsurface study of the Skinner and Red Fork sand zones (Pennsylvanian) in portions of Noble and Kay Counties, Oklahoma, by K. Paul Clements.

Petrology of the Hogshooter Formation (Missourian), Washington and Nowata Counties, Oklahoma, by William R. Cronoble.

Subsurface geology of east-central Lincoln County, Oklahoma, by Jerry K. Greer.

Areal geology of western Major County, Oklahoma, by Gene L. Jeary.

Subsurface geology of McIntosh County, Oklahoma, by Everett Richard Neff.

Areal geology of the Quinlan area, Woodward County, Oklahoma, by Frank D. Sorrel.

One doctoral dissertation, *Plant microfossils of the laminated sediments of the Lower Eocene Wilcox Group in south-central Arkansas,* by Eugene Laverne Jones, was also added to the library.

—L. F.

Natural Gas in Pushmataha County, Oklahoma

Louise Jordan

The first producer of hydrocarbons in Pushmataha County is a small gas well, but its location in the Ouachita Mountains is a stimulus to the belief that the Ouachita province is a potential area of commercial gas production. Completion of the J. F. Stevenson and King-Stevenson Oil Company No. 1 Brame test (sec. 15, T. 3 S., R. 15 E.), in December 1960, made Pushmataha the seventy-first county of Oklahoma with hydrocarbon production. The one-well field was officially recognized by the Oklahoma Nomenclature Committee as Southwest Moyers. The test, which took nearly a year in drilling to 8,371 feet, flowed only at a rate of 500,000 cubic feet of gas per day, but the resultant discovery is an encouragement to geologists to unravel the structure of Pushmataha County with its more than 1,420 square miles of area.

The earliest hole in the county (T. 1 N., R. 20 E.) was drilled in 1923 to 3,537 feet (Chenoweth, 1959, p. 206). Honess (1927, fig. 2) showed six dry holes, of which only two logs are filed with the Oklahoma Corporation Commission, but he did not show a test in this township. Several shallow (less than 1,000 feet) tests were drilled in the 1923-to-1936 period. In 1937, the Halliburton No. 1 Bagnell test (T. 3 S., R. 15 E.) was abandoned at a depth of 6,000 feet (fig. 1). Chenoweth (1959, p. 203) reported that a strong odor of kerosene could be detected at the site of this test. In the same year, a test in T. 1 S., R. 15 E., was reported to have made some oil, and again in 1950, oil was reported from a hole in T. 1 N., R. 17 E.

In 1957, a serious attempt to explore the geologic section was made by Southwest Exploration at its No. 1 Perrin (sec. 9, T. 2 S., R. 15 E.) near the surface axis of the Jumbo anticline. The hole was drilled through 6,400 feet of Stanley sandstones and shales, penetrated Arkansas Novaculite, Missouri Mountain Shale, and Polk Creek Shale and bottomed in Bigfork Chert (which was repeated because of a fault) at a total depth of 11,328 feet. Several shows of gas were present in Stanley sandstones, which were perforated for testing, but the operators reported no commercial shows of oil or gas.

In the 1958-to-1961 period, eight holes totaling 35,976 feet were drilled. Four of these, drilled in 1961, resulted in dry holes. The Harvest Queen Mill and Elevator No. 1 Brame (sec. 16, T. 2 S., R. 15 E.) tested Stanley rocks to a depth of 5,567 feet on the Jumbo anticline about one mile southeast of the deep Southwest Exploration test of 1957. Apache Corporation No. 1 Brame (sec. 22, T. 2 S., R. 16 E.), at a site near the surface axis of the Kiamichi or Kiamichi River anticline, penetrated 5,827 feet of Stanley interbedded sandstone and shale. A minor amount of gas was recovered from sandstones between 3,600 and 3,655 in a drill-stem test and at 2,675 feet in a wire-line test. No other sandstones were considered worth testing after the electric-log survey. The third test was that of the Shell Oil Company No. 1 Dierks, located north of the Octavia fault and apparently on the nose of the Nashoba anticline in sec. 31, T. 1 N., R. 21 E. The hole was drilled to a total depth of 5,001 feet into the Stanley Group, but no shows of gas were

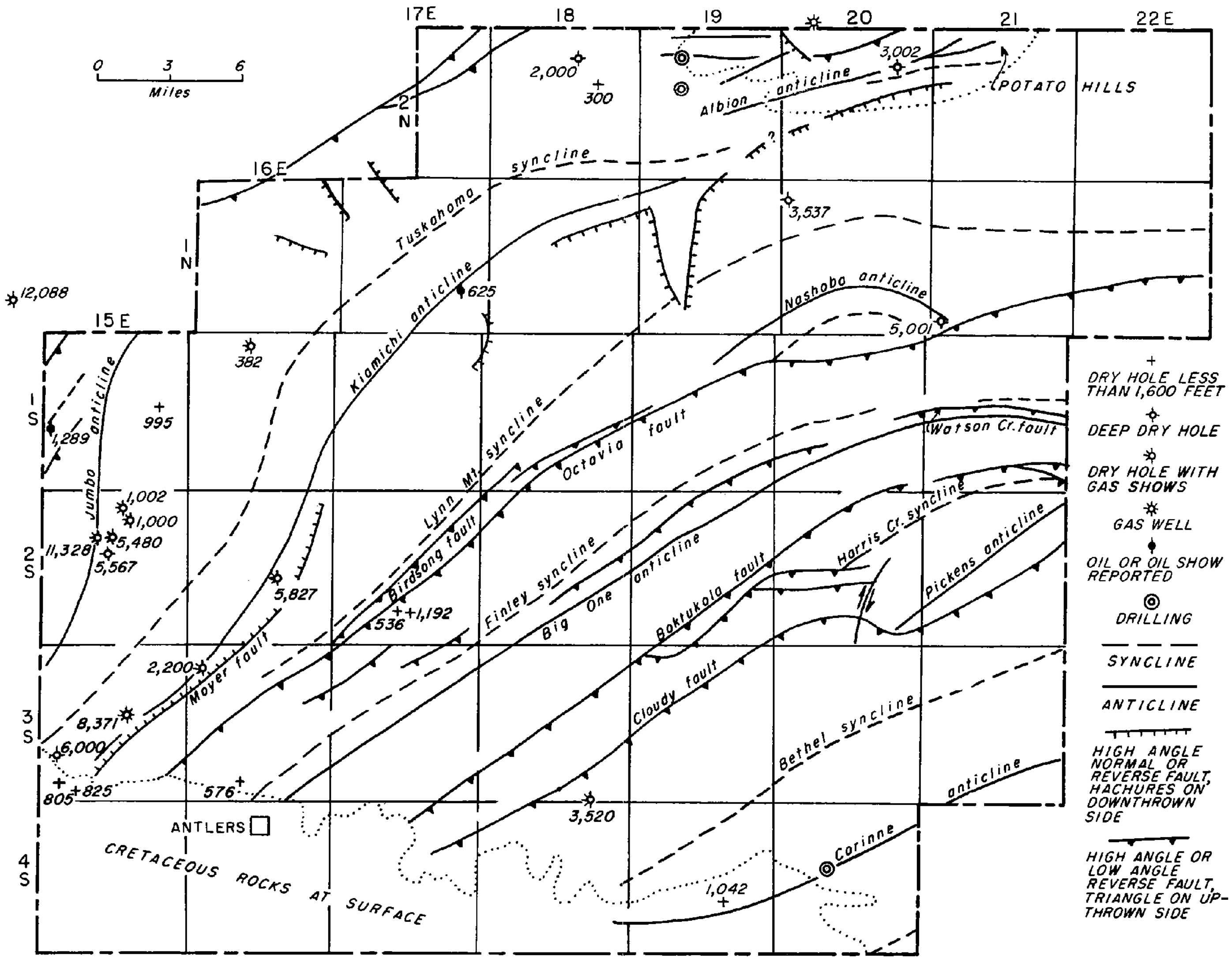


Figure 1. Map showing structural features of the Ouachita Mountains in Pushmataha County, Oklahoma, and location of wells drilled for oil and gas. (Modified after Arbenz, 1956; Cline, 1960; and Shelburne, 1960).

reported and no tests were made after electric, gamma-ray, sonic, and microlog surveys were made. The fourth test in 1961 was drilled on the Albion anticline in the Potato Hills by Sinclair Oil and Gas Company at its No. 1 Herrick in sec. 11, T. 2 N., R. 20 E. This test followed the 1959 discovery of gas flowing at a rate of 1.85 million cubic feet per day from Sinclair's No. 1 Reneau (sec. 32, T. 3 N., R. 20 E.) in the Potato Hills in southern Latimer County. (The test is shown as a gas well on figure 1 just north of the Pushmataha County boundary.) Production is at a depth of 2,340 to 2,410 feet from the Bigfork Chert, equivalent to the Viola Limestone, Middle Ordovician in age. The Sinclair No. 1 Herrick test was drilled to a depth of 3,002 feet into the Womble Shale, which underlies the Bigfork. A drill-stem test, made in the Bigfork between 1,005 and 1,105, recovered eight feet of mud and no show of gas. No other tests were made after the electric-log survey.

Three tests for the remainder of 1961 are projected. Gragg Drilling Company No. 1 Kenman (sec. 8, T. 2 N., R. 19 E.) is being drilled on the nose of an anticline in the western part of the Potato Hills. Gragg Drilling has also made a location in sec. 17, T. 2 N., R. 19 E., about one mile south. Contract depth for each test is 4,000 feet, which will test pre-Stanley rocks. Sunray Mid-Continent Oil Company proposes to drill a test, No. 1 Dierks, in the most southeastern township of the county. The location, in C NE¼ SW¼ sec. 16, T. 4 S., R. 20 E., is on the Corinne anticline, where rocks of the Stanley Group are exposed at the surface, about 20 miles west of the "core" of Ouachita Mountains.

Without doubt, more exploration in the Ouachita province will uncover a substantial reserve of natural gas for the nation.

References

Arbenz, Kaspar, 1956, Tectonic map of Oklahoma: Okla. Geol. Survey, Map GM-3.

Bike, Peter B., 1961, Watchful waiting in Ouachitas may end pending outcome of key test: Oil and Gas Jour., vol. 59, no. 14 (April 3), p. 266-268.

Chenoweth, P. A., 1959, Is there oil and gas in the Ouachita Mountains?: Okla. Geol. Survey, Okla. Geology Notes, vol. 19, p. 199-208.

Cline, L. M., 1960, Stratigraphy of the Late Paleozoic rocks of the Ouachita Mountains, Oklahoma: Okla. Geol. Survey, Bull. 85, 113 pages.

Gardner, Frank J., 1961, Eight strikes lend glamour to Arkoma basin's future: Oil and Gas Jour. vol. 59, no. 1 (Jan. 2), p. 123-129.

Honess, C. W., 1927, Geology of Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties, in Oil and Gas in Oklahoma: Okla. Geol. Survey, Bull. 40-R, 32 p.

Shelburne, O. B., 1960, Geology of the Boktukola syncline, southeastern Oklahoma: Okla. Geol. Survey, Bull. 88, 84 p.

Arkoma Basin Symposium

The *Proceedings of the Seventh Biennial Geological Symposium* are now available for purchase from the Department of Business and Industrial Services, Extension Division, The University of Oklahoma. The symposium was held at The University of Oklahoma on March 7 and 8, 1961, with the theme *The Arkoma Basin.* Thirteen technical papers were presented at the two-day meeting.

The printed proceedings consist of 234 pages with 86 figures. The price is $5.00 per copy.

Pre-Womble Rocks of the Ouachita Mountains

Hulon M. Madeley

INTRODUCTION

In August 1961 this writer undertook a detailed sediomentological study of the rocks of pre-Womble age in the Ouachita Mountains of Arkansas and Oklahoma. The four stratigraphic units involved were the Collier Shale, the Crystal Mountain Sandstone, the Mazarn Shale, and the Blakely Sandstone. Because some parts of these units had not been described and measured in detail before, this was the first task undertaken. Successive vertical sections were sampled concurrently with this work. This was done in order to ensure that the samples to be studied would represent known stratigraphic intervals. In areas such as the Ouachita Mountains where the stratigraphy is imperfectly known, no other means of sampling can provide this assurance.

Since the field phase of this study has been completed, several significant observations about the pre-Womble rocks in their type areas can be made.

COLLIER SHALE

The most complete section of the Collier Shale in Arkansas is along Collier Creek, SW¼ NW¼ sec. 21, T. 3 S., R. 24 W. (Pitt, 1961). This 197-foot section was measured and described by the writer. Because the base of the Collier Shale is not exposed, the total thickness of the unit is unknown.

Most of the lower 17 feet of this section is dark-gray to brown, fine- to medium-grained sandstone. A preliminary analysis of this basal sandstone showed it to be poorly sorted with the grain-size distribution slightly fine-skewed. This 17 feet is superseded by 5 feet of black, thinly laminated, silty shale. Above this shale is an interval of 11 more feet of massive fine-grained sandstone.

Especially noteworthy is the presence of some dark bluish-gray silty limestone beds, averaging two inches in thickness, in the section from 36 to 75 feet above its base. The presence of limestone was mentioned by several of the earlier workers (Miser and Purdue, 1929; Pitt, 1961). This writer agrees with these workers that these limestones do resemble those in the Mazarn Shale, but they are not so abundant; hence, not so significant. Above the 75-foot level, four massive sandstone members of the Crystal Mountain type were measured. (This writer defines the Crystal Mountain type of sandstone as being a well-cemented, massive unit with many quartz-filled joints.) These massive sandstones are separated by covered intervals. The Collier Shale section through the second massive sandstone was measured and described by Pitt (1961). The present description closely parallels his up to this point, which is 102 feet above the base of the exposed section.

Above the fourth massive sandstone is a covered interval of 48 feet. Above this interval is the lower massive sandstone member of the Crystal Mountain Sandstone. No evidence of the unconformity that has been reported by Miser and Purdue (1929) and other geologists as separating the Collier and the Crystal Mountain Formations was found by Pitt (1961) or by this writer during his two visits to the area. A local unconformity has been found, however, by Cohoon (1959) and by others in the upper part of the Crystal Mountain Formation. In as far as is known, it seems justifiable to consider the contact between the Collier Shale and the Crystal Mountain Sandstone a conformable one in its type area although unconformities between these units could conceivably be present elsewhere in the Ouachita Mountains.

CRYSTAL MOUNTAIN SANDSTONE

The Crystal Mountain Sandstone consists of four members (Pitt, 1961): (1) a basal massive sandstone, 30-60 feet thick; (2) about 110 feet of shale and siltstone; (3) an upper massive sandstone member, 40-80 feet thick; and (4) an uppermost member of interbedded sandstone, shale, and rare chert beds, approximately 50 feet thick.

The basal massive sandstone was measured in W½ sec. 21, T. 3 S., R. 24 W., where it rests upon the Collier Shale. Its thickness here is 65 feet. The sandstone is well cemented, is mostly medium grained, and contains numerous quartz veinlets.

The shale and siltstone member was measured in SE¼ sec. 21, T. 3 S., R. 24 W., where it is 103 feet thick. The beds are quite variable in thickness, ranging from 1/16 to 4 inches. They are twisted and contorted and are generally gray to brown. A few thin dark limestone beds are present. The upper 66 feet of this interval is covered.

The upper massive sandstone member is 77 feet thick on the north side of Collier Creek, W½ sec. 21, T. 3 S., R. 24 W. It is well cemented, fine to medium grained and contains numerous quartz veinlets.

The uppermost member of interbedded sandstones and shales is only locally present and was not measured by this writer; however, it was described in general terms by Cohoon (1959), Lee (1959), Robb (1960), and Watson (1959).

MAZARN SHALE

The Mazarn Shale is the oldest unit in the Ouachita Mountains which has been given a precise age. The late Charles E. Decker and William Berry, Jr., examined graptolites in this shale as did Ulrich, and all three concluded that the Mazarn Shale is of Lower Ordovician age (Pitt, 1961). The Mazarn Shale is predominantly a dark fissile or splintery shale, but stratigraphically significant thicknesses of limestone do occur in the section.

Miser (1929) estimated the thickness of the Mazarn section as more than 1,000 feet. Other workers have made similar estimates. This writer measured 2,090 feet of Mazarn Shale along Collier Creek. This figure is considered to be a conservative one. The intensely deformed shale beds have numerous dip reversals whose magnitude varies from only a few horizontal feet to several hundreds of feet. The lack of observable variation through hundreds of feet of section also compounded the problem of measuring accurately. To overcome these difficulties, the writer measured the thicknesses with a marked six-foot board along the stream bottom and carefully estimated the amount of bed repetition in areas of dip reversal. Locally, it was necessary to measure the strike and dip of an exposed bed and the direction of the stream channel and from them to compute the thickness of partly covered intervals trigonometrically.

The base of the Mazarn Shale is gradational with the Crystal Mountain Sandstone. The contact with the overlying Blakely Sandstone also is gradational. Between these two sandstones, a monotonous sequence of dark-gray, thin-bedded, locally calcareous shales and siltstones characterizes the Mazarn Shale. However, the few lighter-colored, thin limestone beds found within the interval can be excellent subsurface stratigraphic markers. Field descriptions of these limestones are as follows:

FEET ABOVE BASE	THICKNESS (FEET)	DESCRIPTION
105- 122	17	Ls: white to light-gray, avg. 2 inches thick with some sh: dark-gray, thin-bedded
940- 950	10	Ls: dark-gray to black, silty, beds avg. 1 inch thick
975- 998	23	Ls: light-gray with small white bands, avg. 2 inches thick
1060-1089	29	Ls: bluish-gray with small white bands, silty in places, avg. thickness 2 inches, ranges from ½ to 6 inches

BLAKELY SANDSTONE

The Blakely Sandstone was measured and described along the west side of Collier Creek where it flows through a water gap in N½ sec. 27, T. 3 S., R. 24 W. The top of the uppermost and the base of the lowermost sandstone beds encountered were considered the top and bottom of the Blakely Sandstone. Between these two sandstone members, several hundred feet of shales and siltstones closely resembling those in the Mazarn Formation were found, along with several distinct sandstone members. The total thickness of the Blakely Sandstone was measured as 904 feet. This figure is nearly twice as large as the estimates of earlier workers. The significant sandstone members encountered in the measured section are as follows:

FEET ABOVE BASE	THICKNESS (FEET)	DESCRIPTION
0-1	1	Ss: light-yellow with some red zones, fine- to medium-grained, massive
22-27	5	Same as above
145-147 and 155-160	7	Ss: yellow to rust, fine-grained, jointed, massive, locally thick quartz veins
162-210	48	Ss: yellow to rust, massive, fine-grained, few quartz veinlets, quartzitic in appearance
222-235	13	Ss: yellow to rust, shiny, fine-grained, well-cemented
246-268	22	Ss: light-gray with rust spots, fine-grained, quartzitic appearance
453-465	12	Ss: dark gray, massive, fine- to medium-grained, quartz crystals along joints

472-499	27	Ss: light to dark-gray, fine-grained, beds 1 to 3 feet thick, alternating with sh: dark gray, silty in lower part
880-904	24	Ss: light-yellow to dark-gray, fine-grained with ss veinlets avg. 1 inch thick alternating with sh: light to dark-gray, avg. ½ inch thick

SUMMARY

Although deductions cannot yet be made as to the conditions of sedimentation under which the pre-Womble rocks of the Ouachita Mountains were deposited, several observations about the stratigraphy of these rocks have been arrived at from systematic field work. These observations are as follows:

1. The Collier Shale is incompletely exposed, but has a measured thickness of 197 feet along Collier Creek, sec. 21, T. 3 S., R. 24 W. The descriptions by Pitt and this writer of the lower 102 feet are in close agreement.
2. The similarity of the Collier shales and siltstones to those of the Crystal Mountain Formation and the lack of evidence for an unconformity between these rock units implies that they were deposited in the same geologic period.
3. The present description of the Crystal Mountain Sandstone agrees closely with the estimates made by Pitt (1961) for the thicknesses of its different members. The lower massive sandstone member is 65 feet thick; the shale and siltstone member, 103 feet; and the upper massive member, 77 feet.
4. The Mazarn Shale is conformable to the Crystal Mountain Sandstone below and the Blakely Sandstone above it. Its thickness is not less than 2,090 feet. The limestone members within the section are stratigraphically significant.
5. The Blakely Sandstone has a thickness of 904 feet instead of approximately 500 feet as previously estimated. Although this unit is bounded at its top and bottom by small amounts of sandstone, significant sandstone members are present within the Blakely section.

References Cited

Cohoon, R. R., 1959, Geology of the Mount Ida area, Ouachita Mountains, Arkansas: Okla., Univ., unpublished MS thesis.

Lee, H. C., 1959, Geology of the Gaston area, Ouachita Mountains, Arkansas: Okla., Univ., unpublished MS thesis.

Miser, H. D., and **Purdue, A. H.**, 1929, Geology of the DeQueen and Caddo Gap quadrangles: U. S. Geol. Survey, Bull. 808, 195 p.

Pitt, W. D., 1961, Ouachita Mountain core area, Montgomery County, Arkansas: Amer. Assoc. Petroleum Geologists, Bull., vol. 45, p. 72-94.

Robb, M. G., 1960, Areal geology of the eastern Mount Ida area, Montgomery County, Arkansas: Okla., Univ., unpublished MS thesis.

Watson, John, 1959, Geology of the Bear Den Mountain area, Montgomery County, Arkansas: Okla., Univ., unpublished MS thesis.

TYPE OF *Schizotremites*, A DEVONIAN BLASTOID FROM NEW YORK

ROBERT O. FAY

The type species of *Schizotremites* Reimann, 1945, is *S. kopfi* Reimann, 1945, from the Hamilton beds of western New York. The genus may be characterized as a spiraculate blastoid, with 5 paired spiracles, or 4 paired spiracles and a paired anispiracle, 4 deltoids seen in side view, radials overlapping deltoids, with 4 anal deltoids or a superdeltoid, two cryptodeltoids, and hypodeltoid, with anal opening between, an elongate conical pelvis, lancet covered by side plates, 4-6 hydrospire folds on each side of an ambulacrum, and one pore between side-plate margins along radial margins only. Specimens of this species have been found in the Kashong Member of the Moscow Shale, West Alden, Livingston County, New York, and in the *Pleurodictyum* beds of the Wanakah Shale, Bay View, New York. The type specimens are on deposit in the Buffalo Society of Natural Sciences Museum, consisting of two cotypes and three other specimens. I wish to thank Miss Carol A. Heubusch, Curator, for loan of the specimens; and Mr. Irving G. Reimann of the Exhibit Museum, University of Michigan, for loan of a thin section. Some specimens are in the private collection of Mr. Max J. Kopf, Buffalo, New York.

Schizotremites kopfi Reimann, 1945

Plate I, figures 1-4

Schizotremites kopfi Reimann, 1945, p. 25-27, 42, pl. 6, figs. 4-7; pl. 9, fig. 12.

This is the only species of this genus described. The description is mainly that of cotype E 15,986, supplemented by information about other specimens.

Theca subfusiform, with rounded summit and conical base, 14.5 mm long by 8 mm wide, with periphery below midheight at radial lips. Vault 8 mm long, pelvis 6.5 mm long, and pelvic angle approximately 65 degrees. Basalia conical, 3 mm high by 4 mm wide, tapering to a small triangular base with a small rounded crenellar stem about 1 mm in diameter, with 3 normally disposed basals. Radials 5, each elongate pentagonal, 11.5 mm long by 4.5 mm wide, with slightly shorter limbs on the anal side, with narrow, long, moderately shallow sinus 8 mm long by 1 mm wide, not extending to aboral surface. Radials overlap deltoids.

Deltoids 4, short, lancet-shaped, each 3 mm long by 1.5 mm wide, with an elongate U-shaped paired spiracle notched in the adoral tip and along the ambulacral margins, extending slightly to the adjacent margins of the radial limbs. On the anal side there are 4 anal deltoid plates. The superdeltoid is adjacent to the oral opening, with two cryptodeltoids resting upon the aboral face of the superdeltoid, internally separating the anal hydrospire canals from the anal opening, but not developed externally, thus forming a paired anispiracle. The hypodeltoid is missing but the suture facets show that it is pentagonal, abutting against the adjacent radial limbs, and resting upon the cryptodeltoids which abut against the radial limbs below. Thus there are 5 paired spiracles, comprising a paired anispiracle and 4 other paired spiracles, about the oral opening. The oral opening is immediately surrounded by the 4 deltoid lips and the superdeltoid plate. Internally there are 4 to 6 hydrospire folds on each side of an ambulacrum.

Ambulacra 5, linear, moderately long, each 10 mm long by 1 mm wide, with lancet covered by side plates. There are approximately 30 side plates in 10 mm length of an ambulacrum, with one pore between adjacent side plates along the radial margins only. An outer side plate rests upon the adoral-abmedial bevelled corner of each primary side plate and there are approximately 4 cover-plate sockets per side plate along the main food groove and 2 cover-plate sockets along the side food grooves. The surfaces of the thecal plates are ornamented with extremely fine growth lines subparallel to plate margins. There is a raised area on the radial limbs, parallel to the radiodeltoid suture, just below the suture.

Types and occurrence.—All localities are in New York State. Cotypes, E 15,986 (figured) and E 15,988, from Kashong Shale, Livingston County; plesiotype, E 22,493, Kashong Shale, West Alden; paratype, E 16,570, from the *Pleurodictyum* beds of Wanakah Shale, Bay View; fragmentary specimen, E 16,085, from Kashong Shale, East Bethany; all at the Buffalo Society of Natural Sciences Museum. The Reimann collection contains a thin section of a specimen from the Kashong Shale Member, West Alden, and a fragmentary specimen from the Kashong Shale, near the salt shaft, Wadsworth. Other specimens are in the private collection of Mr. Max J. Kopf, Buffalo, New York.

Reference Cited

Reimann, I. G., 1945, New Devonian blastoids: Buffalo Soc. Nat. Sciences, Bull., vol. 19, no 2, p. 22-42, pls. 5-9.

Explanation of Plate I

Schizotremites kopfi **Reimann, 1945. Middle Devonian, Hamilton Group, Moscow Shale, western New York.**

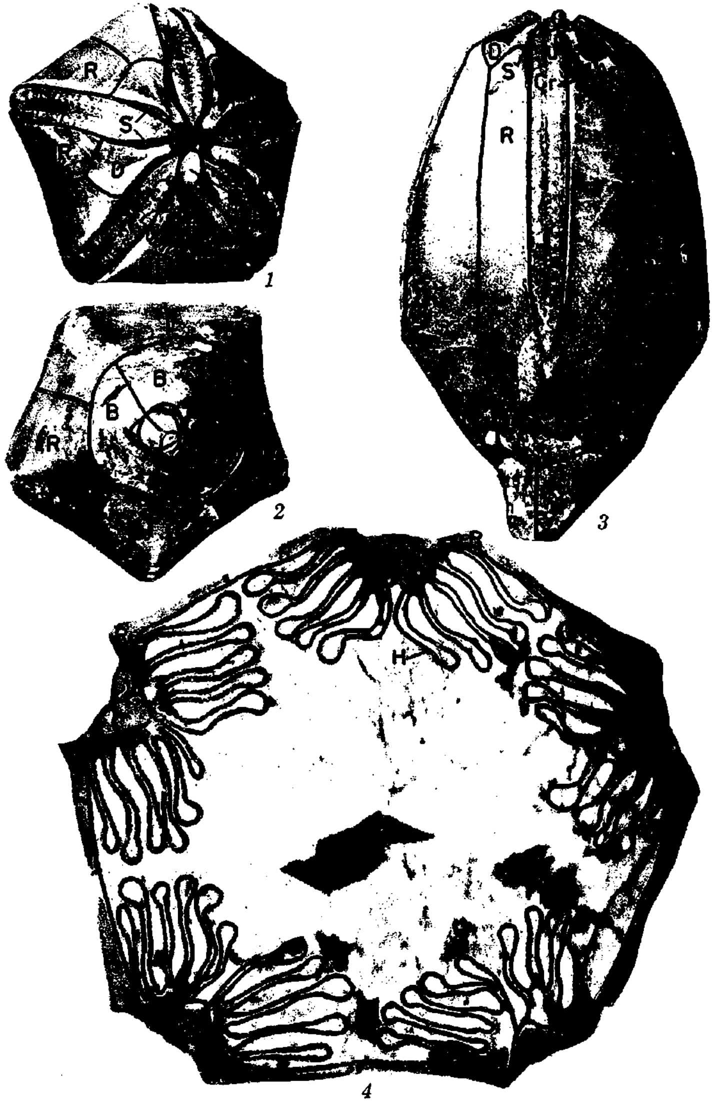
Figures 1-3. Oral, aboral, and (D) ambulacral views of cotype E 15,986, Buffalo Society of Natural Sciences Museum. From Kashong Shale Member, Livingston County, New York, x5.6

Figure 4. Cross-section through radial plates of a plesiotype, E 22,493, Buffalo Society of Natural Sciences Museum. From Kashong Shale Member, West Alden, New York, collected by Reimann, x19.6

An—anal opening	**L—lancet plate**
B—basal plate	**R—radial plate**
Cr—cryptodeltoid	**S—spiracle**
D—deltoid plate	**Sp—side plate**
H—hydrospire fold	**Su—superdeltoid plate**
Hc—hydrospire canal	**Z—azygous basal plate**

HD—hypodeltoid plate (suture slant lined)

Plate I



Oklahoma Bryozoa Under Study

Dr. Richard S. Boardman, Associate Curator of Invertebrate Paleontology, United States National Museum, Washington, D. C., studied Bryozoa of the Oil Creek Formation of Middle Ordovician age in the Arbuckle Mountains in September and October. The recipient of a National Science Foundation grant to study the earliest Bryozoa of the world, Dr. Boardman spent three months in western Europe during the summer of 1960 making extensive collections from Middle Ordovician strata. Later he will investigate Bryozoa from the Pogonip Formation of Nevada.

In the Arbuckle Mountains the Oil Creek Formation ranges in thickness from 200 to 800 feet. It normally consists of a lower sandstone member and an upper limestone member. The limestone member is mostly fossiliferous bioclastic calcarenite, containing brachiopods, trilobites, clams, gastropods, ostracodes, and Bryozoa. No Bryozoa have been found in the underlying Joins Formation or in limestones of the Arbuckle Group, thus they are apparently absent in strata of Early Ordovician and Late Cambrian age.

Dr. William E. Ham of the Oklahoma Geological Survey spent two days in the field with Dr. Boardman, guiding him to some of the best collecting localities. On October 4, Dr. Boardman lectured at The University of Oklahoma before Sigma Gamma Epsilon, honorary geology fraternity, speaking on "A Biological Approach to Some Middle Devonian Bryozoa from New York State."

—W. E. H.

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