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PENNSYLVANIAN MORROWAN ROCKS AND FUSULINIDS OF KANSAS

By

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ABSTRACT

Subsurface pre-Desmoinesian Pennsylvanian rocks of Kearny county, southwestern Kansas, are named the Kearny formation, and, mainly on the basis of their fusulinid faunas, they are referred to the Morrowan series. Four species and one variety of fusulinids from the type section of the Kearny formation are described and illustrated as *Millerella marblensis* Thompson, *M. pressa*, n. sp., *M. pinguis*, n. sp., *M.? advena*, n. sp., and *M.? advena* var. *ampla*, n. var. Also, the fusulinid fauna from the type section of the Morrowan series at Morrow, Arkansas, is here described and illustrated for the first time. All four of the species of fusulinids, and possibly the variety, present in the Kearny formation in Kansas are also recognized in Morrowan rocks of Arkansas.

INTRODUCTION

A microscopic examination of samples obtained from deep wells drilled in southwestern Kansas has revealed the presence of Pennsylvanian rocks of pre-Desmoinesian age at a number of localities from Meade county on the south to at least as far north as Kearny county. The best samples that I have been able to obtain from pre-Desmoinesian rocks of Kansas are cores and cuttings taken from the Stanolind Oil and Gas Company No. 1 Patterson well. This well was completed in August, 1941, as the discovery well of the Patterson field, located in the SE cor. sec. 23, T. 22 S., R. 38 W., Kearny county (fig. 1). The producing sand, the "Patterson sand" of probable Cherokee age, was encountered from a depth of 4,740 to 4,752 feet. Cores were obtained from the lower part of the "Patterson sand" and intermittently from the base of the sand to below the top of the Mississippian limestone, which was encountered at a depth of 4,879 feet.

Through the courtesy of the Stanolind Oil and Gas Company, I have had an opportunity to study in detail samples of all available cores from the stratigraphic section between the "Patterson sand" and the top of the Mississippian limestone. I have also examined the cutting samples from this well in the files of the State Geological Survey of Kansas. Most of the shales and limestones cored between the base of the "Patterson sand" and the top of the Mississippian limestone, and also the cutting samples from this interval, contain an abundant fusulinid fauna which is almost identical to the fusulinid fauna of the type section of the Morrowan series exposed at Morrow, Arkansas. It is believed, therefore, that this close similiarity of fusulinid faunas demonstrates that this part of

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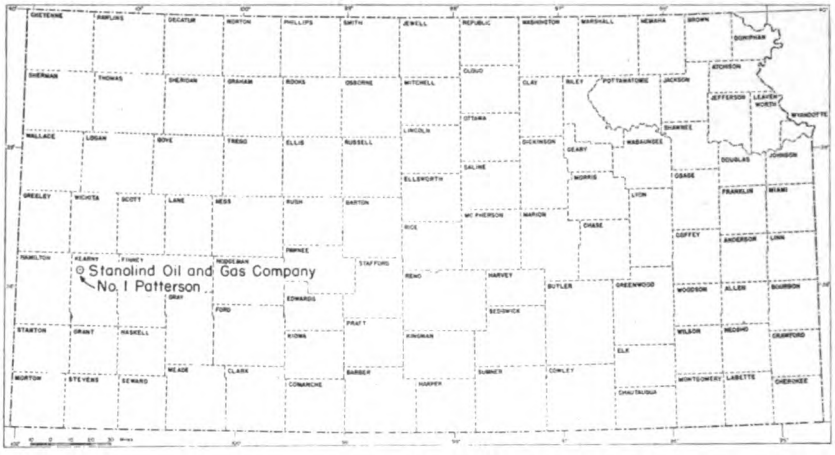

FIG. 1. Index map of Kansas, showing the location of the No. 1 Patterson well.

the subsurface section in Kansas is of Morrowan age. Rocks of similar lithology which contain an identical fusulinid fauna have been examined from several other wells in southwestern Kansas. However, only the Patterson well of Kearny county will be considered in this report.

Rocks that were believed to be of Morrowan age in the subsurface of southwestern Kansas and extreme northwestern Oklahoma have been briefly mentioned in several reports (Ver Wiebe, 1942, p. 52; Ryniker, in Schoff, 1943, p. 42). However, no detailed information concerning the rocks of Morrowan age in Kansas has been published, and the fauna from this part of the Kansas section has not been described or even listed by name. Therefore, the discovery of an abundant fusulinid fauna in cored samples from this lower Pennsylvanian section is of more than ordinary interest. For the sake of direct comparison with the fusulinid fauna of southwestern Kansas described below, the fusulinids discovered in the type section of the Morrowan series in Arkansas (Thompson, 1942a) are being described and illustrated here for the first time.

No rocks of Morrowan age have been recognized at surface exposures in Kansas. However, rocks of Morrowan age occur at the surface several hundred miles to the east in Arkansas, to the southeast in Oklahoma, and probably to the west in Colorado. The

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lithology of the rocks of Morrowan age in the subsurface of southwestern Kansas is not identical to the lithology of the rocks at the other localities mentioned. This fact, in addition to the geographic remoteness of this area from exposures of rocks of equivalent age, seems to warrant the application of a formal stratigraphic name to the strata between the "Patterson sand" and the top of the Mississippian in the Stanolind Oil and Gas Company No. 1 Patterson well. I am, therefore, proposing below the name Kearny formation for these rocks.

ACKNOWLEDGMENTS

I wish to express my sincere thanks to Mr. Wm. C. Imbt, district geologist for Stanolind Oil and Gas Company, who made available to me samples of the cores obtained from the Patterson discovery well and who also kindly furnished additional information on the lithology of the lower Pennsylvanian Morrowan section here named the Kearny formation.

TYPE SECTION OF THE MORROWAN SERIES

The Morrowan rocks of Arkansas were described as the Morrow formation by Adams and Ulrich (1904, pp. 28, 109-113). Three years later the Morrow formation was raised to the rank of a group (Purdue, 1907) and was divided into the Hale formation below and the Bloyd shale above. The Bloyd shale contains two zones of interbedded limestones and shales; the lower of these is called the Brentwood limestone member and the upper the Kessler limestone member. In 1933, Moore (p. 299) proposed the Morrow series as the lowermost series of the Pennsylvanian system in the Mid-Continent region, and the Morrowan is used in that sense in this report.

During the field season of 1941 I visited Hale Mountain just south of Morrow, Arkansas, and obtained numerous samples from the Kessler and Brentwood limestone members of the Bloyd shale and from limestone beds between these limestone members. Several dozen thin sections have been prepared. Those prepared of the collections from near the top of the Brentwood limestone member reveal the presence of numerous specimens of minute fusulinids that are being described and illustrated below as *Millerella marblensis* Thompson; *M. pinguis*, n. sp.; *M.? advena*, n. sp.; and *M.? advena* var. *ampla ?*, n. var. Although I did not obtain

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fusulinids from other parts of the type Morrowan section, more detailed collecting will undoubtedly prove that fusulinids are more widely distributed than my collections indicate.

Giles and Brewster (1930) described in considerable detail and graphically illustrated the type section of the Morrowan exposed on Hale Mountain. I am reproducing (fig. 2) their graphic illustration in order to show more clearly the stratigraphic positions of the fusulinids from that locality which I am describing below.

KEARNY FORMATION

The name Kearny formation is proposed for the 127 feet of rocks encountered between the base of the producing sand at a depth of 4,752 feet and the top of the highly oölitic limestone believed to be of Mississippian age at a depth of 4,879 feet in the Stanolind Oil and Gas Company No. 1 Patterson well. The name is derived from Kearny county in which the well is located.

The type section of the Kearny formation is composed of greenish-gray, bluish-gray, and dark-gray, coarsely crystalline to dense, glauconitic, fossiliferous limestones interbedded with dark-gray and green fossiliferous shales; a subordinate amount of sandstone and sandy glauconitic fossiliferous limestone occurs in the lower part. Four different although gradational lithologic zones can be recognized in the type section. (1) The lowest zone is about 5 feet thick and is composed of white medium- to coarse-grained calcareous sandstone. (2) The next zone, about 28 feet thick, contains glauconitic, sandy, crystalline limestone at the base and top, and interbedded green to gray shale and crystalline limestone in the middle part. (3) The next zone is about 81 feet thick and is composed of interbedded greenish-gray to dark-gray coarsely crystalline and dense limestone, dark-gray to black shale, and green shale. Glauconite is common in many of the limestone beds of this zone and is abundant in some of the green shales. Also, scattered grains of well-rounded highly polished quartz occur in the limestone encountered at a depth of 4,807 to 4,810 feet. Most of the limestones are hard, but some of those associated with or adjacent to the green shales are highly nodular. (4) The uppermost zone, about 13 feet thick, is alternating soft and hard black fossiliferous shale. The accompanying graphic illustration (fig. 2) shows the general lithology of the type section of the Kearny formation as interpreted from an examination of the cores and cut-

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tings. Descriptions of the individual cores obtained from this part of the section are given below.

Descriptions of core samples obtained from the Stanolind Oil and Gas Company No. 1 Patterson well, SE cor. sec. 23, T. 22 S., R. 38 W., Kearny county, Kansas

(Based largely on information supplied by Mr. Wm. C. Imbt)

4,752 - 4,755	Shale, black, thin-bedded, micaceous and silty.
4,756 - 4,760	Shale, dark bluish gray to black, micaceous, laminated; lower 2 to 3 feet hard and highly fossiliferous.
4,761 - 4,765	Shale, black, fossiliferous.
4,765 - 4,767	Limestone, greenish gray to light brown, finely crystalline; green shale streaks near base.
4,767 - 4,771	Shale, green, highly fossiliferous; contains thin streaks of limestone and scattered grains of glauconite.
4,771 - 4,775	Shale, black.
4,775 - 4,776	Limestone, greenish gray, hard, finely crystalline, fossiliferous, glauconitic; contains thin shale streaks.
4,776 - 4,777	Shale, dark greenish gray, carbonaceous.
4,777 - 4,777½	Limestone, greenish gray, finely crystalline, partly nodular, fossiliferous; contains green shale inclusions.
4,777½ - 4,780	Shale, green, fossiliferous, and interbedded nodules and streaks of marly limestone.
4,780 - 4,781	Shale, green, fossiliferous.
4,796 - 4,798½	Limestone, gray, crystalline, fossiliferous, glauconitic.
4,798½ - 4,803½	Shale, dark green to black.
4,803½ - 4,805	Limestone, gray, fine-grained to microgranular.
4,805 - 4,807½	Interbedded black shale and gray granular limestone, fossiliferous.
4,807½ - 4,808¼	Shale, green.
4,808¼ - 4,810½	Limestone, grayish green, fossiliferous; contains streaks of green shale and scattered highly polished grains of quartz.
4,810½ - 4,814	Limestone, gray, finely crystalline; interbedded 1 to 2 inch beds of black shale make up about 20 percent of the interval.

Fusulinids referable to the genus *Millerella* are abundant in the cutting samples from throughout almost all the Kearny formation. Also, cores of shales and limestones obtained from depths of 4,776 to 4,814 feet contain an abundance of fusulinids, all of which belong to the same genus. These are being described and illustrated below as *Millerella marblensis* Thompson, *M. pressa,* n. s., *M. pinguis,* n. sp., *M.? advena,* n. sp., and *M.? advena* var. *ampla,* n. var. As will be noted, all these species except *M.*

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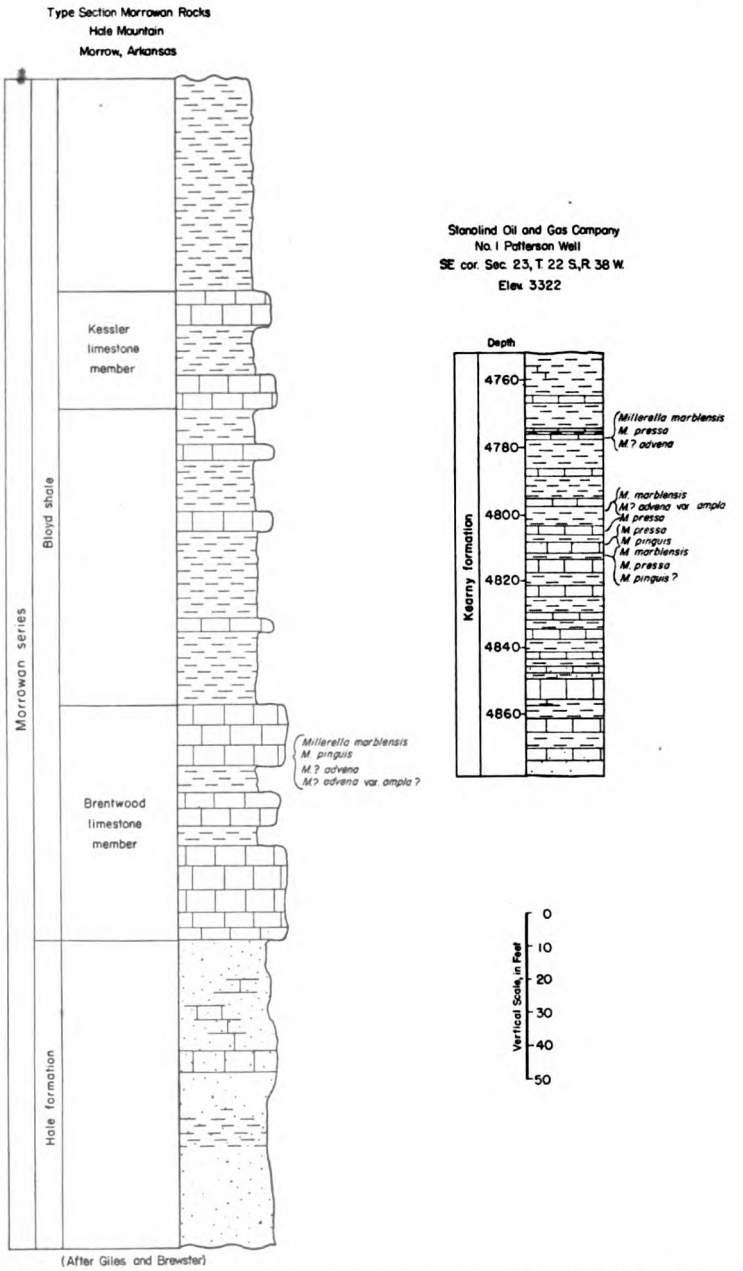

FIG. 2. Diagrams of the type section of Morrowan rocks and of the type section of the Kearny formation.

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pressa also occur in the type section of the Morrowan series of Arkansas. It should be mentioned that Foraminifera other than fusulinids are abundant in the cores and cuttings from the Patterson well. Thin sections of limestones from the type Morrowan section also show the presence of abundant Foraminifera other than fusulinids. These two foraminiferal faunas are closely similar and have many species in common.

STRATIGRAPHIC CORRELATION

In the recent publication "Correlation of Pennsylvanian formations of North America," Moore *et al.* (1944) have indicated the presence of definite, probable, and possible Morrowan rocks at many localities in North America, from California on the west to Pennsylvania on the east. Many of the supporting data for these correlations have not as yet been published, however.

During the preparation of a report on the fusulinids of the Pennsylvanian of New Mexico, I examined several thousand thin sections of limestones and washed shale samples from the lower part of the Pennsylvanian section below the top of the Derryan series, including Derryan and Morrowan rocks, of extreme southwest Texas, New Mexico, north-central Texas, Oklahoma, and Arkansas. It has been established that representatives of the fusulinid genus *Millerella* are abundant throughout most of the Morrowan and all of the Derryan in these areas. *Millerella* also occurs less commonly stratigraphically much higher in the Pennsylvanian. In localities where *Millerella* has been found in the Derryan, it is closely associated with biologically more highly developed genera of fusulinids, such as *Profusulinella, Fusulinella,* and *Pseudostaffella.* The fusulinid faunas of Morrowan rocks are composed almost exclusively of species of *Millerella.*

One of the few localities at which *Millerella* has been found associated with forms of other fusulinid genera in rocks here considered of Morrowan age is about 150 feet below the top of the Marble Falls limestone at Marble Falls, Texas. The possibility has been suggested, however, that the upper part of the Marble Falls limestone at Marble Falls may be younger in age than the Morrowan (Moore *et al.,* 1944). Thompson (1942) reported a species of *Ozawainella?* associated with *Millerella marblensis* in the Marble Falls limestone, but it has not been described or illus-

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trated. That species of *Ozawainella?* is not biologically a highly developed fusulinid, although closely similar forms have been found stratigraphically higher in the section in other areas. Also, the species described below as *M.? advena* from the type section of the Morrowan and from the Kearny formation may not be referable to the genus *Millerella.*

In 1928, Galloway and Harlton described and illustrated (with drawings) a species of *Millerella* as *Orobias radiata* (Brady) from the Morrowan Wapanucka limestone of Oklahoma. The species *radiata* Brady was originally described from the Carboniferous of England and referred to the genus *Involutina,* but Brady's type specimens were not illustrated. Galloway and Harlton also described a form from the Wapanucka as *Orobias biumbonata* Galloway and Harlton. The latter species was described and illustrated (drawings) as being biumbonate and as possessing limbate sutures. Its biological affinities are uncertain, as no known definite fusulinid is umbonate or possesses limbate sutures. This species possibly is referable to the genus *Millerella,* but the type specimens should be restudied in the light of more recent information concerning primitive fusulinids.

About 400 feet of limestones which are considered to be of Morrowan age are exposed at the west end of Powwow Canyon east of El Paso, Texas, underlying rocks of Derryan age. These limestones contain an abundant fusulinid fauna of the genus *Millerella.*

Henbest and Read (1944) described a limestone from the base of the Pennsylvanian section of northern New Mexico that contains a species of *Millerella* and that may possibly be of Morrowan age.

As mentioned above, Ryniker (in Schoff, 1943, p. 42) stated that rocks of possible Morrowan age are present in the subsurface of Cimarron county, northwestern Oklahoma. Fusulinids have not been reported from this Oklahoma section, however.

Moore *et al.* (1944) referred the Glen Eyrie shales exposed near Colorado Springs, Colorado, to the Morrowan, and also reported an unpublished Morrowan fauna from near Minturn, Colorado. However, fusulinids have not been reported or described from either of these sections in Colorado.

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SYSTEMATIC DESCRIPTIONS

Genus MILLERELLA Thompson, 1942

Genotype: *Millerella marblensis* Thompson, 1942

All of the fusulinids so far reported from rocks in America that are considered to be of Morrowan age are referable to the genus *Millerella*, with one and possibly three exceptions: namely, an undescribed species of *Ozawainella?* in the upper part of the type section of the Marble Falls limestone, mentioned above; possibly the species described below as *M.? advena* from the type Morrowan section and the Kearny formation; and possibly the form described by Galloway and Harlton (1928) as *Orobias biumbonata* Galloway and Harlton from the basal shales of the Wapanucka limestone in Oklahoma.

The original diagnosis and comparison of the genus *Millerella* is as follows (Thompson, 1942, pp. 404-405):

> Shell minute, discoidal, with short axis of coiling and narrowly rounded to sub-angular periphery; planispiral throughout growth. The inner three to four volutions are involute but the outer one or two volutions of mature specimens become partially evolute and they only reach approximately one-half the distance to the poles of the preceding volution. Polar regions of mature specimens are depressed (umbilicate). Mature specimens consist of four to seven volutions and measure about 0.3 to 0.6 mm. in width and less than 0.3 mm. in axial length. Spirotheca very thin, consisting of a thin middle layer (tectum and diaphanotheca?) and very thin upper and lower layers which may be tectoria. However, the middle layer is the only layer which can be recognized in all specimens. The rate of expansion of the shell is essentially uniform. Septa are very thin and numerous, and they show a prominent curving in well oriented sagittal sections. Proloculum minute; tunnel low and narrow and bounded by low, narrow chomata.
>
> Representatives of *Millerella* can be distinguished from those of most of the other of the fusulinid genera by their short axis of coiling, narrowly rounded to sub-angular periphery, evolute outer volutions, and prominently curving septa. Representatives of *Millerella* differ from those of the genus *Ozawainella* Thompson by their evolute outer volutions, less sharply angular periphery, much more poorly developed chomata, and smaller size of mature specimens. The genotype of *Nummlostegina* Schubert, *N. velibitana* Schubert, is very poorly known but Schubert's illustrations of external views show completely involute specimens and they also indicate that representatives of the genus *Nummulostegina* are more highly inflated than are those of *Millerella*.

Information obtained from the species described below as *M. pressa*, *M. pinguis*, and *M.? advena* does not greatly change the above generic diagnosis. However, the outermost part of the last

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volution of one specimen referred below with question to *M. marblensis* embraces less than one-fifth of the preceding volution. Also, both *M.? advena* and *M. pinguis* have a larger form ratio than any previously described species of this genus, and they both have only slightly evolute outer volutions.

Three and possibly four species of *Millerella* have been described previously from America: *Staffella ciscoensis* Harlton, "*Orobias radiata* (Brady)" Galloway and Harlton, *M. marblensis* Thompson (the genotype), and questionably *Orobias biumbonata* Galloway and Harlton. Studies of many hundreds of free specimens and of thin sections of specimens embedded in limestone indicate that the genus *Millerella* is more highly varied than previously believed. However, the minute size of representatives of this genus makes it difficult to differentiate species or varieties. It has become obvious that specific and varietal differentiation can be made to best advantage by both external studies of free specimens and studies of oriented thin sections. A combined external and thin section study is not so necessary for specific or varietal recognition of most other genera of fusulinids, for well-oriented thin sections are sufficient for a thorough understanding of species and varieties of most of them.

Age.—Specimens of the genus *Millerella* are extremely abundant in rocks of Morrowan age in many areas. In fact, they are so abundant in Morrowan rocks, almost to the exclusion of other fusulinids, that this part of the stratigraphic section may well be referred to as the Zone of *Millerella*. It is entirely possible, if not probable, that species of *Millerella* or of a closely allied ancestral genus of fusulinids will be found in rocks of Mississippian age. In America, *Millerella* has a known stratigraphic range from near the base of the Morrowan to the Pennsylvanian Cisco of Texas. Representatives of *Millerella* are abundant in the Morrowan and Derryan of many regions and are common throughout most of the Desmoinesian, at least in New Mexico (Thompson, 1942).

MILLERELLA MARBLENSIS Thompson

Plate 1, figures 1-9; plate 2, figures 1-14, (?) 15, 24

Millerella marblensis THOMPSON, *1942*, Am. Jour. Sci., vol. 240, pp. 405-407, pl. 1, figs. 3-14.

?Orobias radiata GALLOWAY AND HARLTON, *1928*, Jour. Paleontology, vol. 2, p. 350, pl. 45, figs. 12a-c.

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Specimens here referred to this species are abundant in the upper part of the Brentwood limestone member of the Bloyd shale of Arkansas and in core samples from the type section of the Kearny formation of Kansas. Three somewhat different groups of specimens can be recognized among these collections. One of these groups is from the Brentwood limestone and these specimens are illustrated on Plate 1 as figures 1 to 9. Another group is from the top part of a core taken at a depth of 4,776 to 4,781 feet in the Patterson well, and these specimens are illustrated on Plate 2 as figures 9 to 15. The third group is from the top of a core taken at a depth of 4,810 to 4,814 feet in the Patterson well, and the specimens are illustrated on Plate 2 as figures 1 to 8. As there is considerable variation among these different groups of specimens, it is doubtful that they are all conspecific with the holotype from the Marble Falls limestone. However, for the present at least, it seems desirable to refer all of them to this species and to merely point out some of the differences that can be recognized among them.

Statistical data for some of the specimens here referred to this species from the Brentwood limestone member of the Bloyd shale, from about 25 feet below the top of the Kearny formation (upper part of the core taken at a depth of 4,776 to 4,781 feet in the No. 1 Patterson well), and from about 59 feet below the top of the Kearny formation (upper part of the core taken at a depth of 4,810 to 4,814 feet in the No. 1 Patterson well) are given in the accompanying table of measurements.

The specimens from the Brentwood limestone member are considerably larger in size for corresponding volutions than the holotype of this species. One of these specimens of only six volutions measures about 1.0 mm in width, and it is one of the largest specimens referable to this genus that I have studied. In addition to size, there are several other differences in measurements between the specimens from the Brentwood limestone and the holotype, but they may all be due to differences in environment and not biological differences.

Several dozen thin sections of specimens and numerous free specimens taken from a core sample about 25 feet below the top of the Kearny formation are being referred to *M. marblensis*. All of these specimens are small, they contain a maximum of five volutions, and the shell is highly evolute in the outer part of the last volution. As so many specimens of this general type are

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TABLE OF MEASUREMENTS (in millimeters)

	Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions 1	2	3	4	5	6	Form ratio of volutions 1	2	3	4	5
Brentwood limestone	1	.20	.67	1:0.30	.036	.022	.041	.054	.079	.124		1:0.65	1:0.50	1:0.46	1:0.40	1:0.39
	2		.63		.032	.020	.032	.045	.072	.113						
	3		.60						.080	.112						
	4	.28	1.00	1:0.28			.040	.050	.085	.128	.157	1:0.55	1:0.51	1:0.47	1:0.46	1:0.29
25′ below top of Kearny formation	1	.17	.64	1:0.25	.023	.036	.050	.104	.126			1:0.55	1:0.50	1:0.42	1:0.27	
	2	.17	.43	1:0.39		.020	.036	.063	.108							
	3	.16	.40	1:0.40	.032							1:0.77	1:0.65	1:0.70	1:0.40	
	4		.40		.027	.018	.032	.059	.090							
	5	.14	.50	1:0.28				.063	.124							
59′ below top of Kearny formation	1	.20	.50	1:0.40	.050	.025	.041	.061	.092			1:0.58	1:0.50	1:0.51	1:0.43	
	2	.21	.61	1:0.34	.041	.020	.032	.058	.072	.106						
	3		.68		.042	.023	.027	.054	.095							
	4		.77		.034	.023	.032	.050	.090	.135						
	5		.59			.018	.036	.068	.090	.117						
	6	.18	.66	1:0.27												

		Thickness of spirotheca 1	2	3	4	5	Septal count 1	2	3	4	5	Tunnel angle (degrees) 1	2	3	4	5
Brentwood limestone	1														11	11
	2		.008	.011	.014		7	11	14	17	22					
	3						8	10	12	15	18					
	4			.010	.014	.016										
25′ below top of Kearny formation	1		.014	.014	.009								11	12	14	
	2			.014	.014									12		
	3															
	4						5	9	12	16						
	5				.007											
59′ below top of Kearny formation	1		.009	.011	.014								15	22	26	
	2															15
	3		.009	.012	.014	.015	9	13	15	20	22					
	4	.006	.009	.014	.018	.018	6	10	14	19	22					
	5						6	7	9	15						
	6															

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present in this core, it is believed that they represent mature individuals, and they probably are referable to an unnamed variety of this species. The specimen illustrated as figure 15 on Plate 2 is from this same core sample of the Kearny formation. However, it is one of the most highly evolute representatives of the genus *Millerella* so far observed. In fact, the outermost volution is only slightly impressed by the preceding volution. It is doubtful that this specimen is referable to *M. marblensis.*

Samples from the upper part of the core taken at a depth of 4,810 to 4,814 feet in the Patterson well, that is, about 59 feet below the top of the Kearny formation, contain an abundance of specimens, some of which are here illustrated, that are closely similar to the holotype of this species from the Marble Falls limestone. However, the accompanying statistical data indicate that these Kansas specimens are larger for corresponding volutions than the holotype, their spirotheca is thicker, and their proloculum is larger.

Occurrence.—Specimens here referred to *M. marblensis* are abundant in the upper part of the Brentwood limestone member of the Bloyd shale at Morrow, Arkansas, and from about 25 feet and about 59 feet below the top of the type section of the Kearny formation. The holotype came from about 150 feet below the top of the type section of the Marble Falls limestone. Specimens which are possibly conspecific with the holotype have been described and illustrated from rocks of Derryan age in south-central New Mexico and from rocks of Derryan age in Powwow Canyon east of El Paso, Texas. Undescribed specimens which are probably conspecific with the holotype occur in rocks of Morrowan age in Powwow Canyon east of El Paso. The form described and illustrated by Galloway and Harlton from the Wapanucka limestone of Oklahoma as *Orobias radiata* (Brady) possibly is conspecific with the holotype of this species.

MILLERELLA PRESSA Thompson, n. sp.

Plate 2, figures 16-23

Shell minute, subdiscoidal, planispiral throughout growth, narrowly and deeply umbilicate; with narrowly rounded periphery and slightly convex lateral sides. The holotype, a mature specimen of five volutions, measures 0.19 mm in axial length and

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0.63 mm in width. The form ratios of the first to the fifth volution of the holotype are 1:0.50, 1:0.47, 1:0.47, 1:0.46, and 1:0.30. As is obvious from these determinations, the shell retains essentially the same shape throughout growth of the first four volutions. This uniformity of shape is also evident in other specimens of this species. The inner two to three volutions are involute and are only slightly umbilicate. However, from the third volution to maturity, the shell gradually becomes more highly evolute, and the uncoiling of the shell is rapid during development of the last volution.

The proloculum is minute, and its outside diameter measures 36 to 41 microns in five specimens, averaging 37 microns. The

---

EXPLANATION OF PLATE 1

All illustrations on this plate are unretouched photographs.

FIGURE — PAGE

1- 9—*Millerella marblensis* Thompson 420

1, Oblique sagittal section, x75; *2, 7*, tangential sections, x70; *3, 5, 8*, axial sections, x75; *4*, sagittal section, x75; *6*, tangential section, x75; *9*, illustration of the same axial section as *8* but having the magnification at which most larger fululinids are generally illustrated, x10. Upper part of the Brentwood limestone member of the Bloyd shale.

10-14, (?) *16, 17*—*Millerella? advena*, n. sp. 427

10, Axial section of the holotype, x70; *11*, sagittal section, x70; *12*, oblique tangential section, x75; *13*, sagittal section, x75; *14*, tangential section, x70; *16*, axial section of a specimen referred to this species with question, x75; *17*, axial section, x75. The specimens of figure *10, 11, 13, 14*, and *16* are from the upper part of the Brentwood limestone member of the Bloyd shale, and those of figures *12* and *17* are from about 25 feet below the top of the Kearny formation.

18-20—*Millerella pinguis*, n. sp. 425

18, Axial section of the holotype, x75; *19*, tangential section of a paratype, x75; *20*, sagittal section of a paratype, x75. The holotype is from the Brentwood limestone member of the Bloyd shale, and the two illustrated paratypes are from 55 to 58 feet below the top of the Kearny formation.

21, 22, (?) *15*—*Millerella? advena* var. *ampla*, n. var. 429

21, Axial section of the holotype from about 45 feet below the top of the Kearny formation, x75; *22*, sagittal section of a paratype from about 45 feet below the top of the Kearny formation, x75; *15*, sagittal section of a specimen from the Brentwood limestone member of the Bloyd shale that is being referred with question to this species, x75.

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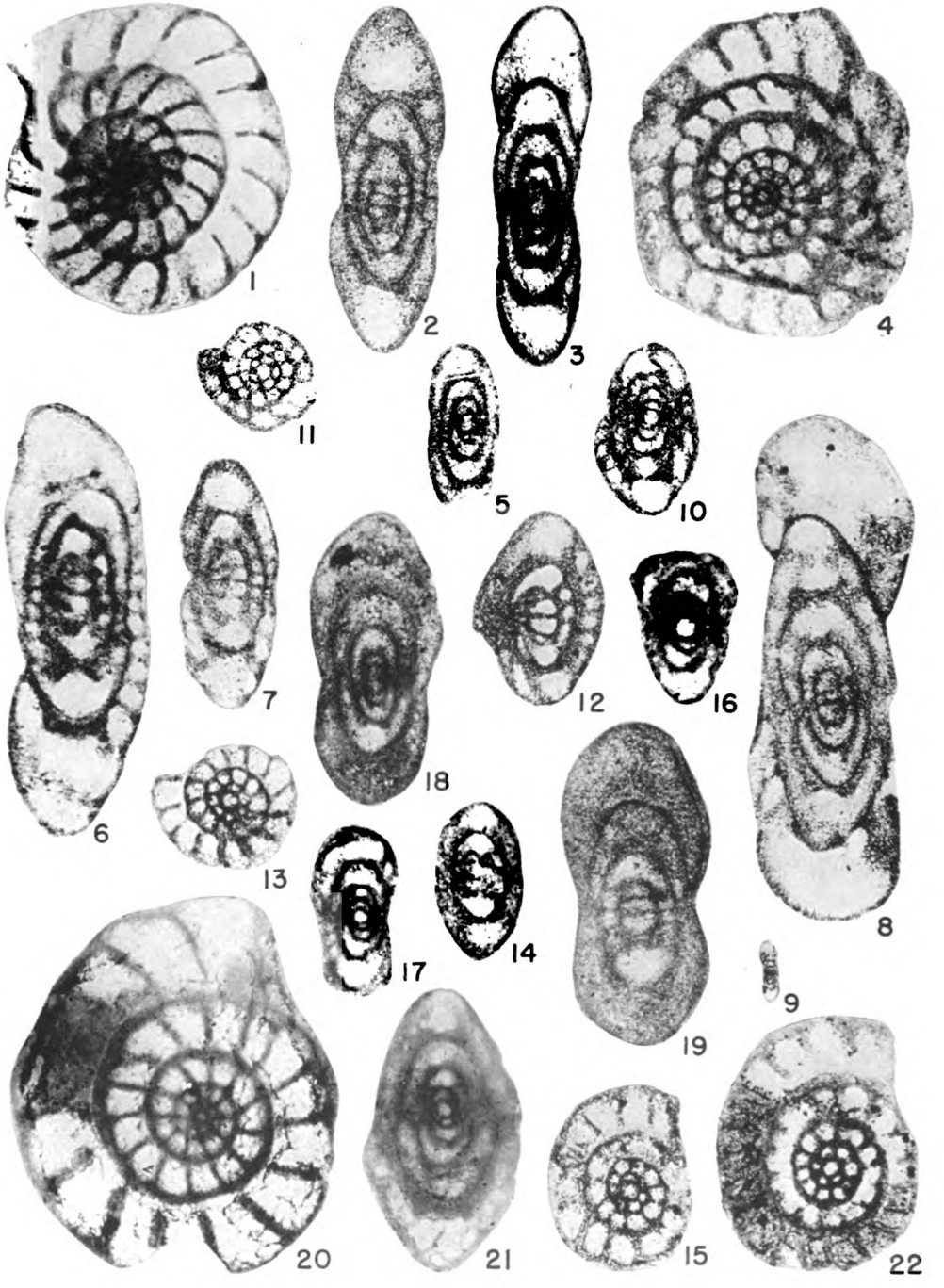

Thompson, Morrowan Fusulinids

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shell expands slowly and uniformly. The heights of the first to the fifth volution of six specimens measure 16 to 27, 27 to 41, 45 to 63, 72 to 90, and 115 to 135 microns, respectively; averaging 20, 32, 55, 79, and 125 microns, respectively. The heights of the first to the fifth volution of the holotype measure 20, 34, 54, 81, and 115 microns, respectively.

The septa are thin, and they are distinctly curved in the outer volutions. The septal counts of the first to the fifth volution in the two illustrated sagittal sections average 8, 11, 14, 19, and 21, respectively. The septa immediately over the tunnel in the first two volutions are essentially normal to the overlying spirotheca. Beyond the second volution the septa extend anteriorly and are arcuate. The septa in the third volution are at an angle of about 15 degrees from normal to the spirotheca, and in the fifth volution they are at an angle of about 26 degrees from normal.

The spirotheca is thin, and it is composed of a thin dense central layer and indistinct thicker and less dense outer layers.

The tunnel is low and narrow. The tunnel angle measures 13 degrees in the third volution, 12 degrees in the fourth volution, and 11 degrees in the fifth volution of the holotype. Low and narrow chomata occur in the third, fourth, and fifth volutions.

Remarks.—*M. pressa* is more closely similar to *M. marblensis*, the genotype of *Millerella*, than any previously described species. Many of the statistical data of these two forms are closely similar. However, in *M. pressa* the shell is more tightly coiled, the axial ends are more evenly compressed, and the outer volution of mature specimens is not so highly evolute as in *M. marblensis*.

Occurrence.—*M. pressa* is abundant in the core samples obtained from 51½ to 59 feet below the top of the Kearny formation in the Stanolind Oil and Gas Company No. 1 Patterson well. The holotype was obtained from the core taken in this well at a depth of 4,807 to 4,810 feet; that is, 55 to 58 feet below the top of the Kearny formation.

Millerella pinguis Thompson, n. sp.

Plate 1, figures 18-20

Shell minute, subdiscoidal to ellipsoidal in axial profile; with depressed axial regions. The axis of coiling is the shortest diameter of the specimen. The periphery is rounded throughout

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growth of the individual. The shell is planispiral throughout growth. The inner three to four volutions are involute, but the outer part of the last volution becomes slightly evolute. The holotype, presumably a mature specimen, contains four and one-half volutions and measures 0.25 mm in axial length and 0.55 mm in width, giving a form ratio of 1: 0.46. A paratype of about five volutions measures 0.28 mm in axial length and 0.64 mm in width. The form ratios of the first to the fourth volution of the holotype are 1: 0.50, 1: 0.52, 1: 0.51, and 1: 0.46, respectively. The inner three volutions are discoidal in shape with essentially smooth polar regions, but the outer one or two volutions become inflated near the periphery and are broadly umbilicate.

The proloculum is minute in size and spherical in shape. Its outside diameter measures about 32 microns in two specimens. The shell expands slowly during the first to the third volution, but the outer two volutions of mature specimens are more inflated. The heights of the first to the fourth volution immediately over the tunnel of three specimens are 27 to 34, 40 to 52, 66 to 90, and 117 to 135 microns, respectively; averaging 30, 45, 76, and 128 microns, respectively. Poleward from the tunnel the chambers decrease in height rapidly.

The septa are relatively thick and in the third and fourth volutions they are composed of three distinct layers, a central dense thin layer (the tectum) and two outer thicker and less dense layers. However, in the outermost two to three chambers, the anterior of these outer layers is absent. The structure of the septa is evident in the illustrated sagittal section of a paratype. The septal counts of the first to the fourth volution of the illustrated sagittal section of a paratype are 8, 10, 12, and 15, respectively. Immediately over the tunnel in the inner volutions, the septa are essentially normal to the overlying spirotheca. However, immediately over the tunnel in the outer volutions the septa extend forward at an angle of about 15 degrees from normal to the spirotheca, and they are slightly arcuate.

The spirotheca is relatively thick. In the last few chambers of the outer volution the spirotheca has a thin dark top layer and a relatively thick lower layer. The spirotheca of the inner volutions contains a thin dark central layer, which corresponds to the top layer of the outer few chambers, and upper and lower less dense but thicker layers. The approximate values of 16, 27, and 27 mi-

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crons, respectively, were determined for the thicknesses of the spirotheca in the second, third, and fourth volutions of the holotype.

The tunnel is low and broad in the outer two volutions of specimens of four to five volutions. However, the tunnel is narrow in the inner two to three volutions. High and broad chomata occur in the second and third volutions of mature specimens, but the chomata are low and narrow in the remainder of the shell. The tunnel angles of the third and fourth volutions of a paratype are about 20 and 22 degrees, respectively.

Remarks.—The broadly rounded periphery, broadly depressed axial region, and almost completely involute shell serve to distinguish this species from other described species of this genus.

Occurrence.—*M. pinguis* is rare in the upper part of the Brentwood limestone member of the Bloyd shale, from which the holotype was obtained, and in the green shales 55 to 58 feet below the top of the Kearny formation in the Stanolind No. 1 Patterson well. Also, a number of unsectioned specimens which are probably referable to this species were obtained from the top of the core taken about 59 feet below the top of the Kearny formation.

MILLERELLA? ADVENA Thompson, n. sp.

Plate 1, figures 10-14, (?) 16, 17

Shell minute, subdiscoidal in shape; with rounded periphery, slightly raised axial region, and distinctly convex lateral slopes. One of the best preserved specimens, the holotype, contains four and one-half volutions, measures 0.23 mm in length and 0.36 mm in width, and has a form ratio of 1: 0.64. The last part of the outermost volution of the holotype and of paratypes tends to become slightly evolute. The remainder of the shell is involute. The first volution is slightly asymmetrical, but the outer volutions are planispiral. The form ratios of the first to the fourth volution of the holotype are 1: 0.73, 1: 0.69, 1: 0.68, and 1: 0.63, respectively.

The proloculum is minute, and its outside diameter measures 36 to 45 microns. The shell of the holotype expands slowly and uniformly, and the heights of the first to the fifth volution are about 23, 26, 32, 54, and 72 microns, respectively. The heights of the first to the third volution of two paratypes are 18 to 20, 32, and 41 to 63 microns, respectively.

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The septa are thin, and they contain a thin dark central layer and less dense outer layers. However, the detailed structure of the septa is difficult to determine in most specimens. The septal counts of the first to the third volution of two specimens are 6 to 7, 11, and 12 to 13, respectively. The septa are essentially normal to the overlying spirotheca in the inner volutions, and they extend forward only very slightly in the outer part of the shell.

The spirotheca is thin, and it is composed of a thin central layer and somewhat indefinite outer less dense layers. The thicknesses of the spirotheca of the second to the fifth volution of the holotype measure about 5, 9, 9, and 9 microns, respectively.

The tunnel is low. The tunnel angles in the third, fourth, and fifth volutions of the holotype measure about 11, 17, and 21 degrees, respectively. Chomata are well developed in the outer volutions of specimens of five volutions, but they are low and discontinuous in the inner two volutions. In the fifth volution of the holotype, the chomata are highly asymmetrical, they are about one-half as high as the chambers, and they extend about one-third the distance from the tunnel to the poles.

EXPLANATION OF PLATE 2

All illustrations on this plate are unretouched photographs, and all of them are magnified x75, except figure 8 which is x10.

FIGURE **PAGE**

1-14, (?) *15, 24*—*Millerella marblensis* Thompson 420

1, 4, 7, 8, 13, 14, Sagittal sections; *2, 5, 6, 9, 10, 24*, axial sections; *3, 11, 12*, tangential sections; *15*, tangential section of a specimen referred with question to this species. Figure *8* is of the same specimen as that of figure 7 but at a magnification of x10, the magnification at which larger fusulinids are generally illustrated. Specimens of figures *1-7* and *24* are from about 59 feet below the top of the Kearny formation; those of figures *9-15* are from about 25 feet below the top of the Kearny formation.

16-23—*Millerella pressa*, n. sp. 423

16, Tangential section of a paratype; *17, 20, 21*, axial sections of paratypes; *18*, axial section of the holotype; *19*, parallel section of a paratype; *22, 23*, sagittal sections of paratypes. Specimens of figures *16, 17, 20*, and *21* are from about 51½ to 55 feet below the top of the Kearny formation; specimens of figures *18* and *22* are from about 55 to 58 feet below the top of the Kearny formation; and the specimen of figure *23* is from about 59 feet below the top of the Kearny formation.

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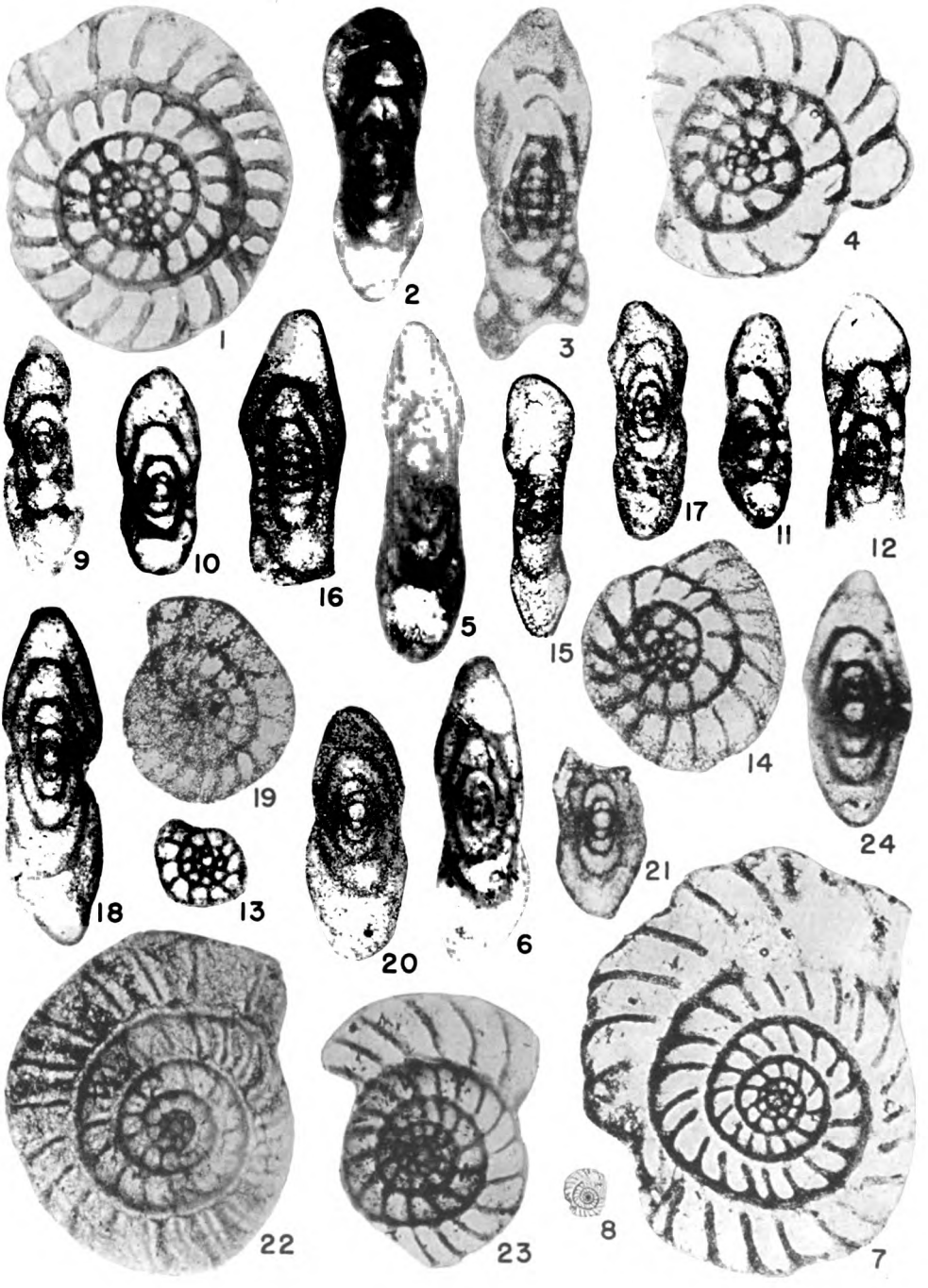

Thompson, Morrowan Fusulinids

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Remarks.—The typical variety of this species and the variety *ampla* described below are referred with question to the genus *Millerella.* They differ from the genotype of *Millerella, M. marblensis,* in that their axis of coiling is more extended, the shell is only very slightly if at all evolute, and the juvenile portion of the shell is slightly asymmetrical.

M.? advena is one of the smallest described species of the fusulinids. It was at first believed that the holotype and the paratypes were young individuals of a larger species. More than a half dozen specimens have been found in thin sections prepared of the Brentwood limestone, and all of them are about the size of the holotype or are slightly smaller. It is, therefore, believed that the holotype is an essentially mature specimen.

The typical variety *advena* differs from the variety *ampla,* described below, mainly in its smaller size, more highly convex lateral slope, and more tightly coiled shell. As would be expected from these differences, the spirotheca of the variety *ampla* is much thicker than that of the typical variety *advena.*

Occurrence.—This species is common in one of the samples of limestone obtained from the upper part of the Brentwood limestone member of the Bloyd shale on Hale Mountain near Morrow, Arkansas, and it occurs sparsely about 25 feet below the top of the Kearny formation.

MILLERELLA? ADVENA var. AMPLA Thompson, n. var.

Plate 1, figures 21, 22, (?) 15

A number of specimens that differ considerably from any previously described species or variety have been obtained from a core about 45 feet below the top of the Kearny formation in the Patterson well. These specimens are so closely similar, and presumably closely related biologically, to the holotype and paratype specimens of *Millerella? advena* that I consider them a variety of that species. Sagittal and poorly oriented axial and oblique sections of specimens that may possibly be referable to the variety *ampla* have been obtained from the Brentwood limestone member of the Bloyd shale.

Shell minute, subdiscoidal in shape; with narrowly rounded periphery, slightly extended axial regions, and slightly convex to

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straight lateral slopes. The holotype contains four and one-half volutions and measures about 0.31 mm in length and 0.54 mm in width, giving a form ratio of about 1: 0.57. An unfigured paratype of five volutions measures 0.28 mm in axial length and 0.58 mm in width, giving a form ratio of about 1: 0.49. The form ratios of the first to the fourth volution of the holotype are 1: 0.65, 1: 0.58, 1: 0.59, and 1: 0.54, respectively. The inner one and one-half volutions are slightly asymmetrical, but the outer volutions are symmetrical. The fifth volution is umbilicate, and it is slightly evolute.

The proloculum is minute, and its outside diameter measures 36 to 41 microns. The shell expands essentially uniformly, and the heights of the first to the fifth volution of the holotype measure 22, 38, 58, 79, and 108 microns, respectively. The heights of the first to the fourth volution of the figured sagittal section of a paratype measure 23, 36, 59, and 86 microns, respectively.

The septa are relatively thick, and they contain a thin dark central layer and outer less dense and thicker layers. The septal counts of the first to the fourth volution of a typical specimen are 6, 11, 14, and 19, respectively. The septa are straight, but they extend slightly anteriorly in the outer part of the shell.

The spirotheca is relatively thick, and it is composed of a thin dark central layer and thicker less dense outer layers. The thicknesses of the spirotheca in the second to the fifth volution of a typical specimen measure about 9, 14, 14, and 18 microns, respectively.

The tunnel is narrow and high. The tunnel angle of the holotype measures about 11 degrees in the fourth volution and 19 degrees in the fifth volution. Chomata are well developed in the third to the fifth volution, and they extend almost to the poles.

Remarks.—This variety differs from the typical variety *advena* in that it is larger in size, has more nearly straight lateral slopes, and has a less tightly coiled shell. Also, the spirotheca of the variety *ampla* is thicker than the spirotheca of the variety *advena*.

Occurrence.—Specimens of this variety are common in a core sample from about 45 feet below the top of the Kearny formation. Specimens which I am referring with question to this variety were obtained from the upper part of the Brentwood limestone member of the Bloyd shale at Morrow, Arkansas.

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