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A stratigraphic study of fusulinid foraminifera in the Cherokee group (Pennsylvanian) of western Missouri and Kansas

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A STRATIGRAPHIC STUDY OF FUSULINID FORAMINIFERA IN THE CHEROKEE GROUP (PENNSYLVANIAN) OF WESTERN MISSOURI AND KANSAS

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ABSTRACT

Limestones or shaly limestones, from four stratigraphic levels in the Cherokee group (Desmoinesian series) of Missouri and Kansas, contain eight species and two varieties of fusulinid foraminifera, of which four species and two varieties are new, and one ophthalmidiid foraminiferal species (Hemigordius cf. regularis Plummer). The next to highest limestone (cap rock of the Fleming coal) is correlated with the Seahorne limestone of western Illinois, the Stonefort limestone of southern Illinois, and the Munterville limestone of Iowa. Hemigordius regularis, a limestone facies foraminifer apparently marks a correlatable interval in the Ardmore limestone. Descriptions of the fusulinids and the opthalmidiid are presented.

INTRODUCTION

A detailed description of fusulinid foraminifera from Pennsylvanian strata of western Missouri and southeastern Kansas is presented. The stratigraphy of the area has been previously determined, in part, because of the economically important coals, but the microfauna has received scant attention. Stratigraphic allocation of these microfossils is intended to corroborate and amplify established Mid-Continent correlations.

Several limestones and shaly limestones (Cherokee group, Desmoinesian series) were collected during 1950 and 1951 in Crawford County, Kansas, and the adjoining Vernon and Barton Counties of Missouri. Supplementary collections of shales and clays, interbedded with limestones, were made in Boone County, central Missouri in 1951.

Earlier correlations of the Ardmore limestone in central and western Missouri has been corroborated by two species of microfossils (Hemigordius cf. regularis and Fusulina new species B). Neither has been reported previously from the Cherokee group. The shaly limestone cap of the Fleming coal, Crawford County, Kansas, contains a microfauna with elements identical with some occurring 35 feet below the Whitebreast coal, Iowa (Munterville limestone), and with the Seahorne limestone of western Illinois. In addition, one species, *Wedekindellina euthysepta*, which is common to both strata, also occurs in the Stonefort limestone of southern Illinois. A tentative correlation of these units is proposed on this basis.

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PREVIOUS WORK

The general features of the Cherokee group (figure 1) were described some fifty years ago, but detailed work on the subdivisions treated in this paper was not published until a comparatively recent date. A comprehensive survey of the development of classification of Pennsylvanian rocks of the Mid-Continent region, by Moore (1948, pp. 2014-2017), includes much material not discussed here, as well as a complete bibliography.

Development of stratigraphic terminology: Strata from the base of the Desmoinesian series to the base of the Blackjack Creek limestone were known until 1948 as the "Cherokee shale." At that time, they were raised to the status of a group (Moore, 1948, pp. 2026). The group was named for Cherokee County, Kansas (Hayworth and Kirk, 1894, p. 105) in which the type section was selected. Prior to 1900, the main features of the Cherokee group had been noted: several coals had been named; the various members, including sandstones, shales and limestones had been noted, but were generally not named; thicknesses had been measured, and the marine and non-marine character of the beds recognized (Hayworth, 1898, pp. 20-30).

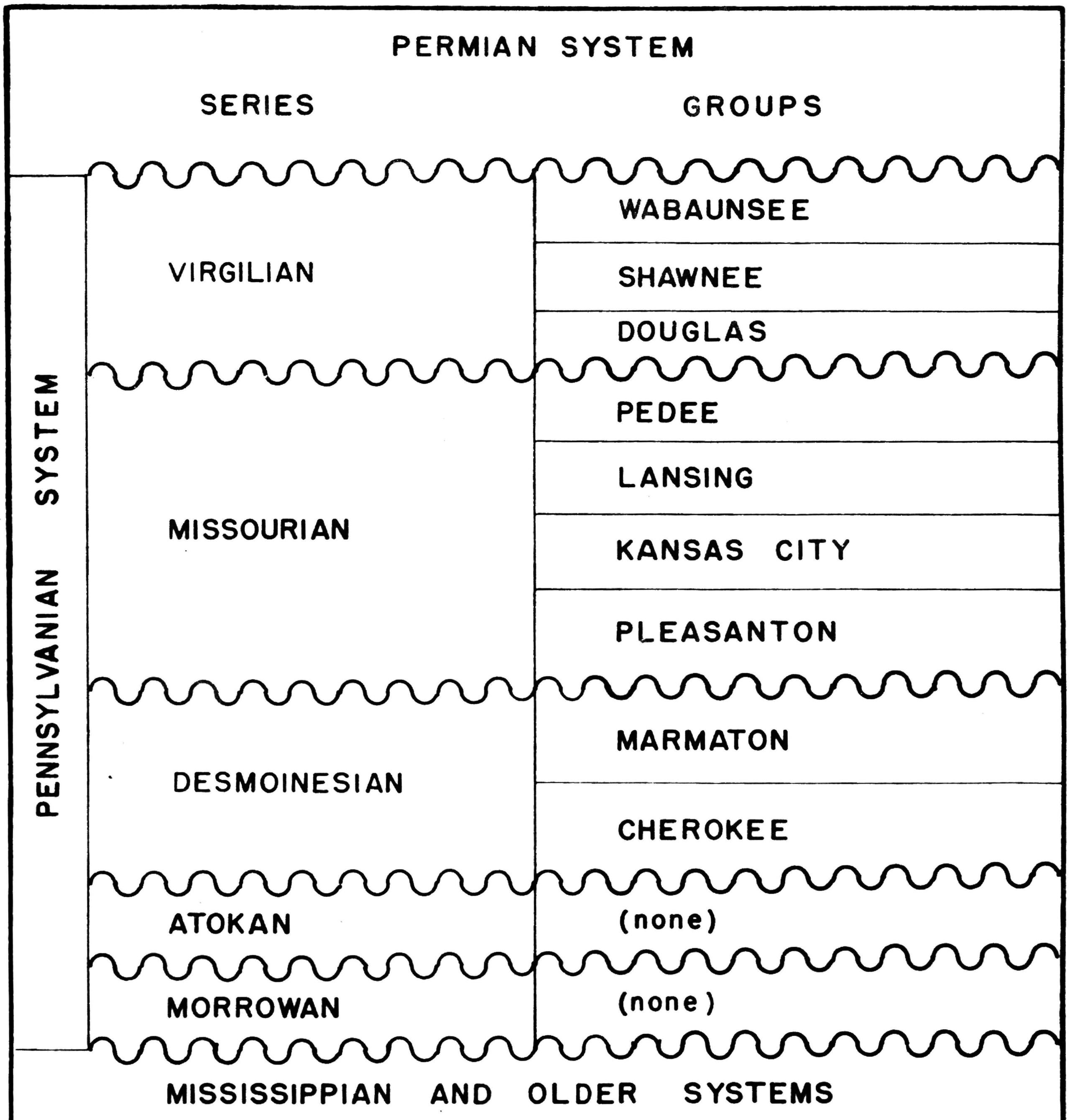


Fig. 1. SERIES AND GROUPS OF PENNSYLVANIAN SYSTEM OF NORTHERN MID-CONTINENT REGION (after Moore, 1948).

The Cherokee group had not been subdivided by 1915, but had been traced across Missouri, from Kansas to Iowa, and correlated with strata in Kansas (Hinds and Greene, 1915, pp. 36-61). Regional variations were carefully noted, many sections measured, and a faunal study undertaken by Girty (1915). Nomenclature was not standardized even within the state.

A detailed description of the stratigraphy of Vernon County, Missouri, partly differentiated the Cherokee "shale." Local names were given to coals and to important limestones and sandstones, and correlation of some these units attempted on a county or interstate basis (Greene and Pond, 1926, pp. 34-54).

A reclassification of Pennsylvanian rocks of Kansas, by Moore (1935, pp. 21-42), included rearrangement of units, definition of boundaries, and description of the "cyclic" nature of the strata. The Cherokee "shale", however, was not subdivided.

In 1938, a highly detailed and comprehensive study of the southeastern Kansas coal field (Pierce and Courtier, 1938, pp. 21-42) was issued. Lithic units were mapped in the entire area, for the first time, and correlation with the western Missouri coal area was made. In addition, faunal and floral collections were a basis for correlation with Illinois and Iowa.

Cline (1941, pp.25-72) made a traverse between Missouri and Iowa in an attempt to clarify middle Pennsylvanian correlation. The upper Desmoinesian and lower Missourian series, of the two states, were correlated with units in Missouri and Kansas. The lowest formation described was the Ardmore limestone.

Recent workers (Moore and Thompson, 1949, pp. 275-302 and Moore, 1949, pp. 37-47) add little information about the Cherokee group. Series names are proposed, and the most recent findings summarized.

Development of biostratigraphy: Fusulines have been described from Pennsylvanian and Permian formations for many years. The most significant results, however, have been published quite recently, especially in relation to the Cherokee group. Although some of the fusulinid species discussed here have been reported elsewhere, only occurrence in the interior basins and areas east of the Rocky Mountains will be considered.

One of the first important papers on the paleontology of the Cherokee group was written by Girty (1915). Two fusulinids were reported, *Fusulina cylindrica* Fischer and *Girtyina ventricosa* Meek and Haydn (=*Triticites*). Their stratigraphic position was not clear, as horizons were not well defined at the time.

In 1927, Dunbar and Condra (1927, pp. 78-80) reported Fusulinella meeki Dunbar and Condra (= Fusulina) from the undifferentiated Cherokee "shale" of Missouri, Roth (1930) using subsurface samples in Kansas, Oklahoma, South Dakota and Colorado, correlated formations as far west as Eagle County, Colorado, with the Cherokee and Marmaton groups of the Mid-Continent. Species of Fusulina, which had not been reported above the Desmoinesian series, were the basis of this correlation. The fauna and stratigraphy of one of these formations (McCoy formation) were subsequently discussed by Roth and Skinner (1930), and many new species of fusulinids were briefly described and figured.

Thompson (1934), in a study of the Desmoinesian series of Iowa, correlated several formations in Iowa and Illinois. Many new species were described, a number of which are commonly widespread in both the eastern and western Basins. Correlation of some middle Pennsylvanian formations, based on additional faunal evidence, was published later by Thompson (1935, pp. 291-298). Seven new species from the Boggy formation of Oklahoma were described, figured and compared with the microfauna found in Iowa, 30 to 60 feet below the Whitebreast coal.

Bailey (1935) made a comprehensive treatment of the microfossils, exclusive of fusulinids, of the lower

Pennsylvanian (Cherokee and a portion of the Marmaton group). Foraminifera, ostracodes, conodonts and other forms were described and stratigraphic ranges of the fauna given. The study has aided in correlating the upper boundary of the Cherokee in central Missouri with that in Kansas.

A number of fusulinid species, from the mid-portion of the Cherokee shale and other Pennsylvanian strata of South Dakota and Wyoming, were reported by Thompson (1936). Similarity to species found in Iowa and Illinois was noted, and one species, <u>Fusulina euryteines</u> Thompson, reported from Wyoming. These forms are conspecific with those previously found in Missouri, Iowa, Illinois and Oklahoma. Because of these faunal relationships, Thompson correlated and stratigraphically placed the formations.

Pierce and Courtier (op. cit., pp. 39-42) collected fossil plants and fusulinids at stations ranging from just above the Pilot coal to a level within the Marmaton group. The microfossils were submitted to Henbest (1938) for examination, and some beds were tentatively correlated with limestones in Illinois. Several species were identified with those previously reported by Thompson in Iowa (1934).

A paper on invertebrate faunas of southeastern Kansas by Williams (1938, pp. 92-122) made little reference to microfossils, as the assemblage consisted mainly of mollusks and brachiopods.

A report on Pennsylvanian strata of western Illinois and southern Iowa, microfaunal and lithological, was made by Weller and others (1942). Their detailed correlations, from the middle Desmoinesian to the lower Missourian series, apply to the Missouri and Kansas sections. Dunbar and Henbest (1942), established generic and specific ranges and summarized Pennsylvanian correlation from Kansas to Ohio. The Ardmore limestone was traced from Kansas through Missouri, Iowa, and Illinois.

Correlations of eastern Utah and northwestern Colorado, with middle Pennsylvanian sections in Kansas and Iowa, were made by Thompson (1945). This work was based on a large fusulinid fauna and a zonation of the genera *Millerella*, *Fusulinella*, *Fusulina*, and *Wedekindellina*. Thompson (pp. 40-42) noted that Pennsylvanian formations in most of North America, can be referred to five major faunal zones, defined by predominance of these and other genera.

The importance of fusulinids in zonation was again stressed by Thompson and Moore (1949). A correlation chart of Pennsylvanian formations, from the Mid-Continent to the Laramee Mountains, Wyoming, was also given.

DESCRIPTION OF AREAS

Vernon and Barton Counties, Missouri, adjoin Crawford County, Kansas, where part of the southeastern Kansas coal field is located. Most of the field work was done in this area, although Boone County, in central Missouri, was the source of additional faunal and stratigraphic material.

The southeastern Kansas coal field contains approximately 1000 square miles. Most of this area is within the Osage Plains Section of the Central Lowland physiographic province. The Ozark uplift is situated to the east. The surface is almost flat throughout. Maximum differences in elevation of 250 feet in Kansas and 150 feet in Missouri have been reported (Pierce and Courtier, 1938; Greene and Pond, 1926). Drainage is southward into the Neosho River in Kansas, and eastward into the Osage River in Missouri. These rivers are broad and shallow, with wide meanders. Cherokee strata are exposed over much of this area; the prevailing dip is low and to the northwest. Thickness varies from 350 to 500 feet, the lesser thickness being more common.

Boone County, just north of the Missouri River, is within the Dissected Till Plains section of the Central Lowland Province. In this "subsection", however, little dissection has occurred, in contrast with other portions of the section. The formerly dissected surface, smoothed by glaciation, forms the present rolling plain. Major drainage is south into the Missouri River. Most of the exposures include Carboniferous rocks, with Mississippian strata in the southern portion of the county and Pennsylvanian in the northern. The rocks dip gently to the northwest and the Cherokee group has a reported maximum thickness of 109 feet near Columbia (Hinds and Greene, 1915).

STRATIGRAPHY OF THE CHEROKEE GROUP

The Cherokee group includes strata from the base of the Desmoinesian series to the base of the Blackjack Creek limestone (lower Fort Scott limestone). It overlaps the Mississippian older rocks at its eastern limits. On the west, it is overlain conformably by Pennsylvanian strata. The Cherokee group outcrops in a belt of varying width extending from northeastern Oklahoma to northwestern Iowa. Exposures have been measured in northeastern Oklahome, southeastern Kansas, Iowa, and various portions of Missouri (Pond and Greene, 1926; Pierce and Courtier, 1938; Cline, 1941; McQueen, 1943).

Many units in Kansas and Missouri have not been named, and can be located stratigraphically only by measurements relative to named coals. Variation in

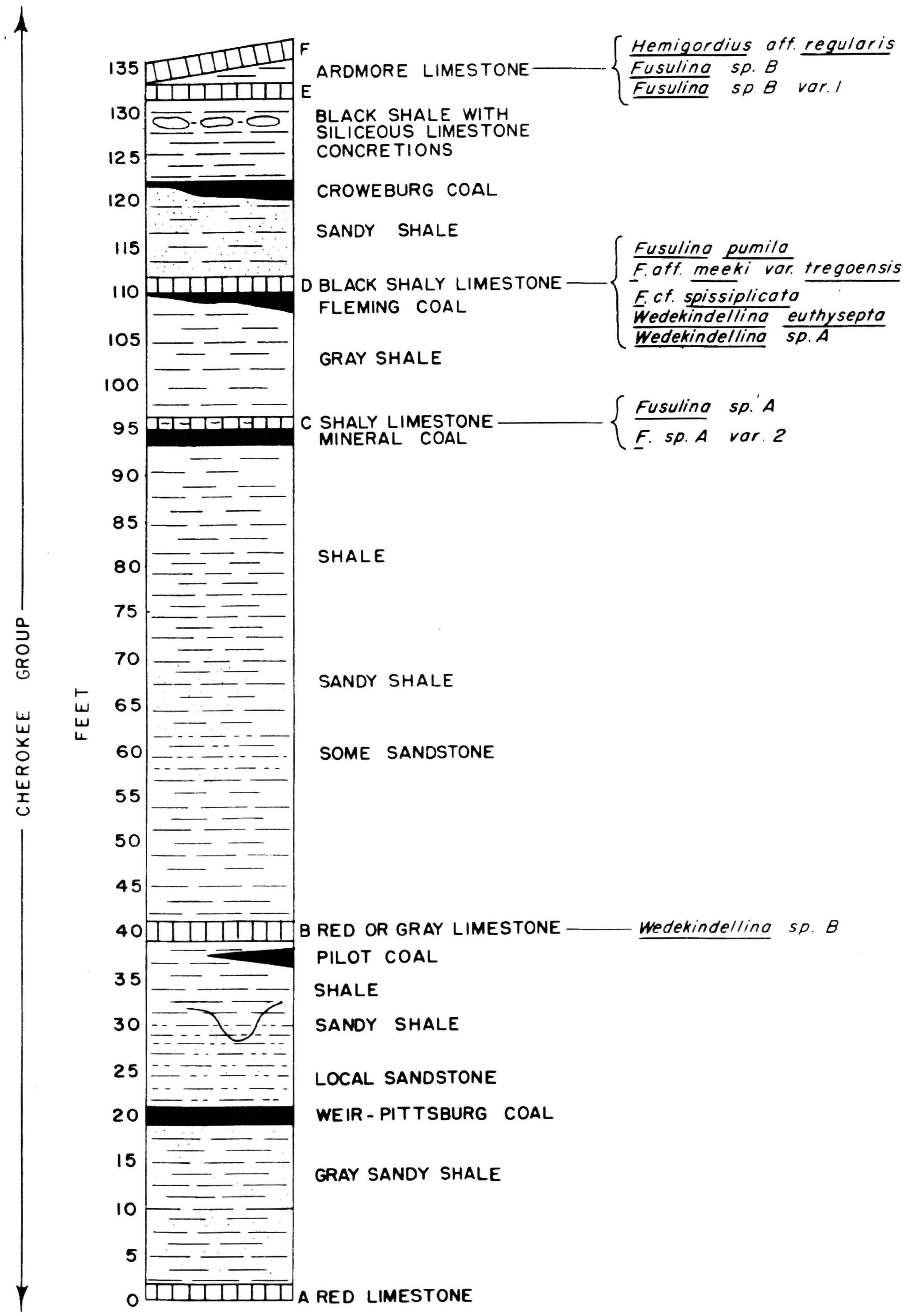


FIG. 2. GENERALIZED SECTION IN CHEROKEE GROUP, CRAWFORD CO. KANSAS (modified from Pierce and Courtier, 1938).

thickness and lithology is common, with resulting difficulty in definition and correlation of beds.

In southeastern Kansas and adjoining areas, the Cherokee belt is about 20 miles wide. Distribution further north is more irregular, and the width of outcrop is frequently greater. Variation in thickness is considerable, both locally and areally. A maximum thickness of several thousand feet is found in Oklahoma. In general, thicknesses decrease north of Oklahoma, with a maximum thickness of 700 feet in northwestern Missouri (Hinds and Greene, 1915).

Clastic rocks predominate, consisting chiefly of shales, sandy shales, and sandstones. Some limestones are also present. Both marine and non-marine units are recognized, and several geologists, including Moore (1936, 1949) and Abernathy (1937), postulate "cyclic" sedimentation in the Cherokee group. The nomenclature of the various units considered here is shown in figure 2.

DESCRIPTION OF SECTIONS

The low relief, varying less than 200 feet over large areas, and the low regional dips limit the extent of exposures, pits and cuts. Therefore, no complete stratigraphic section has been observed or measured at any single locality. A composite chart (figure 3) was prepared from sections observed in several counties. Published sources (Pierce and Courtier, 1938, pp. 19, 40;

Greene and Pond, 1926, Fig. 3) stratigraphically located these sections. Ranges in thickness and differences in lithology are stressed in the chart, as these factors are commonly variable. Usually a single section is given for several localities.

Section 1: A persistant bed of limestone, one to one and a half feet thick, underlies the Weir-Pittsburg coal (not noted by Greene and Pond, 1926). This bed is reddish-brown to reddish-violet, and contains a distinctive brachiopod and crinoid fauna. It has been traced over a portion of Barton County, where it occurs from one to twenty feet below the coal, and maintains its thickness and lithologic character throughout. Pierce and Courtier (1938, p. 119) report its presence in both Barton and Cherokee Counties. No fusulinids were found, although a number of outcrops were examined at several localities.

Section 2. The persistant Walker coal in Barton County is characterized by a cap bed of red or black clay-shale one foot thick. The beds are frequently non-marine and entirely unfossiliferous. A gray marine limestone is frequently present, either replacing the non-marine stratum, or occurring above it. Fusulinids are rare in the limestone, especially when numerous gastropods and pelecypods are present. Only one species,

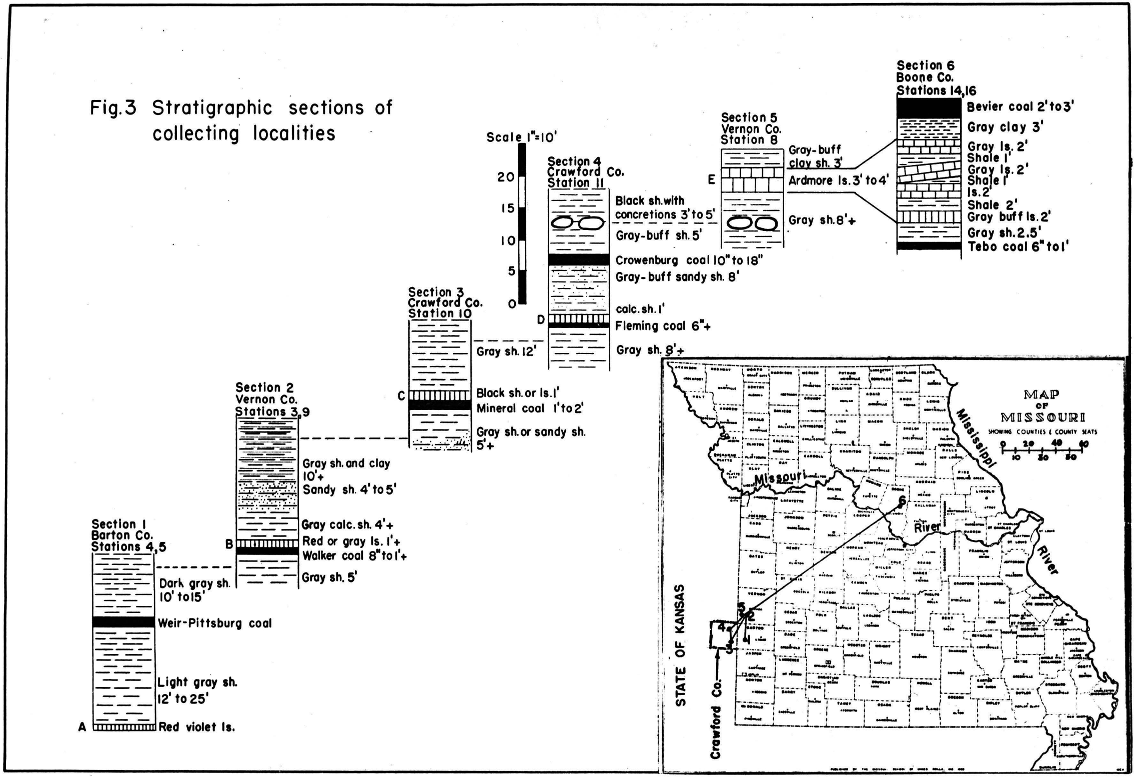


Fig. 3 Stratigraphic sections of collecting localities

Wedekindellina n. sp. B was found. Shales and clays underly the coal, and aid in stratigraphically placing the section.

Section 3. The Mineral coal (Kansas) and the Rich Hill coal (Missouri) have been correlated bacause of the similarity of the overlying black shaly marine limestones and the relationship between older and younger shales and coals (Pierce and Courtier, 1938, pp. 71-72). The diagnostic limestone, and thick underlying shales and sandy-shales, located this section in the stratigraphic column. Collections from the limestone in Missouri contained rare, poorly preserved fusulinids. The bed over the Mineral coal, however, has an abundant fauna, including Fusulina sp. A var. 1. A faunal comparison between the two states was not attempted, as the poor preservation prevented identification of the Missouri forms.

Section 4. The siliceous limestone concretions and the Croweburg coal, observed in both this section and in section 5, are highly diagnostic, and help to place the sections stratigraphically. The gray shaly limestone, immediately overlying the Fleming coal, contains a locally abundant fusulinid assemblage: Fusulina aff. meeki tregoensis, F. cf. spissiplicata, Wedekindellina euthysepta, Wedekindellina n. sp. A. The lithology changes laterally, in a short distance, to a gray shale with few marine fossils.

Section 5. The Ardmore limestone is areally extensive, resistant, and easily recognized. In Vernon county a widely used name is "Diamond Rock" because of the characteristic jointing. It consists of either: (a) a single three to four foot gray limestone bed, weathering to a buff color, or (b) two limestones with an interbedded shale, 12 feet thick. Abundant foraminifera, including Hemigordius cf. regularis, Fusulina n. sp. B and Fusulina n. sp. B, var. 1 are found in the limestone. The siliceous limestone concretions, below the Ardmore and above the Walker (Croweberg in Kansas), are diagnostic for identification and correlation.

Section 6. In Boone County, Missouri, the Ardmore consists of a three or four unit limestone, with interbedded clay-shales. Good exposures are found in stream banks and open cuts. Thickness of twelve feet is common. These shales contain a well preserved fusulinid fauna, apparently identical to that found in the limestone in Vernon County. Hemigordius cf. regularis, however, is limited to the limestone facies.

COLLECTING LOCALITIES

3. Vernon County, Missouri;1/5 mile south of Moundville, Missouri; on Missouri Highway 43, in roadcut 100 yards north of railroad crossing; western part of Section 4, T. 34 N, R. 2 W; massive gray limestone above Walker (Pilot) coal. Fusulinids rare.

4. Barton County, Missouri; 3 miles south of intersection of County Road K and Missouri Highway 43; SE 1/4; Sec. 18, T. 32 N, R. 32 W; limestone below Weir-Pittsburg coal; massive reddish-violet limestone, from 12 to 25 feet below coal in roadcut. No fusulinids found; abundant brachiopods and crinoid parts.

5. Barton County, Missouri;1 mile south of Liberal, Missouri; SW 1/4, SE 1/4, Sec. 12, T. 32 N, R. 33 W., elevation 995 feet; limestone below Weir-Pittsburg coal, massive, reddish-violet, less than 2 feet thick; top of limestone just below coal. No fusulinids found.

6. Barton County, Missouri; Near middle of last cut of Alston Coal Co.; 1 mile north of intersection of

U. S. Highway 160 and Missouri-Kansas state line; NE 1/4, SW 1/4, Sec. 31 T. 32 N, R. 33 W; limestone overlying Walker coal. Fusulinids rare; fauna mainly molluscan.

7. Vernon County, Missouri; Strip pit, 3/4 mile west of Bronaugh; NW 1/4, Sec. 19, T. 34 N, R. 33 W; black calcareous shale weathering to buff; above Rich Hill coal. Sparse fusulinid fauna.

8. Vernon County, Missouri; 5 miles east of Bronaugh; SW 1/4, SW 1/4 Sec. 18, T. 34 N, R. 32 W; massive 3 to 4 foot limestone, with two master vertical joints producing diamond shaped wedges. Abundant fusulinids.

9. Vernon County, Missouri; In strip pit, one mile west of Moundville; NE corner Sec. 6, T. 34 N, R. 32 W; buff to red limestone and calcareous shale overlying the Pilot coal; limestone one foot or less thick. Few fusulinids found.

10. Crawford County, Kansas; 0.4 mile east of Frontenac in strip pit; just off U. S. Highway 160; NE 1/4, NW 1/4, Sec. 4, T. 30 S, R. 25 E; black calcareous

shale above Mineral coal. Many fusulinids found.

11. Crawford County, Kansas; 3 mines north of Mulberry in strip pit; SE 1/4, NW 1/4, Sec. 24, T. 28S, R. 25 E; shaly limestone cap of Fleming coal, dark gray; highly fossiliferous. Abundant fusulinids.

14. Boone County, Missouri; In creek bed, 200 feet behind Gillespie School; SW 1/4, SE 1/4, NE 1/4, Sec. 27, T. 49 N, R. 12 W; shales between Ardmore limestone outcrops. Abundant fusulinids.

16. Boone County, Missouri; In creek bed, NE 1/4, Sec. 12, T. 49 N, R. 12 W; shales between Ardmore limestones. Abundant fusulinids.

18. Crawford County, Kansas; 2 1/2 miles west of Mulberry in strip pit; W half, NE 1/4, Sec. 3, T. 29 S, R. 25 E; limestone and shale directly above Mineral coal. No fusulinids present; large numbers of gastropods.

20. Same as 11, except that shalier portions were sampled. The fauna is similar to that of station 11.

22. Vernon County, Missouri;In strip pit, one mile south of Moundville; SW 1/4, NW 1/4, Sec. 5, T. 34 N, R.

32 W; red limestone and shales above Walker (Pilot) coal. Shales unfossiliferous and nonmarine. Limestone contained no fusulinids.

BIOSTRATIGRAPHY OF FUSULINES OF THE CHEROKEE GROUP

Several fusuline genera are important in zonation of Pennsylvanian rocks of the Mid-Continent region (Dunbar and Condra 1927; Roth and Skinner, 1930; Dunbar and Henbest, 1942; Thompson, 1945; Moore and Thompson, 1949; Moore, 1949). In addition, several sub-zones were established on the basis of the presence of diagnostic species (Dunbar and Henbest, 1942). Ranges and zones of four important genera are given below:

Series	Atokan	Desmoinesian	Missourian
Zone	*Fusulinella*	*Fusulina*	*Triticites*
	Fusulinella — —		
Range		*Fusulina*	
of		*Wedekindellina* — —	
Genera			*Triticites*

Table 1. Ranges and zones of some critical genera in the Mid-Continent region (modified from Moore and Thompson, 1949).

Fusulina is restricted to the Desmoinesian series. *Fusulinella* ranges from the Atokan series into the Desmoinesian, and overlaps the range of *Fusulina*.

Wedekindellina is approximately co-extensive with *Fusulina*, and was long believed to be limited to the Desmoinesian. Evidence of extension of range into the Missourian series, however, has been presented by Newell and Keroher (1937). This extended range has been accepted by Dunbar and Henbest (1942), but questioned by Moore and Thompson (1949).

In the Cherokee strata studied, only *Fusulina* and *Wedekindellina* are represented. The species of *Fusulina* lack characters diagnostic of the more advanced forms of this genus, such as intense septal folding, thinner epithecal deposits, and slighter chomata.

The species of *Wedekindellina* give no evidence regarding stratigraphic position within the range of the genus. Unfolded septa and heavy axial filling are unchanged throughout the Cherokee section. Even the slight folding at the poles, observed in the younger specimens, is also characteristic of the older forms.

The absence of both *Fusulinella* and highly evolved *Fusulina* suggests a position in the lower portion of the *Fusulina* zone defined by Moore and Thompson (1949). This agrees with the generally accepted stratigraphic level of the Cherokee group.

All of the species treated here are restricted to single limestone or shale intervals. This lack of a vertical range may have one or more possible explanations: very rapid evolution, presence of major or minor hiatuses, absence of record of marine deposition, and/or facies changes.

The Ardmore limestone contains one or more shale members. Fusulina n sp. B and Fusulina n sp. B Var. 1 are found in both limestone and shale facies at comparable levels at widespread localities. Hemigordius cf. regularis, however, is restricted to a limestone facies in both western and central Missouri. Apparently, this species is more narrowly restricted than the fusulinids found in this formation.

CORRELATION OF FUSULINID-BEARING STRATA

Some faunal evidence for extension of Mid-Continent correlation was found in one limestone interval. In addition, existing correlations are amplified and corroborated. Figure 4 lists a modification of the most recent data.

On the evidence of Wedekindellina euthysepta (Henbest), the limestone bed overlying the Pilot coal (Kansas), Henbest (1938) placed the bed somewhat lower than the Stonefort limestone of Illinois. However, Wedekindellina

n. sp. B was found above the Walker (Pilot) coal (Horizon B, figure 3) and has not been previously reported. Its use is consequently limited until additional occurances and range are listed.

The Mineral (Kansas) and the Rich Hill coals (Missouri) have been previously correlated (Pierce and Courtier, 1938). A microfauna different from that reported from the overlying limestone at Rich Hill, Missouri (Dunbar and Condra, 1927) was found, however, above the Mineral (Horizon C, figure 3). Further study will be required, therefore, before this correlation can be accepted without reservation.

Samples from the limestone cap of the Fleming coal (Horizon D, figure 3) contained a fairly large assemblage of fusulinids, although the member was previously reported to be unfossiliferous (Moore, 1949). Two of the species, Fusulina pumila Thompson and Wedekindellina euthysepta (Henbest), have been described from the Munterville limestone, 35 feet below the Whitebreast coal in Iowa (Thompson, 1934). Both species have also been found in the Seahorne limestone of western Illinois, and W. euthysepta has been reported from the Stonefort limestone of southern Illinois (Dunbar and Henbest, 1942, pp. 14, 15). It is believed that the Stonefort limestone and the Seahorne are similar in age, although the fusulinids differ in part (1942, p. 22). The cap limestone of the Fleming coal therefore is to be correlated approximately, with the Munterville and Seahorne limestones, and possibly with the Stonefort limestone.

The occurrence of *Hemigordius* cf. *regularis* Plummer, *Fusulina* n. sp. B, and *Fusulina* n. sp. B var. 1, in the Ardmore limestone in both western and central Missouri, corroborates previous correlations. However, the fauna of the Oak Grove limestone in Illinois is not comparable to that of the Ardmore, although correlation of the beds has been widely accepted.

FIG. 4. CORRELATION OF CHEROKEE GROUP IN NORTHERN MID-CONTINENTAL REGION (modified from Moore, 1948).

Interstate	N.E. Oklahoma	S.E. Kansas	Missouri	Southern Iowa	Illinois
Marmaton Group	Marmaton Group	Blackjack Creek ls.	Blackjack Creek ls.	Blackjack Creek ls.	Hanover ls.
CHEROKEE GROUP	Ft. Scott coal	Mulky coal	Mulky coal	Mulky coal	Coal No. 4
		Bevier coal	Bevier coal	Bevier coal	
	Verdigris ls.	Ardmore ls.	Ardmore ls.	Ardmore ls.	Oak Grove ls.
			Tebo coal	Whitebreast coal	Colchester coal No. 2
	Broken Arrow coal	Croweberg coal	Western Missouri: 1 ft.	Seahorne ls.	Seahorne ls.
		Fleming coal	2 ft.	Munterville ls.	Stonefort ls. (S. Ill.)
		Mineral coal	Rich Hill coal	Shale	?
		Pilot coal	Walker coal	Coal	
	Cherokee coal	Weir-Pittsburg coal	Weir-Pittsburg coal	Sandstone	
	Bluejacket ss.	Bluejacket ss.	Clear Creek ss.		?
	Little Cabin ss.	Columbus coal Little Cabin ss.			

TECHNIQUES EMPLOYED IN FUSULINE STUDY

Separation of fusulines: Most foraminifera have been described and figured on external characters, although some modern workers stress internal characters in all forms. Fusulines, however, because of homeomorphy in external characters, require accurately oriented thin sections for classification and identifications. Free specimens are therefore desirable, as they can be most easily prepared for study and identification.

Fusulines in argillaceous limestones can be freed through the use of one of the following methods:

a) In a clay matrix, preparation of fusulines requires only soaking and boiling, with the aid of a deflocculating agent such as tetra sodium pyrophosphate or washing soda, and a decanting of the clay particles.

b) When a smaller proportion of clay is present, the above method is generally ineffective. After soaking and boiling, the broken rock is placed in an iron mortar, covered with water, and crushed by direct blows. A grinding action of the pestle should be avoided. The chief disadvantage of this method is that many of the longer and more slender specimens may be broken. Nevertheless, the rock, when highly fossiliferous, will usually yield enough material to permit an adequate study.

c) In pure limestones, separation of isolated individuals is impossible if specimens are deeply imbedded. Random matrix sections are the only feasible means of study. These may be used satisfactorily if enough sections are made.

Sectioning: Specimens are first separated into tentative specific groups. The following technique has proved successful in sectioning, and has the advantage of using a minimum of mechanical equipment.

Canada balsam is slowly heated on a slide until most of the solvent has evaporated. When cooled, it is tough but not brittle. It has been most practical to prepare several slides at a time on the lowest heat of an electric hot plate. Preheated specimens are imbedded in the warm balsam, oriented and held in position while the balsam cools. Initial grinding is done on a frosted glass plate with a medium abrasive (200 grit silicon carbide), and completed on a second plate with fine powder (600 grit silicon carbide) when the desired plane is closely approached. Sometimes the surface is polished with "levigated alumina". The specimen is then reheated and turned, so that the ground surface is pressed in close, even contact with the slide, and grinding is completed on the second side.

The following precautions should be observed to procure the best results:

1) In mounting, the specimen should be dry to avoid the formation of an excess number of bubbles.

2) While still plastic, the balsam should be packed around the specimen with a heated needle to provide it with necessary support. This is especially true for sagittal sections and the ends of elongate forms.

3) Extreme care should be exercised to avoid contamination of the fine grinding plate by coarser abrasive, since one grain of the coarse powder can seriously mar a polished surface or rip out entire portions of a thin slice.

4) Bubbles beneath the section must be removed, as the bond between the specimen and the slide is destroyed by their presence.

5) The slide must be washed and dried when changing from the coarse to the fine grinding media, before turning the specimen and upon completion. This helps avoid contamination of the grinding plates, and prevents the warmed balsam from retaining any abrasive picked up during grinding.

<u>Covering and labelling</u>: The cover glass is mounted on the completed section with liquid Canada balsam (medium-thin

solution in xylene). The cover is pressed down with a rubber eraser, and excess balsam removed with a needle. The slide is then heated in an oven or drying cabinet for several days at a temperature of 40 to 45 degrees C. It is subsequently cleaned and the edges of the cover glass painted with spar varnish. The permanent label is then added. Temporary labels should be put on slides, before sectioning is begun, with a glass marking pencil.

Orientation: Oriented thin sections reveal structures upon which classification and identification of fusulines is based. Correct orientation permits direct comparison with standard measurements, descriptions, and figured sections. Erroneous measurements and descriptions result from the use of oblique sections.

Two sections passing through the center of the test and coinciding with the major axes, are needed to expose all essential characters. The axial section is cut from end to end, the sagittal through the equatorial plane. In addition, a tangential section, parallel to the major axis but reaching only to the base of the penultimate whorl, is often useful.

A correctly oriented axial section shows bilaterally symmetrical, elliptical or offset hemi-elliptical volutions and cuts the center of the proloculum. A continuous spiral indicates an oblique section.

The following technique has proved most useful, in cutting axial thin sections of poorly preserved specimens. In these sections, the exact location of the center of the proloculum is frequently difficult to ascertain. It is often helpful to cease grinding somewhat short of the proloculum, turn the specimen, and grind to the center of the proloculum on the other side, using transmitted light. This thin slice, although fragile, can be turned in the heated balsam with the aid of a wooden matchstick sharpened to a sliver-like point.

A detailed description of all phazes of orientation and sectioning is given by Dunbar and Henbest (1942, pp. 57-74).

Preparation of illustrations: Illustrations of fusuline foraminifera (Plates 1-4) were made with a photographic enlarger. The three by one inch thin section slides were placed upon a 35 mm. negative holder, and the image projected upon a high-contrast enlarging paper. Projecting distance varied from three to seven feet, depending upon the size of the microfossil. Exposure time ranged from 30 to 90 seconds, increasing geometrically with distance. Images of the opthalmidiid species were too small for successful use of this method, and therefore, were magnified by a petrographic microscope before exposure on the photographic paper. Projection distance of two feet enlarged the image sufficiently.

MORPHOLOGY OF THE FUSULINID SHELL

The fusulinid foraminifera are characterized by a calcareous-perforate test and a planispiral-involute plan of growth, of which the outstanding feature is generally an elongate axis of coiling. A fusiform or subelliptical axial profile results. Unlike many foraminifera, fusulinids have neither single nor multiple apertures. Microscopic pores in the antetheca (septal face) serve the function of the aperture, according to current views.

The centrally located proloculum is commonly spherical to subspherical, with a fairly large size range (about 20 to 300 microns). Successive spiral walls are secreted around the proloculum. In the family Fusulinidae, two types of wall can be distinguished; the fusulinine and the schwagerinine (Dunbar, in Cushman, 1948, p. 144). Only the fusulinine is duscussed here, as the fauna examined contained no schwagerinine forms.

The completely developed fusulinine wall is composed of four calcareous layers, differing in density and thickness. The two innermost, combining to form the protheca, consist of a thin, dark, outer layer, the tectum, and a thicker, less dense, inner layer, the diaphanotheca. The protheca is present in all volutions. The outer layers, the epitheca, coat the protheca above and below. The inner tectorium below adjoins the diaphanotheca and the outer tectorium (above) is adjacent to the tectum. Epithecal deposits are scant in the penultimate whorl, and entirely missing in the latter portion of the outermost whorl. On this evidence, many workers (White, 1932; Dunbar and Henbest, 1942; Thompson, 1948) consider the protheca a primary deposit and the epitheca a secondary deposit.

The area between successive spiral walls is divided into chambers by transverse partitions, the septa. These traverse the full length of the test and are formed consecutively by a flexure of the chamber wall toward the preceeding volution. The septa, like the spiral wall, show a four layered structure. The traces of the septa on the exterior are seen as fine depressions called septal furrows (sutures). The degree of septal folding is an important taxonomic and evolutionary character.

Septal pores are tiny scattered holes penetrating the septa. Because of epithecal filling, they are rarely seen except in the outermost septa. Mural pores, seen in transverse section, are fine tubules passing through the entire wall, and are sometimes visible in the outermost whorls of well preserved specimens.

The <u>tunnel</u> and the <u>chomata</u> are believed to be secondary structures, as evidenced by their absence or incomplete development in the outermost volutions of both mature and immature forms (White, 1932, p. 13) (Plate 1, fig. 7; Plate 4, fig. 7). In eroded specimens, the tunnel is visible externally as a shallow depression in the plane of the coiling, encircling the central portion of the equatorial plane. It is bordered laterally by two ridges, the chomata, formed by accumulations of epithecal material. The tunnel is formed by resorption of a portion of the septa in the equatorial area and appears as a passageway in axial section. It appears to have provided, at least partly, an opening for inter-communication between chambers.

MEASUREMENT OF FUSULINID CHARACTERS

Many fusulinid characters lend themselves to precise measurement. Methods of measurement, however, must be described so that the resulting numbers can be correctly analyzed. For example, measurements of the tunnel angle may vary several degrees, depending upon which portion of the chomata is used to define the tunnel. Therefore, measuring techniques are briefly outlined below.

<u>Axial Length</u>: Measurement has been made of a half length, from the center of the proloculum to the tectum

at the polar region of each volution, or of a full length, from the tectum of one pole to that of the other. Half lengths were usually measured when one end of a specimen was broken or showed obscure structure, or when an arcuate axis produced a pronounced foreshortening of one end. In all cases of half length measurement, the largest side was measured. For standardization, half lengths have been doubled in all tables.

Diameter: The diameter was measured at the widest part of the test in the equatorial plane. The tectum of successive volutions serves as the boundary of each measurement. Most frequently, half diameter (radius vector) measurements were made from the center of the proloculum, in axial section, to the tectum in the tunnel floor of successive volutions. Half diameters are used for speed and convenience, and are doubled in the tables given.

Wall Thickness: Thickness of the spiral wall was measured in the floor of the tunnel, following the practice recommended by Dunbar and Henbest (1942, p. 63), to standardize this measurement. The outer tectorium, which belongs to the succeeding volution, is thinnest here because of resorption of this portion of the wall in the development of a tunnel. Variation in these measurements, however, is still great. In a single tunnel floor, thickness of the outer tectorium may differ as much as five or more microns. It is also commonly thicker in the center of the tunnel. The other three wall layers are usually fairly constant in this area. Measurements were usually made in the central portion of the tunnel floor, and included all four wall elements.

Tunnel Angle: The revolving stage of a petrographic microscope was used to measure the tunnel angle. The center of the proloculum forms the apex of the angle to be measured; in each volution, a point approximately midway on the slope of the chomata bordering the tunnel completed the desired angle. All tunnel measurements given used the center of the proloculum as the apex, according to the procedure outlined by Dunbar and Henbest (1942, p. 63). (In cases of a rapidly expanding tunnel angle, it is possible that the apex of the angle may not be the center of the proloculum. The intersection of lines between successive chomata of the outermost volutions would form the apex of the expanded angle. For this method, the general trend of the tunnel must be followed, although the angle is measured at each volution.)

Septal Count: In sagittal section, the count is easily made by running a cross hairline between the center of the proloculum and the posterior side of the first chamber, and counting the number of septa to this line. Counts of incomplete outermost volutions are not listed.

Fig. 5 DISTRIBUTION OF MICROFOSSILS IN CHEROKEE GROUP

	Ardmore limestone				Shaly limestone Cap of Fleming coal Horizon D		Limestone Cap of Mineral coal Horizon C	Limestone Above Pilot coal Horizon B		
	Limestone Horizon F		Shale Horizon E							
	8	16	14	16	11	20	10	3	6	9
Fusulina n.sp. B	VA	VA	VA	VA						
Fusulina sp. B, var. I	A	A	A	A						
Hemigordius sp. cf. H regularis	VA	VA								
Fusulina sp. aff. F. meeki var. tregoensis					C	C				
F. pumila					VA	VA				
F. sp. cf. F. spissiplicata					A	A				
Wedekindellina euthysepta					F	F				
Wedekindellina n. sp. A					VR	R				
Fusulina n. sp. A							VA			
F. n. sp. A, Var. I							VA			
Wedekindellina, sp. B								VR	VR	R

VA = Very abundant = over 50

A = Abundant = 25 to 50

C = Common = 10 to 25

F = Few = 6 to 10

R = Rare = 2 to 5

VR = Very rare = 1

Order Foraminifera D'Orbigny, 1826

Family Fusulinidae Moller, 1878

Subfamily Fusulininae Rhumbler, 1895 (emend. Dunbar and Henbest, 1930)

Genus **WEDEKINDELLINA** Dunbar and Henbest, 1933

Boultonia (in part) Lee, 1927, Paleontologica Sinica, ser. B, vol. 4, fasc., 1, p.11.

Fusulinella (in part) Henbest, 1928, Jour. Paleontology, vol. 2, p. 80.

Wedekindella Dunbar and Henbest, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 357.

Wedekindia Dunbar and Henbest, 1931, Am. Jour. Sci., 5th ser., vol. 21, p. 458. Skinner, 1931, Jour. Paleontology, vol. 5, p. 259.

Wedekindellina Dunbar and Henbest, 1933, in Cushman, Foraminifera, etc., Cushman Lab. Foram. Research, Spec. Pub. 4, p. 134 (for full synonymy, see Thompson, 1948, Univ. Kansas, Paleont. Contrib., Protozoa, Art. I, p. 43).

Genotype: Fusulinella euthusepta Henbest, 1928, original designation.

WEDEKINDELLINA EUTHYSEPTA (Henbest)

Plate 1, figures 1-4

Fusulinella euthusepta Henbest, 1928, Jour. Paleontology, vol. 2, pp. 80-81, pl. 8, figs. 6-8, pl. 9, figs. 1-2.

Wedekindella euthysepta (Henbest). Dunbar and Henbest, 1930, Am. Jour. Sci., 5th ser., vol. 20, pp. 357-364.

Wedekindia euthysepta (Henbest). Dunbar and Henbest, 1931, Am. Jour. Sci., 5th ser., vol. 21, p. 458.

Wedekindellina euthysepta (Henbest). Dunbar and Henbest, 1933, in Cushman, Foraminifera, etc., Cushman Lab. Foram. Lab. Research, Spec. Pub. 4, p. 134, key plate 10, figs. 13-15.

Wedekindellina dunbari Thompson, 1934, Univ. Iowa Studies, vol. 16, pp. 285-287, pl. 20, figs. 3, 6, 15, 16, 21.

Description: Test elongate, lateral slopes fairly straight, ends bluntly pointed, septal furrows shallow, axis straight; antetheca lacks septal folding. Maximum length, 2 mm.; diameter, 0.55 mm.; maximum number volutions seven; form ratio at seventh volution, 4.2.

Proloculum spherical to subspherical, minute, 45-54 microns. Elongation proceeds fairly regularly;

form ratio 2 in early volutions, 4.2 in later volutions.

Spiral wall relatively thin; tectum a thin dark line, frequently visible through heavy epithecal deposits. Diaphanotheca thin, apparently structureless. Inner and outer tectoria approximately equal in thickness, equal to or exceeding diaphanotheca. Chomata asymmetrical, sharply curved toward tunnel, gently sloped toward poles, laterally fusing with septa. Septa not folded, except at poles, where weak folding appears. Heavy epithecal deposits fill axial region from near center to poles. No septal pores observed.

Septal counts average ten per whorl in first volution, increasing regularly to 23 in eighth whorl. Tunnel narrow, frequently erratic in course; angle fairly constant, increasing slightly in outer whorls; angles of inner whorls from 13 to 16 degrees, outer whorls 18 to 20 degrees.

Locality: Station 11, Crawford County, Kansas.

Range and distribution: Shaly limestone cap of Fleming coal, Cherokee group, Crawford county, Kansas.

Also reported from: thirty-five feet below Whitebreast coal, Cherokee group, Iowa (Thompson, 1934, p. 285); several limestone intervals, Cherokee group, southeastern Kansas (Henbest, 1938, pp. 41-42); Ardmore limestone, Cherokee group, central Missouri (Johnson, 1939);

TABLE 2. MEASUREMENTS IN MM. OF WEDEKINDELLINA EUTHYSEPTA (HENBEST)

Vol.	Length 1	Length 2	Length 3	Length 4	Length 5	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4	Form Ratio 5
0	0.045	.....	.....	0.054	.....	0.050	.....	.....	0.054	.....	...	...	...	...	...
1	0.20	.....	0.16	0.16	.....	0.08	0.08	0.08	0.10	0.08	2.5	...	2.0	1.6	...
2	0.32	0.32	0.36	0.28	0.36	0.15	0.14	0.12	0.14	.....	2.1	2.3	3.0	2.0	...
3	0.44	0.64	0.52	0.60	0.56	0.19	0.20	0.18	0.18	0.13	2.3	3.2	2.9	3.3	4.3
4	0.68	0.84	0.92	1.00	0.80	0.21	0.30	0.22	0.24	0.17	3.2	2.8	4.3	2.8	4.7
5	1.12	1.36	1.28	1.36	1.08	0.31	0.36	0.34	0.34	0.26	3.6	3.5	3.7	4.1	4.0
6	1.72	1.60	1.60	1.60	1.50	0.44	0.44	0.45	0.44	0.38	3.9	3.6	3.5	3.8	4.0
7	2.08	2.08	.....	.....	.....	0.50	0.54	0.59	0.54	.....	4.2	3.9	...	...	...
8	.....	.....	.....	.....	.....	0.64	0.65	.....	.....	.....	...	...	...	...	...

Vol.	Tunnel Angle in Degrees 1	2	3	4	5	Wall Thickness 1	2	3	4	5	Septal Count 6	7	8
1	...	...	...	...	...	.....	.....	.....	0.014	.....	11	10	10
2	16	...	13	16	...	0.007	.....	0.009	0.009	0.009	14	14	14
3	17	13	13	14	17	0.011	0.014	0.009	0.009	0.009	15	15	15
4	18	18	18	...	20	0.009	0.014	0.009	0.011	0.011	18	18	18
5	18	...	...	16	...	0.023	0.023	0.014	0.014	0.011	21	19	19
6	...	23	...	...	...	0.014	0.023	.....	0.009	.....	29?	20?	19
7	...	22	...	...	...	.....	0.032	.....	.....	.....	...	...	19

Seville and Stonefort limestones, Tradewater group and Oak Grove limestone, Carbondale group, Desmoinesian series, Illinois (Dunbar and Henbest, 1942, p. 29).

Comparisons: Wedekindellina euthysepta resembles W. henbesti (Skinner) (1931, p. 259) most closely; it differs chiefly in relative size and density of epithecal filling. W. euthysepta is consistantly smaller at similar stages in development, and its axial filling is pronouncedly denser.

Sectioned specimens fall within the size range of both W. uniformis Thompson (1934, p. 289) and W. elfina Thompson (1934, p. 287). W. euthysepta is appreciably more slender in later volutions than either of these. It also shows a heavier axial filling than W. elfina, especially in early whorls.

Remarks: Comparatively few individuals were found, and preservation is generally poor. The chamber filling consists of brown argillaceous material in addition to the usual crystalline calcite. Ten thin sections were ground.

Most sectioned specimens are small, attaining a maximum of seven volutions, whereas nine to ten whorls are reported by Dunbar and Henbest (1942, p. 99). Wall thickness and chomata also seem somewhat slighter than those described by Dunbar and Henbest.

WEDEKINDELLINA new species A

Plate 1, figures 8-10

Description: Test very elongate, lateral slopes straight to convex, ends moderately to sharply pointed, external furrows straight and shallow, axis arcuate. Specimens of maximum size 8 to 9 volutions; length, 3.9 mm.; diameter, 0.8 mm.; form ratio, 4.9 to 5.0.

Proloculum spherical to slightly subspherical, small (61 to 65 microns in diameter). Rapid elongation shown in ontogeny; form ratios 1.4 in first whorl to 4.4 in fourth; subsequent change gradual, form ratio 5.0 in outermost volution.

Protheca very thin, rarely exceeding nine microns; diaphanotheca clear, apparently structureless; tectum thin and dense, frequently visible through thick epithecal deposits. Both inner and outer tectoria generally thinner than protheca in equatorial region. Axial region almost completely filled with dense epithecal material.

Chomata weakly developed, forming low asymmetrical ridges approximately one-fifth to one-third height of chamber, fusing laterally with septa. Septa not folded, apparently not even at poles. No septal pores observed.

Septal number increases slowly and regularly from 10 in first volution to 23 in last. Tunnel narrow, slit-like, angle fairly constant, ranging from 18 to 21 degrees. Floor covered with thin epitheoal layer, frequently locally absent.

Locality: Station 11, Crawford County, Kansas.

Range and distribution: Known only from the cap rock of the Fleming coal, Crawford County, Kansas.

Comparisons: Wedekindellina n. sp. A closely resembles W. henbesti (Skinner) (1931, p. 259) in length at comparable volutions, axial filling and wall thickness. It differs, however, in several outstanding characters. In specimens of 10 to 11 whorls, the form ratio of W. henbesti is 4.0, while the new species reaches a ratio of about 5.0 in the seventh to eighth volutions. The tunnel angle and proloculum of the new species are smaller than those of W. henbesti.

W. euthysepta (Henbest)(1928, p. 80) is smaller at corresponding volutions, has a smaller proloculum and heavier axial filling, and is less elongate than the new species. W. ultimata Newell and Keroher (1937, p.700) has a larger proloculum and tunnel angle; length and diameter for corresponding volutions are greater; and the axial profile is blunter than in the new species. W. ellipsoides Dunbar and Henbest (1942, p. 101) is too thick and blunt to be confused with this species. All other described American species are smaller and more ventricose.

TABLE 3. MEASUREMENTS IN MM. OF WEDEKINDELLINA new species A

Vol.	Length 1	Length 2	Diameter 1	Diameter 2	Form Ratio 1	Form Ratio 2
0	0.061	0.065	0.061	0.061	...	...
1	0.14	0.18	0.10	0.10	1.4	1.8
2	0.36	0.37	0.15	0.16	2.4	2.3
3	0.68	0.74	0.20	0.20	3.2	3.7
4	0.92	1.24	0.27	0.28	3.4	4.4
5	1.66	1.68	0.35	0.38	4.8	4.4
6	2.32	2.36	0.48	0.52	4.8	4.5
7	3.04	3.32	0.61	0.67	5.0	5.0
8	3.94	.....	0.80	.....	4.9	...

Vol.	Tunnel Angle in Degrees 1	Tunnel Angle in Degrees 2	Wall Thickness 1	Wall Thickness 2	Septal Count 3
1	12	...	.....	0.007	10
2	...	20	0.009	0.009	13
3	18	20	0.009	0.009	15
4	21	19	0.011	0.014	18
5	20	20	0.011	0.009	18
6	...	18	0.012	.....	21
7	20	...	0.009	.....	23

Thompson (1934, p. 284) doubtfully refers some specimens to W. euthysepta, although they are remarkably more elongate and possess a wider tunnel than the holotype. The form ratio compares favorably with Wedekindellina n. sp. A., but the smaller proloculum and wider tunnel of Thompson's species serve to separate these forms.

Remarks: This species is based on three specimens found at station 11. It is rare; although the limestone was highly fossiliferous, a thorough search for additional specimens proved fruitless.

WEDEKINDELLINA new species B
Plate 1, figures 5-7

Description: Test small, elongate fusiform, lateral slopes straight to slightly convex, ends acutely pointed, axis straight. External furrows straight and shallow. Specimen of 9 whorls has length, 2.84 mm.; diameter, 0.98mm.; form ratio, 2.9.

Proloculum spherical, minute, diameter 56 microns. Elongation proceeds rapidly in ontogeny, near maximum proportions of 2.8 reached in fifth volution. Subsequent changes in form ratio slight.

Protheca very thin, not exceeding 9 microns; diaphanotheca clear, apparently structureless; tectum very thin and dark. Inner and outer tectoria thin in equatorial region, approximately equal in thickness to protheca. Axial region almost completely filled with epithecal material.

Chomata have fairly weak development, forming asymmetrical ridge bordering tunnel, and merging laterally with septa. Height approximately one-third that of chamber. Septa not folded except for weak folding at poles. No septal pores observed.

Septal number increases slowly from 10 in the first volution to 26 in the fifth; very little change in subsequent volutions. Tunnel narrow, slit-like, ranging from 16 to 20 degrees throughout, with no ontogenetic changes apparent. Floor covered with thin epithecal layer, frequently locally absent.

Locality: Stations 3 and 9, Vernon County, Missouri, and station 6, Barton County, Missouri.

Range and distribution: Known only from the limestone overlying the Walker (Pilot) coal, Vernon and Barton Counties, Missouri.

Comparison: *Wedekindellina* n. sp. B is similar to *W. uniformis* Thompson (1934, p. 289) but differs in the following important characters; the new species has a greater number of volutions, is larger at comparable volutions, and has a larger proloculum. *W. coloradoensis*

(Roth and Skinner) (1930, p. 341) is larger at comparable volutions and in gross size, has a wider tunnel angle, stronger chomata, and a thicker spiral wall than W. n.sp. B. _W. excentrica_ (Roth and Skinner) (1930, p. 340) is also larger at comparable volutions and in gross size and has thicker septa and stronger chomata, than the new species. This new species is found at the same stratigraphic level as _W. euthysepta_ (Henbest) (1928, p. 80), but differs from it in smaller size, more obese form, lower tunnel angle and slighter chomata.

Vol.	Length 1	Diameter 1	Form Ratio 1	Tunnel Angle (Degrees) 1	Wall Thickness 1	Septal Count 2
0	0.056	0.056	...	...	.....	...
1	0.10	0.08	1.3	...	0.009	10
2	0.24	0.12	2.0	16	0.009	14
3	0.42	0.16	2.6	16	0.014	17
4	0.64	0.24	2.7	20	0.014	22
5	0.96	0.34	2.8	16	.....	26
6	1.24	0.45	2.8	20	0.012	24
7	1.76	0.60	2.9	16	0.018	26
8	2.24	0.80	2.8	17	0.018	27
9	2.84	0.98	2.9	17	0.014	...

TABLE 4. MEASUREMENTS IN MM. OF WEDEKINDELLINA new species B

Remarks: This species is based upon three specimens, an axial, a sagittal, and a slightly oblique axial section which was not measured. Weathering of additional specimens prevented the preparation of measurable thin sections. However, sectioned specimens from stations 3 and 6 are believed conspecific with specimens described from station 9 because of similar size, form ratio, and character of septa.

Genus FUSULINA Fischer, 1829

Fusulina Fischer, 1829, Bull. Soc. Natrualistes Moscou, vol. 1, p. 330. (For complete synonymy, see Thompson, 1948. Univ. Kansas, Paleont. Contrib., Protozoa, Art. 1, p. 41)

Schellwienia Staff and Wedekind, 1910, Upsala Univ. Geol. Inst., Bull., vol. 45, Art. 4, pp. 24-25.

Girtyina (in part) of authors (not Girtyina Staff, 1909).

Beedeina Galloway, 1933, Manual of Foraminifera, p. 401. (Type species: Fusulinella girtyi Dunbar and Condra, 1927, Nebr. Geol. Survey, ser. 2, Bull. 2, pp. 76-78, original designation).

Genotype: Fusulina cylindrica Fischer 1829 (monotypy).

FUSULINA sp. aff. F. MEEKI var. TREGOENSIS Roth and Skinner

Plate 2, figures 1-3

?Fusulina meeki var. tregoensis Roth and Skinner, 1930, Jour. Paleontology, vol. 2, pp. 345-346, pl. 29, fig. 8.

Description: Test small, globular, poles bluntly pointed, lateral slopes convex to slightly concave, axis straight; antetheca slightly folded. Largest specimens of seven volutions; length, 2.2 mm., diameter, 1.3 mm. Form ratio, 1.7 in largest observed specimens.

Proloculum spherical to subspherical; diameter, 54 to 90 microns. Coils tight, growth regular, with little variation from whorl to whorl. Protheca thin, increasing in outer whorls, reaching maximum thickness of 14 microns; diaphanotheca appears cloudy, structureless; tectum a thin dark line. Inner tectorium weakly developed, generally thinner than protheca; outer tectorium heavy. Tectoria appear denser than diaphanotheca.

Chomata highly developed, forming typical asymmetrical ridges; length twice height, height two-thirds that of chamber. Epithecal deposits heavy, thickening septa, partly filling chambers in axial region. First volutions fusulinelloid, with fairly straight septa, folding restricted to end zones; outer volutions typical of Fusulina, with three to four folds laterally in seventh volution. No septal pores observed.

Chambers increase regularly from 10 in first volution to approximately 29 in seventh. Tunnel moderately narrow, angle remaining fairly constant throughout all volutions, ranging between 17 and 25 degrees. Inner walls of chomata straight, normal to long axis, giving slit-like appearance to tunnel. Floor covered with heavy epithecal deposits.

Locality: Station 11, Crawford County, Kansas.

Range and distribution: Shaly limestone cap of Fleming coal, Crawford County, Kànsas. F. meeki var. tregoensis is found at the horizon of "Cherokee age", in reddish-brown shale from 3850-3960 feet below the surface, in Trego County, Kansas (Roth and Skinner, 1930, p. 346).

Comparison: A strong similarity exists between this form and Roth and Skinner's variety. Both forms show well developed, persistant chomata, similar wall thickness, narrow tunnels of 19 to 23 degree angles, small prolocula and comparable septal counts. Some important differences, however, are apparent. Roth and Skinner describe "septa strongly folded throughout" and a form ratio of 1.47. Our specimens, on the contrary, exhibit fusulinelloid septal structure in the first few volutions with pronounced septal folding in the outer whorls only.

TABLE 5. MEASUREMENT IN MM. OF FUSULINA cf. F. MEEKI var. TREGOENSIS ROTH AND SKINNER

Vol.	Length 1	Length 2	Length 3	Length 4	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4
0	0.086	0.086	.....	0.059	0.090	0.086	.....	0.054	...	...	...	...
1	0.20	0.18	0.14	0.12	0.14	0.10	0.14	0.12	1.4	1.8	1.0	1.0
2	0.38	0.28	0.30	0.24	0.23	0.18	0.28	0.20	1.6	1.6	1.1	1.2
3	0.60	0.54	0.54	0.36	0.35	0.28	0.33	0.30	1.7	1.9	1.6	1.2
4	0.98	0.80	0.76	0.72	0.50	0.40	0.46	0.44	2.0	2.0	1.7	1.6
5	1.34	1.06	1.08	1.02	0.72	0.66	0.62	0.66	1.9	1.6	1.7	1.5
6	.....	1.70	1.60	1.42	0.98	0.94	0.91	0.90	...	1.8	1.8	1.6
7	.....	2.20	.....	1.96	.....	1.30	1.26?	1.18	...	1.7	...	1.7

Vol.	Tunnel Angle in Degrees 1	Tunnel Angle in Degrees 2	Tunnel Angle in Degrees 3	Tunnel Angle in Degrees 4	Wall Thickness 1	Wall Thickness 2	Wall Thickness 3	Wall Thickness 4	Septal Count 5	Septal Count 6	Septal Count 7	Septal Count 8
1	20	23	17	...	0.011	0.016	0.009	.....	9	13	...	10
2	18	24	17	18	0.011	0.014	0.016	0.009	14	18	14	15
3	19	21	15	19	0.011	0.016	0.018	0.009	15	21	17	17
4	24	18	20	25	0.014	0.032	0.016	0.020	18	26	21	21
5	22?	...	...	...	0.016	.....	0.018	0.027	31	27	24	22
6	...	21	25	19	0.018	0.032	0.027	0.027	34	...	27	27?
7	....	20	...	...	.....	.....	0.027	.....	...	...	29?	...

Form ratios reach a maximum of 2.0. No further comparisons with this species can be made, as the original description is very brief and only one polished axial section figured.

F. pumila Thompson (1934, p. 313) resembles this form in septal folding, tunnel angle, form ratio, and chomata. Chief differences are the smaller size and thicker epithecal deposits of the Kansas form. Dunbar and Henbest (1942, p. 108) suggested that *F. pumila* may be identical with *F. meeki* var. *tregoensis*. This view seems untenable. The difference in size and septal folding of the two species seem adequate for separation. The Kansas form appears to be intermediate between *F. meeki* var *tregoensis* and *F. pumila*.

F. euryteines Thompson (1934, p. 310) has a somewhat larger tunnel angle than *F.* aff. *meeki tregoensis*. It is also larger, more slender, and has a markedly higher septal count. *F. distenta* Roth and Skinner (1930, p. 346) is larger, in all stages, with more strongly folded septa.

Remarks: *F.* aff. *meeki tregoensis* is abundant at station 11, but poor preservation makes measurements past the seventh volution impossible. Fifteen thin sections were ground.

One specimen had a "juvenarium" of one and a half volutions nearly at right angles to the plane of coiling of the remainder of the test. The proloculum was only slightly smaller than average, so the specimen apparently was not microspheric.

FUSULINA PUMILA Thompson

Plate 2, Figures 7-9

Fusulina pumila Thompson, 1934, Iowa Univ. Studies, vol. 16, no. 4, p. 313, pl. 22, figs. 6, 8, 10, 11.

Description: Test small, bluntly fusiform, lateral slopes frequently convex above and concave below; axis straight. Length at 6 volutions, 2.12 mm., diameter of 1.04 mm. Form ratio of largest specimen, 2.0.

Proloculum spherical to subspherical, diameter 77 to 95 microns. Rate of growth regular with little change in relative proportions throughout ontogeny.

Protheca thin, increasing from approximately 8 in third volution to 12 microns in sixth volution. Diaphanotheca appears structureless and cloudy; tectum thinner and denser, tectoria somewhat thicker and darker. Inner and outer tectoria equal.

Chomata prominent, broadly rounded at top, assymmetrical, steepest slope toward tunnel, height three quarters that of chamber, considerably wider than tunnel, becoming nearly rectangular in outermost volutions. First few volutions have septal folding confined to ends of axes, where it is rather intense; in later volutions, lateral slopes contain more numerous and higher fluting. In seventh volution, approximately 4 folds on each half-volution attain one-half to three-quarters height of chamber.

Septa increase regularly from 11 in first to about 30 in fifth volution. Tunnel angle relatively constant, frequently varying one to two degrees in entire ontogeny, average range 18 to 23 degrees. Straight sides of chomata give tunnel a broad slit-like appearance.

Locality: Station 11, Crawford County, Kansas.

Range and distribution: Shaly limestone cap of Fleming coal, Crawford County, Kansas. F. pumila has been reported from Monroe County, Iowa, 35 feet below the Whitebreast coal (Thompson, 1934, p. 313); Seahorne limestone, Randolph County, Illinois (Dunbar and Henbest, 1942, p. 109).

Comparison: For a detailed comparison of F. pumila with F. meeki var. tregoensis, (1950 pp. 345-346) see that species. F. pumila differs from F. kayi Thompson (1934 p.303) in its more obese form, smaller size, bluntly pointed poles, and more massive chomata. It is similar to F. euryteines Thompson (1934 p. 310) but the latter

TABLE 6. MEASUREMENTS IN MM. OF FUSULINA PUMILA THOMPSON

	Length					Diameter					Form Ratio				
Vol.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	0.090	.....	.....	.....	0.077	0.095	.....	.....	.....	0.077	...	...	...	...	...
1	0.20	0.18	0.18	0.18	0.24	0.16	0.16	0.14	0.16	0.14	1.3	1.1	1.3	1.1	1.7
2	0.40	0.38	0.36	0.36	0.40	0.24	0.27	0.22	0.28	0.20	1.7	1.4	1.6	1.3	2.0
3	0.68	0.66	0.68	0.76	0.60	0.41	0.42	0.34	0.40	0.28	1.7	1.6	2.0	1.9	2.1
4	1.16	1.36	1.20	1.24	0.88	0.56	0.58	0.52	0.56	0.40	2.1	2.3	2.3	2.2	2.2
5	1.64	2.34	1.66	1.92	1.24	0.78	.....	0.76	0.80	0.50	2.1	...	2.2	2.4	2.5
6	2.40	.....	2.12	.....	1.76	1.06	.....	1.04	.....	0.72	2.3	...	2.0	...	2.4
7	.....	.....	.....	.....	.....	1.24	.....	.....	.....	1.00	...	...	...	...	...

	Tunnel Angle in Degrees					Wall Thickness					Septal Count			
Vol.	1	2	3	4	5	1	2	3	4	5	6	7	8	9
1	...	22	...	...	20	0.014	0.014	.....	0.012	.....	11	16	...	10
2	24	21	19	20	18	0.020	0.009	0.011	0.014	0.009	19	20	19	17
3	22	23	19	21	13	0.018	0.014	0.018	0.023	0.014	20	21	22	19
4	20	20	19	26	19	0.023	0.020	0.020	0.014	0.018	25	25	24	22?
5	20	29	19	25	16	0.023	0.014	0.020	0.032	0.018	30?	...	...	...
6	22	28	23	...	14	0.027	.....	.....	.....	0.014	...	...	...	...
7	22	...	...	...	...	.....	.....	.....	.....	0.018	...	...	...	...

can be distinguished by its larger size, ventricose form, less highly developed chomata, and more intense septal folding (especially at the poles).

Remarks: This species, like *F. meeki* var. *tregoensis*, shows an ontogeny which seems both to indicate and to corroborate a low stratigraphic position in the Cherokee group. The first few volutions are typically fusulinelloid, while the outer whorls display the more intense folding indicative of *Fusulina*.

In one specimen, the first one and a half volutions are coiled obliquely to the plane of the remainder of the test, producing an unsymmetrical "juvenarium". This is not diagnostic of a microspheric individual, for the proloculum varies only slightly from the norm.

FUSULINA sp. cf. F. SPISSIPLICATA Dunbar and Henbest

Plate 2, figures 4-6

?*Fusulina spissiplicata* Dunbar and Henbest, 1942, Ill. Geol. Survey, Bull. 67, pp. 105-107, pl. 7, figs., 1-12

Description: Test elongate, fusiform, poles fairly acute, axis straight, lateral slopes straight to gently convex. Septal furrows shallow, straight to sinuous. Specimens reach maximum of 7 volutions; length, 3.7 mm., diameter, 1.2 mm; form ratio, approximately 3.1.

Proloculum spherical to subspherical, diameter 72 to 103 microns. Length of test increases with growth; form ratio in first volution 1.7, gradually reaching 3.1 to 3.3 in seventh.

Protheca thin, increasing from 6 microns in early volutions to 12 microns in seventh volution. Diaphanotheca apparently structureless; tectoria thin, approximately equal in thickness to protheca. Chomata massive, asymmetrical, steepest slope toward tunnel; sometimes the slope drops abruptly to floor of tunnel, at others a distinct concavity is apparent; height one-half to three-quarters that of chamber; height twice width.

Septa not folded except at ends in first two or three volutions; folding moderately intense on lateral slopes in succeeding volutions, reaching one-half to two-thirds height of volution; highly intense in end zones throughout ontogeny.

Chambers increase from 11 in first volution to approximately 32 in sixth. Tunnel narrow, slit-like or ellipsoidal depending on characteristic chomata; floor with variable thickness of epitheca; tunnel angle increases from 18 degrees in first volution to 28 in sixth.

TABLE 7. MEASUREMENTS IN MM. OF FUSULINA sp. cf. F. SPISSIPLICATA DUNBAR AND HENBEST

	Length					Diameter					Form Ratio				
Vol.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	0.090	0.090	0.099	0.076	0.072	0.081	0.090	0.095	0.076	0.077	...	...	...	...	...
1	0.20	0.24	0.28	0.16	0.20	0.19	0.16	0.16	0.16	0.11	1.0	1.5	1.7	1.0	1.8
2	0.36	0.52	0.48	0.30	0.40	0.29	0.24	0.26	0.28	0.17	1.2	2.2	1.8	1.1	2.3
3	0.88	0.88	0.76	0.64	0.62	0.42	0.36	0.32	0.38	0.26	2.1	2.4	2.4	1.7	2.4
4	1.64	1.26	1.28	1.04	1.00	0.58	0.48	0.50	0.52	0.34	2.8	2.6	2.6	2.0	3.0
5	2.28	1.96	2.00	2.16	1.54	0.84	0.68	0.68	0.72	0.46	2.7	2.9	2.9	3.0	3.4
6	3.40	2.96	2.72	2.66	2.28	1.18	0.88	0.90	0.92	0.68	2.9	3.3	3.0	2.9	3.4
7	.....	.....	3.68	.....	.....	.....	1.20	.....	.....	0.88	...	...	...	...	...

	Tunnel Angle in Degrees					Wall Thickness					Septal Count		
Vol.	1	2	3	4	5	1	2	3	4	5	6	7	8
1	22	17	18	25	...	0.011	0.009	0.009	.....	.....	13	11	13
2	21	16	18	25	27	0.011	0.011	0.016	0.011	0.011	17	18	17
3	23	21	23	24	21	0.018	0.009	0.018	0.014	0.018	20	21	21
4	20	24	20	24	20	0.027	0.014	0.020	0.023	0.016	25	23	25
5	29	25	26	26	29	0.025	0.018	0.016	0.023	0.023	27	24	26
6	28	26	...	...	...	0.032	0.018	.....	0.023	0.023	32?	29?	28?

Locality: Station 11, Crawford County, Kansas.

Range and distribution: Shaly limestone cap of the Fleming coal, Crawford County, Kansas; *F. spissiplicata* is common in the Oak Grove limestone, Madison County, Illinois (Dunbar and Henbest, 1942, p. 105).

Comparison: *F. spissiplicata* resembles this form closely in its fusulinelloid stage, tunnel angle, form ratio, character and thickness of wall, size, and external appearance. Differences are minor: septa appear more intensely folded in the outer volutions of *F. spissiplicata* than in the Kansas specimens, and chomata show an ontogenetic change which is not present here.

F. kayi Thompson (1934, p. 303) is described as having septa "very highly fluted throughout the length of the shell" (Thompson, 1934, p. 303).

F. cf. *spissiplicata* lacks such fluting in the first several volutions, is slightly more elongate, and contains more massive chomata. Similarities include size of proloculum, nature of tunnel and tunnel angle, gross size, and wall thickness.

Both *F. pumila* Thompson (1934, p. 313) and *F. meeki* var. *tregoensis*, Roth and Skinner, (1930, pp. 345-6) resemble *F.* cf. *spissiplicata* in ontogeny, although they are distinguished by form ratio, nature of chomata, and difference in size.

Remarks: Verification of this tentative identification would extend the range of *F. spissiplicata* to a lower limestone. Ontogenetic features seem to indicate a stage of development parallel to other species of *Fusulina* found in this horizon.

Preservation was fairly good, and the species was quite abundant. Fifteen thin sections were made. One specimen with a large proloculum has a "juvenarium" of one volution coiled obliquely to the plane of coiling.

FUSULINA new species A

Plate 3, figures 1-5

Description: Test small, fusiform, broadly and evenly arched, poles bluntly pointed, lateral slopes straight to slightly convex, axis straight, antetheca folded at poles. External furrows shallow, straight to sinuous, twisted at poles. Length (specimens of 7 volutions), 3.6 to 4.0 mm., diameters, 1.6 to 1.9 mm., form ratio, 2.0 to 2.3.

Proloculum subspherical, small (diameter from 59 to 86 microns). Growth regular; form ratio changes slowly from approximately 1.1 in first volution to about 2.1 in fifth, remaining constant in subsequent whorls. Protheca thin, (maximum thickness 9 to 10 microns in sixth volution); tectoria dense, darker than diaphanotheca; tectum a thin dark layer. Inner tectorium fairly thin, equal to or slightly thinner than diaphanotheca; outer tectorium two to three times thickness of inner. Fairly coarse mural pores penetrate all wall layers.

Chomata massive, symmetrical to asymmetrical, width somewhat greater than height; height one-half to three-quarters that of volution. Septal folding intense, at end zones in early volutions, extending to equatorial region in third or fourth volution. Folding in septa reaches three-quarters to full height of chamber; folds do not meet in central region.

Septa increase regularly from about 10 in the first whorl to approximately 33 in seventh volution. Tunnel moderately broad, slit-like, frequently expanding rapidly in last volution. Tunnel angle increases from average of 17 degrees in early volutions to about 29 in sixth whorl. Floor of tunnel covered with varying thicknesses of epithecal deposits, increasing toward outer volutions.

Locality: Station 10, Crawford County, Kansas.

Range and distribution: Known only from the shaly limestone above the Mineral coal.

Comparison: This species is very similar to *F. kayi* Thompson, (1934, p. 303), but certain consistent differences

TABLE 8. MEASUREMENTS IN MM. OF FUSULINA new species A

Vol.	Length 1	Length 2	Length 3	Length 4	Length 5	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4	Form Ratio 5
0	.....	0.081	0.072	0.070	0.086	.....	0.072	0.065	0.063	0.076	.....	.....	.....	.....	....
1	0.18	0.12	0.12	0.16	0.14	0.13	0.12	0.12	0.12	0.13	1.4	1.0	1.0	1.3	1.1
2	0.36	0.28	0.24	0.26	0.26	0.22	0.24	0.20	0.20	0.20	1.6	1.2	1.2	1.2	1.3
3	0.56	0.48	0.46	0.56	0.44	0.34	0.36	0.30	0.32	0.32	1.6	1.3	1.5	1.7	1.4
4	1.12	0.88	0.88	1.00	0.76	0.50	0.56	0.44	0.57	0.46	2.2	1.6	2.0	1.8	1.7
5	2.04	1.60	1.45	1.85	1.24	0.80	0.86	0.68	0.92	0.72	2.6	1.9	2.1	2.0	1.7
6	2.84	2.16	2.44	2.56	2.24	1.16	1.24	1.00	1.28	1.04	2.4	1.7	2.4	2.0	2.2
7	3.95	3.56?	3.16?	.....	3.08	1.60	1.80	1.52	.....	1.38?	2.3	2.0	2.1	.....	2.2

Vol.	Tunnel Angle in Degrees 1	Tunnel Angle 2	Tunnel Angle 3	Tunnel Angle 4	Tunnel Angle 5	Wall Thickness 1	Wall Thickness 2	Wall Thickness 3	Wall Thickness 4	Wall Thickness 5	Septal Count 6	Septal Count 7	Septal Count 8
1	...	...	...	28	...	0.014	.....	0.009	0.014	.....	12	9	9
2	30	...	24	28	16	0.014	.....	0.014	0.023	0.014	14	13	14
3	28	21	24	24	19	0.023	0.023	0.018	0.041	0.014	17	17	16
4	30	23	25	19	21	0.023	0.023	0.014	0.050	0.018	21	19	15
5	28	25	26	23	29	0.027	0.045	0.032	0.041	0.032	21	26	19
6	33	29	26	...	...	0.045	0.045	0.052	0.032	0.032	31	28	24?
7	...	...	...	...	...	.....	.....	.....	.....	.....	...	33?	...

seem to indicate that it is new. Fusulina kayi has a form ratio of 2.8, in the outermost whorl, and is described as having a uniform rate of increase. Fusulina new species A, on the contrary, reaches a maximum form ratio of 2.1 to 2.3 fairly early in the ontogeny, and maintains it with little variation to the outermost whorls, sometimes even showing a slight increase in thickness in the last volution. The proloculum of the new species is smaller, tunnel angle is larger, (especially in the outermost volutions), and the spiral wall of the later whorls is twice the thickness of that of F. kayi. In addition, the septal number of F. kayi is appreciably higher.

F. euryteines Thompson (1934, p. 310) is larger, has a higher septal count, and a larger proloculum than Fusulina new species A. F. rockymontana, Roth and Skinner (1930, p. 344) is larger, has a considerably larger proloculum than in the new species, and the septal number is higher.

Remarks: This species is abundant at station 10. Preservation was good; fifteen thin sections were ground.

FUSULINA new species A new variety

Plate 3, figures 6-10

This variety differs from Fusulina new species A mainly in its elongate axial profile. Fusulina new species

A attains a maximum form ratio of 2.1 to 2.3 in largest specimens, whereas the new variety reaches a ratio of 2.9 to 3.3. Elongation is fairly rapid and, in half the specimens sectioned, relative adult proportions are reached in the fifth volution. Differentiation on other characters is difficult, since they are all similar to those of *Fusulina* n. sp. A.

Locality: Station 10, Crawford County, Kansas.

Range and distribution: Known only from the shaly limestone above the Mineral coal, Crawford County, Kansas.

Comparison: The form ratio of *Fusulina kayi* Thompson (1934, p. 303) is similar to that of this variety, but the uniform rate of increase separates it. In the third volution, *F. kayi* has an average form ratio of 1.9, and the new variety one of 2.1. However, in the fifth volution, where *F. kayi* has a form ratio of 2.4, the new variety averages 2.9. In addition, the proloculum of the new variety is smaller, the tunnel is wider (especially in the outermost volutions) and the septal number appreciably lower than in *Fusulina kayi*.

Remarks: Separation of this variety *Fusulina* n. sp. A on external features is difficult, as the poles are frequently worn, producing a thickened appearance. The new variety is abundant at station 10. Eight sections were made.

TABLE 9. MEASUREMENTS IN MM. OF FUSULINA new species A, new variety

Vol.	Length 1	Length 2	Length 3	Length 4	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4
0	0.081	0.072	0.081	0.070	0.081	0.068	0.081	0.068	...	...	...	...
1	0.16	0.16	0.14	0.13	0.16	0.15	0.12	0.12	1.0	1.1	1.1	1.1
2	0.44	0.32	0.44	0.34	0.28	0.24	0.22	0.18	1.6	1.3	2.0	1.9
3	1.04	0.74	0.76	0.56	0.50	0.36	0.34	0.28	2.1	2.1	2.2	2.0
4	1.88	1.50	1.24	1.08	0.80	0.56	0.47	0.43	2.4	2.7	2.6	2.5
5	2.96	2.40	2.24	1.76	1.20	0.84	0.70	0.62	2.5	2.9	3.0	2.8
6	.....	3.64	3.04	2.68	1.48?	1.14	0.92	0.94	...	3.2	3.3	2.9
7	.....	.....	3.80	......	.....	.....	1.33	1.38	...	...	2.9	...

Vol.	Tunnel Angle in Degrees 1	Tunnel Angle in Degrees 2	Tunnel Angle in Degrees 3	Tunnel Angle in Degrees 4	Wall Thickness 1	Wall Thickness 2	Wall Thickness 3	Wall Thickness 4	Septal Count 5	Septal Count 6	Septal Count 7
1	21	18	19	...	0.014	0.014	0.009	0.009	12	9	10
2	19	20	22	25	0.027	0.018	0.014	0.015	13	14	16
3	25	26	24	36	0.036	.....	0.014	0.014	17	16	16
4	28	32	26	32	0.045	0.041	0.018	0.018	19	21	19
5	...	30	36	30	0.027	0.054	0.018	0.018	20	21	21
6	...	...	29	34	.....	.....	0.041	0.045	25	22	22
7	...	...	...	...	.....	.....	0.041	.....	...	26?	31

FUSULINA new species B

Plate 4, figures 1-5

Description: Test moderately large, elongate fusiform, poles acutely pointed, axis straight to slightly arcuate, lateral slopes straight to somewhat convex. Septal furrows sinuous across equatorial zone, twisted at poles. Specimens of 7 to 8 volutions; length, 6.8 to 7.1 mm.; diameter, 2.3 to 2.5 mm.; form ratio, 2.7 to 3.2.

Proloculum small, spherical to subspherical, diameter, 68 to 104 microns; elongation proceeds regularly throughout ontogeny. Spiral wall moderately thick, protheca thinner than either of the tectoria; inner tectorium generally exceeds outer in thickness, tectum not easily distinguished. Epithecal deposits thin but extensive. No septal or mural pores observed.

Chomata fairly massive, symmetrical to asymmetrical, high, (frequently reaching three-quarters to seven-eights of volution) width less than height. Septal folding intense throughout, reaching three-quarters to full height of volution in equatorial region. Septa fused in outer volutions.

Number of chambers per volution increase slowly and regularly from about 10 in the first whorl to 33 in the seventh. Tunnel high and slit-like, angle ranging from

TABLE 10. MEASUREMENTS IN MM. OF FUSULINA new species B

Vol.	Length 1	Length 2	Length 3	Length 4	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4
0	0.095	0.104	0.081	0.076	0.095	0.095	0.076	0.068	...	...	...	...
1	0.30	0.28	0.36	0.26	0.20	0.18	0.24	0.16	1.5	1.6	1.5	1.6
2	0.64	0.64	0.88	0.56	0.32	0.32	0.38	0.28	2.0	2.0	2.3	2.0
3	1.12	1.08	1.44	1.20	0.58	0.56	0.56	0.44	1.9	1.9	2.6	2.7
4	1.92	2.08	2.04	2.00	0.93	0.92	0.84	0.66	2.1	2.3	2.4	3.0
5	3.36	3.64	3.60	2.76	1.36	1.38	1.16	1.00	2.5	2.6	3.1	2.8
6	5.40	4.84	4.64	4.40	1.80	1.80	1.60	1.34	3.0	2.7	2.9	3.3
7	7.12	6.00	6.48	.....	2.32	2.12	2.08	1.74	3.0	2.8	3.2	...
8	.....	6.80	.....	.....	.....	2.56	.....	.....	...	2.7	...	...

Vol.	Tunnel Angle in Degrees 1	2	3	4	Wall Thickness 1	2	3	4	Septal Count 5	6	7	8
1	15	20	22	...	0.014	0.018	.....	.....	11	11	9	8
2	15	21	29	25	0.018	0.018	0.011	.....	12	13	14	13
3	17	21	29	23	0.027	0.032	0.014	.....	16	14	14	16
4	21	28	32	21	0.036	0.045	0.014	.....	18	21	17	19
5	...	22	25	31	.....	0.045	0.036	0.045	24	28	22	23
6	17	...	...	30	.....	0.036	0.032	0.045	27	32?	31	27?
7	...	...	...	30	.....	0.041	0.027	0.032	33?	...	...	...

15 to 32 degrees. Floor covered by thin epithecal deposit.

Locality: Station 8, Vernon County, Missouri; stations 14 and 16, Boone County, Missouri.

Range and distribution: Known only from the Ardmore limestone, western and central Missouri.

Comparisons: *Fusulina hayworthi* (Beede) (Dunbar and Henbest, 1942, p. 119) resembles *Fusulina* n. sp. B in length, and character and angle of tunnel. However, the proloculum of *F. hayworthi* is considerably larger, the form thicker, the septal folding more intense, and the chomata slighter than *Fusulina* n. sp. B.

It seems unlikely that the new species would be confused with other described fusulinids from the middle Pennsylvanian. The small proloculum and large size are highly diagnostic of the species.

Remarks: *Fusulina* new species B seems to have some affinity with *F. hayworthi*, which is found stratigraphically higher in Illinois and Kansas (1942, p. 121). It is possibly an earlier from of the higher species.

The forms found in western Missouri were abundant in the "Diamond Rock", but preservation was very poor, and only two good axial sections were made. Large numbers of specimens were obtained from the shale and clay between the second and third limestones of the Ardmore in Boone County, Missouri; six thin sections were ground. The external preservation was excellent, although internally, many specimens were partly filled with argillaceous material.

FUSULINA new species B new variety

Plate 4, figures 6-8

This variety differs from Fusulina new species B in several characters: shorter length, more ventricose form, and in pattern of growth. Specimens of 7 to 8 volutions reach a length of 5.0 to 6.5 mm.; diameter of 1.9 to 2.6 mm.; form ratio, 2.4 to 2.6, average 2.5. Fusulina new species B, on the contrary, reaches a length of 6.8 to 7.1 mm. at comparable volutions, and a form ratio of 2.7 to 3.3, with an average of 3.0. Relative adult proportions of the new variety are found in the fourth or fifth volutions, subsequent volutions remaining constant, or becoming slightly more obese in form. Fusulina new species B generally does not show this rapid elongation.

Locality: Stations 14 and 16, Boone County, Missouri.

Range and distribution: Known only from the Ardmore limestone, Boone County, Missouri.

Comparison: Fusulina hayworthi (Beede) (Dunbar and Henbest, 1942, p. 119) has a comparable length, form ratio, and tunnel. It differs in having a much larger prolo-

TABLE 11. MEASUREMENTS IN MM. OF FUSULINA new species B, new variety

Vol.	Length 1	Length 2	Length 3	Length 4	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Form Ratio 1	Form Ratio 2	Form Ratio 3	Form Ratio 4
0	0.081	0.090	0.086	.....	0.081	0.090	0.081	.....	...	...	...	...
1	0.36	0.40	0.28	0.32	0.20	0.24	0.16	0.16	1.8	1.7	1.7	2.0
2	0.76	0.80	0.52	0.68	0.41	0.40	0.34	0.32	1.9	2.0	1.5	2.1
3	1.48	1.24	1.20	1.16	0.62	0.60	0.54	0.52	2.4	2.1	2.2	2.2
4	2.08	1.84	1.88	1.88	0.86	0.88	0.76	0.72	2.4	2.1	2.5	2.6
5	3.24	3.12	3.04	2.92	1.12	1.24	1.16	1.14	2.9	2.5	2.6	2.6
6	4.48	4.40	4.04	3.80	1.80	1.72	1.54	1.62	2.5	2.6	2.6	2.4
7	5.60	5.08	5.04	5.00	2.20	2.20	1.92	2.10	2.6	2.5	2.6	2.4
8	.....	6.48	.....	.....	.....	2.60	.....	.....	...	2.5	...	...

Vol.	Tunnel Angle in Degrees 1	Tunnel Angle in Degrees 2	Tunnel Angle in Degrees 3	Tunnel Angle in Degrees 4	Wall Thickness 1	Wall Thickness 2	Wall Thickness 3	Wall Thickness 4	Septal Count 5	Septal Count 6	Septal Count 7
1	...	16	25	...	0.018	0.018	.....	.....	10	14	10
2	24	16	25	...	0.023	0.027	.....	.....	14	16	13
3	24	21	32	24	0.018	0.018	0.032	0.032	18	15	16
4	31	21	27	22	0.023	0.027	0.041	0.023	18	18	15
5	31	21	...	29	0.023	0.032	0.032	0.018	23	30	23
6	23	20	16	20	.....	0.041	0.036	0.032	31	31?	29
7	...	...	...	...	.....	0.032	0.027	0.036	33?	...	29?

culum, more intense septal folding, and slighter chomata than the new variety.

Remarks: This variety was found at stations in Missouri, in lesser numbers than *Fusulina* new species B. Preservation was comparable to that of *Fusulina* n. sp. Ten thin sections were made.

It is possible that the new variety may fall within the range of specific variation of *Fusulina* new species B, but it is believed that the characters listed above serve to separate one from the other.

Family Opthalmidiidae
Subfamily Cornuspirinae

Genus HEMIGORDIUS Schubert, 1908

Cornuspira Howchin, 1895, Roy. Soc. South Australia, Trans. Proc., vol. 19, p. 195, (not Schultze, 1854).

Hemigordius Schubert, 1908, Jahrb. k. k. Geol. Reichs., vol. 58, p. 381.

Genotype: *Cornuspira schlumbergeri* Howchin, 1895, original designation.

HEMIGORDIUS sp. cf. H. REGULARIS Plummer

Plate 4, figures 9-10

?*Hemigordius regularis* Plummer, 1930, Texas Univ., Bull., No. 3019, p. 20, fig. 1.

Description: Test calcareous-imperforate, discoidal, composed of a non-septate evolute tube, coiled in varying planes in early stages, planispiral in later whorls, attaining about four planispiral volutions; greater diameter range, 0.21 mm. to 0.46 mm.; mode, 0.26 to 0.36 mm.; thickness range, 0.7 to 0.12 mm.; aperture formed of open end of tube; periphery rounded; evolute character not easily seen externally, the exterior being obscured by a secondary calcareous deposit. Some dimensions are shown in the following table.

TABLE 12. MEASUREMENTS IN MM. OF HEMIGORDIUS cf. REGULARIS PLUMMER

Specimen No.	Greater Diameter	Thickness
1	0.21	....
2	0.22	0.7
3	0.24	....
4	0.26	....
5	0.32	0.11
6	0.34	....
7	0.34	0.11
8	0.42	....
9	0.46	0.12

Locality: Station 8, Vernon County, and station 16, Boone County, Missouri.

Distribution: Ardmore limestone, Desmoinesian series, Missouri; Hemigordius regularis was described from the "Grayford" formation, Brownwood shale, Pennsylvanian, Wise County, Texas (Plummer, 1930, p. 20).

Comparison: Hemigordius regularis Plummer reaches a diameter of 0.30 mm., which is within the modal range of H. cf. regularis. The figured specimen is evolute (Plummer, 1930, Pl. 1, fig. 1). The Missouri form has a similar plan of growth, comparable aperture, and reaches a somewhat larger size. However, a secondary calcareous deposit covers or obscures the exterior.

Remarks: Free specimens were unavailable for study, although some entire tests were seen imbedded in matrix. The above description is based on nine thin sections, five median and four vertical. The species is very abundant in the Ardmore limestone of western Missouri and central Missouri. H. cf. regularis seems restricted to the limestone facies of the Ardmore limestone. Bailey (1935, p. 489) does not list the species in a listing of foraminifera from the shale and clay beds of central Missouri, and it was also not found in the shale facies of the Ardmore.

Explanation of Plate 1

Figs. 1-4: Wedekindellina euthysepta (Henbest). Shaly limestone cap of Fleming coal, station 11 (Crawford County, Kansas). (Page 41.)

1. Tangential section, length 2.20 mm. 2. Axial section, length 1.60 mm. 3. Axial section, length 2.08 mm. 4. Sagittal section, greater diameter 0.72 mm. (Figures 2-4 are numbered in Table 2 as specimens 3, 2, and 8, respectively).

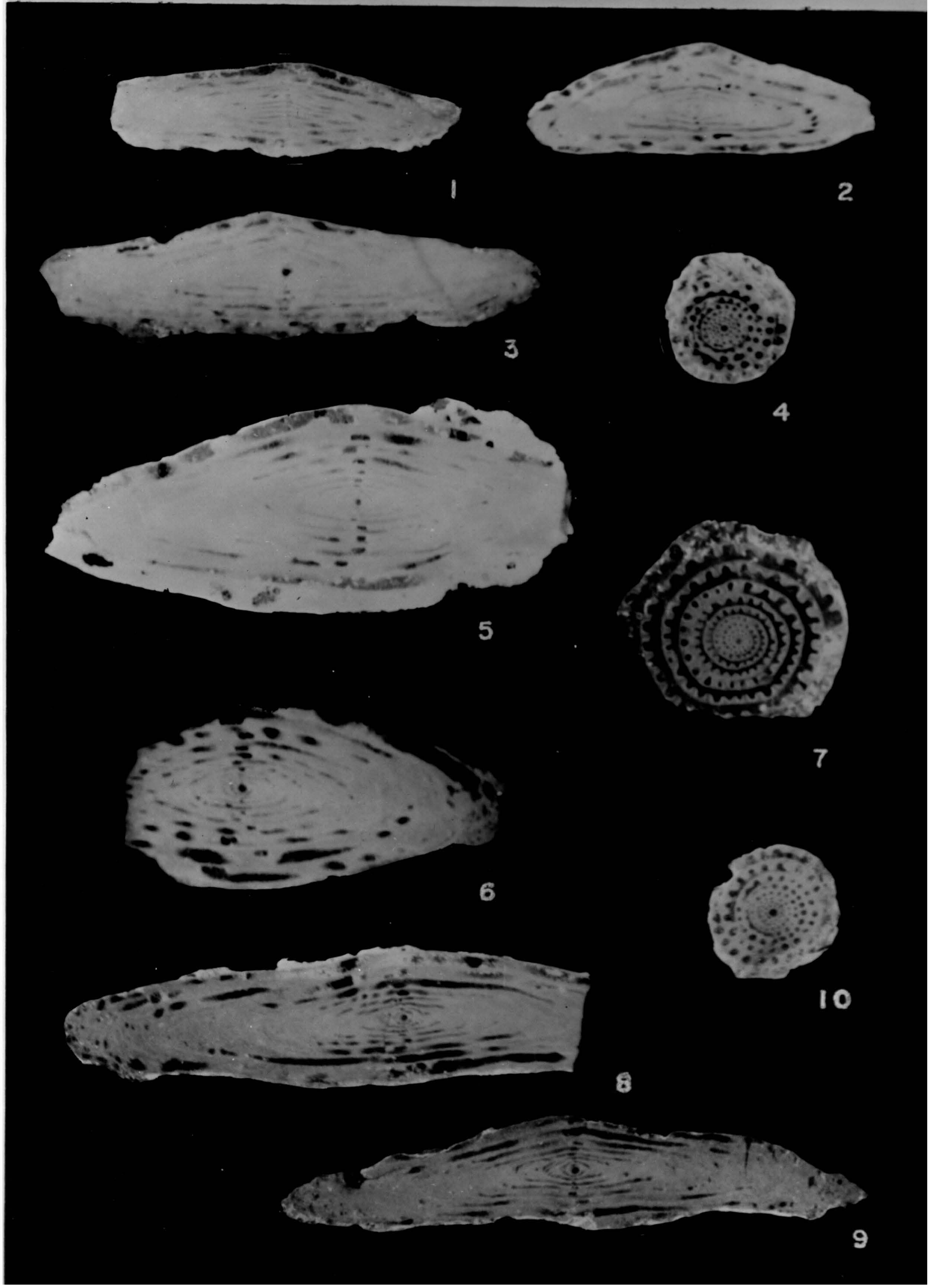
Figs. 5-7: Wedekindellina n. sp. B. Limestone cap of Walker (Pilot) coal, station 9, (Vernon County, Missouri). (Page 48.)

5. Axial section, length 2.84 mm. 6. Oblique axial section, length 1.86 mm. 7. Sagittal section, greater diameter 1.00 mm. (Figs. 5 and 7 are numbered in Table 4 as specimens 1 and 2, respectively).

Figs. 8-10: Wedekindellina n. sp. A. Shaly limestone cap of Fleming coal, stations 11 and 20, (Crawford County, Kansas.) (Page 45.)

8. Axial section, station 11, length 3.94 mm.
9. Axial section, station 20, length 3.32 mm.
10. Sagittal section, greater diameter 0.66 mm. (Figures 8-10 are numbered in Table 3 as specimens 1, 2, and 3, respectively.)

PLATE I



Explanation of Plate 2

Figs. 1-3: Fusulina aff. meeki var. tregoensis Roth Skinner. Shaly limestone cap of Fleming coal, station 11 (Crawford County, Kansas). (Page 52).

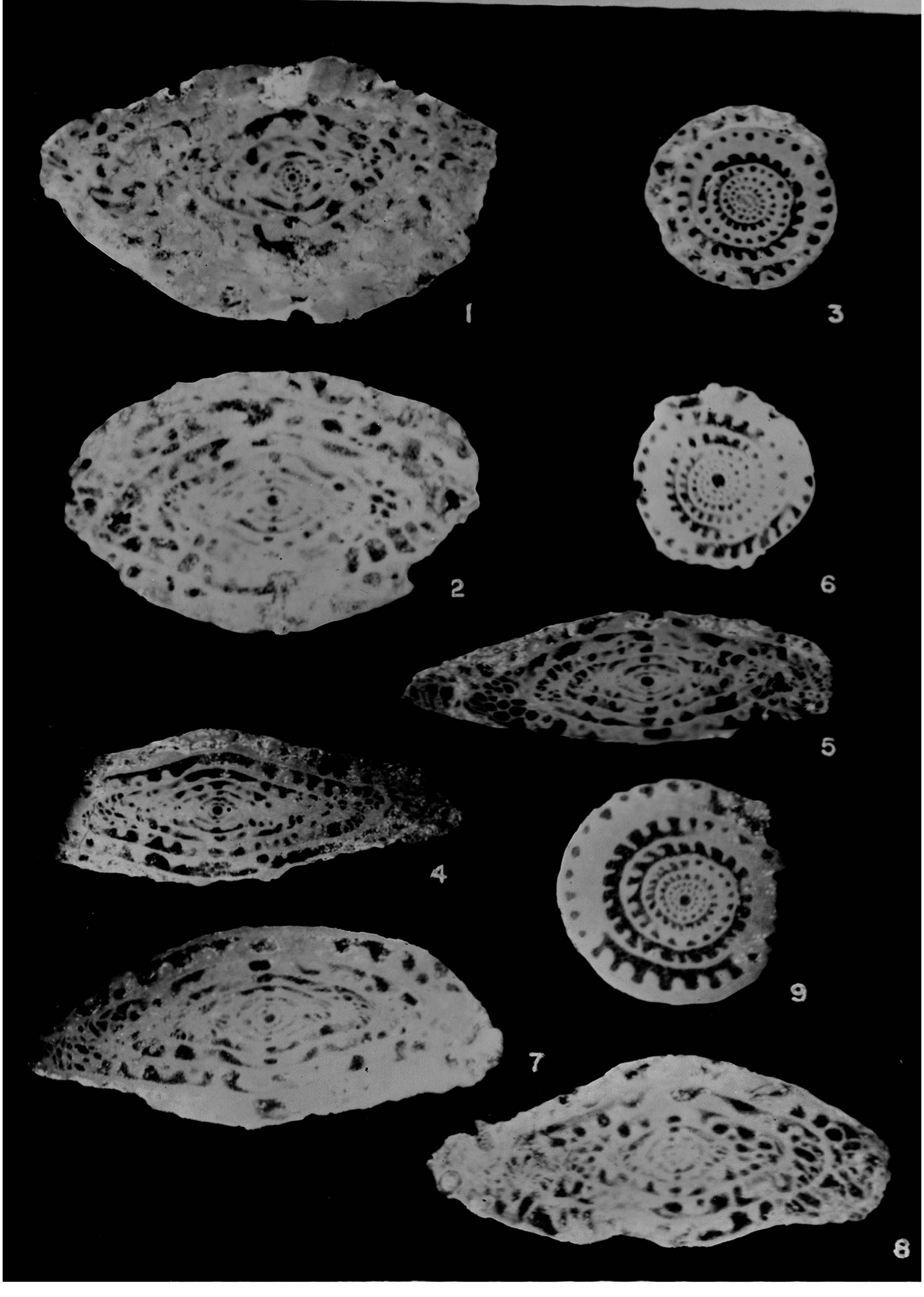
1. Axial section, length 1.96 mm., showing oblique "juvenarium". 2. Axial section, length 2.20 mm. 3. Sagittal section, greater diameter 0.96 mm., apparently specimen had "juvenarium" at right angles to plane of coiling. (Figs. 1-3 are numbered in Table 5 as specimens 4, 2, and 7, respectively.)

Figs. 4-6: Fusuline cf. spissiplicata Dunbar and Henbest. Shaly limestone cap of Fleming coal, station 11, (Crawford County, Kansas). (Page 59.)

4. Axial section, length 3.40 mm. 5. Axial section, length 3.68 mm. 6. Sagittal section, greater diameter 1.00 mm. (Figs. 4-6 are numbered in Table 7 as specimens 1, 3, and 8, respectively.)

Figs. 7-9: Fusulina pumila Thompson. Shaly limestone cap of Fleming coal, station 11, (Crawford County, Kansas). (Page 56.)

7. Axial section, length 2.12 mm. 8. Axial section, length 1.76 mm. 9. Sagittal section, greater diameter 1.38 mm. (Figs. 7-9 are numbered in Table 6 as specimens 3, 5, and 7, respectively.


1
3
2
6
5
4
9
7
8

Explanation of Plate 3

Figs. 1-5: *Fusulina* new species A. Limestone cap of the Mineral coal, station 10, (Crawford County, Kansas.) (Page 63.)

1. Axial section, length 2.56 mm. 2. Axial section, length, 3.16? mm. 3. Axial section, length 3.08 mm., showing "juvenarium" of one and a half whorls. 4. Tangential section, length 2.56 mm., showing character of septal folding. 5. Sagittal section, greater diameter 1.28 mm. (Figs. 1-3, and 5, numbered in Table 8 as specimens 4, 3, 5, and 6, respectively).

Figs. 6-10: *Fusulina* new species A new variety. Limestone cap of the Mineral coal, station 10, (Crawford County, Kansas). (Page 66.)

6. Axial section, length 2.96 mm. 7. Axial section, length 2.68 mm., showing sagittal section of fusulinid inside test, between chomata on right side and fold in outermost volution. 8. Axial section, length 3.80 mm. 9. Sagittal section, greater diameter 1.70 mm. 10. Sagittal section, greater diameter 1.44 mm. (Figs. 6-10 are numbered in table 9 as specimens 1, 4, 3, 6, and 5, respectively.

PLATE 3

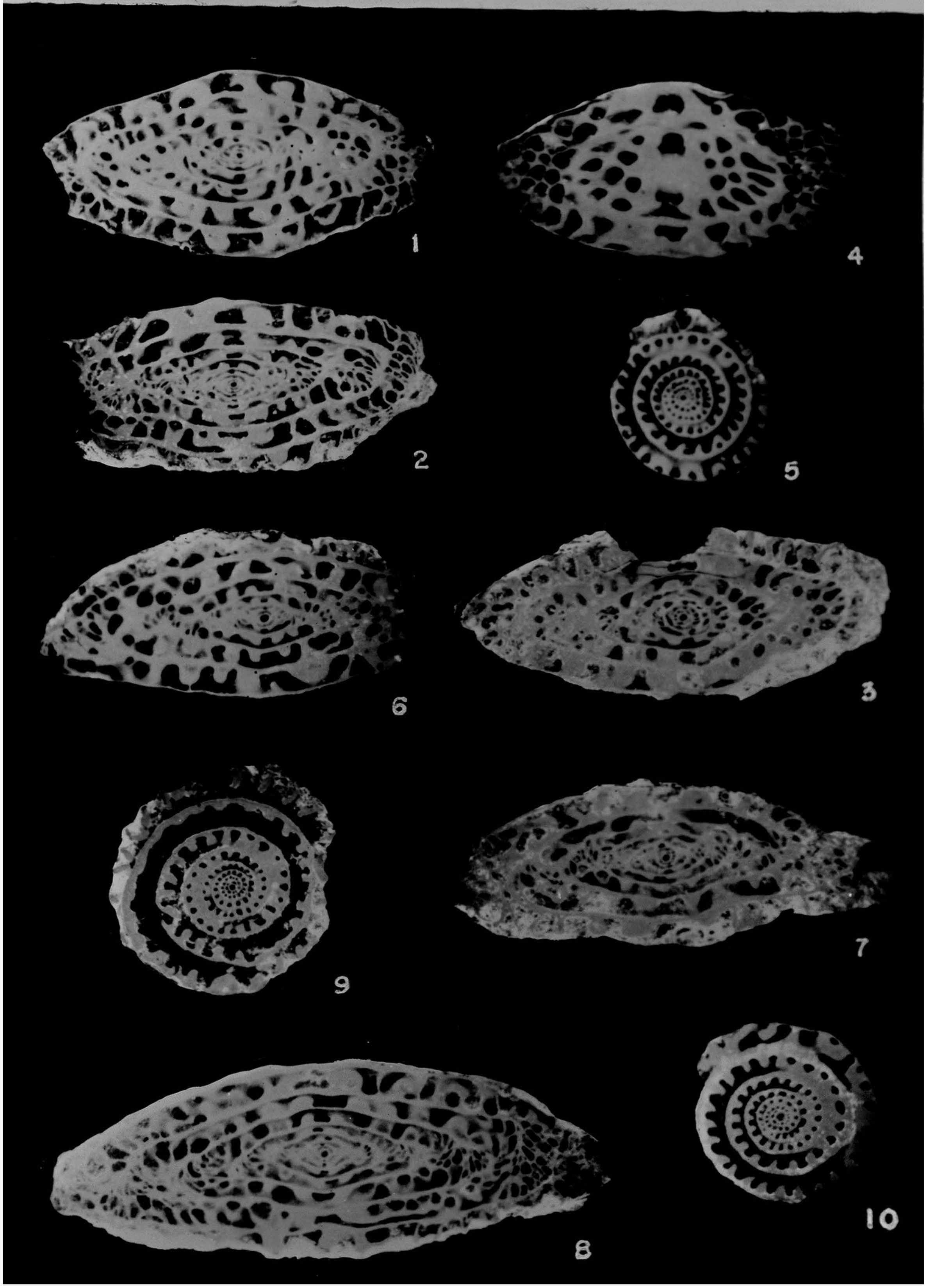
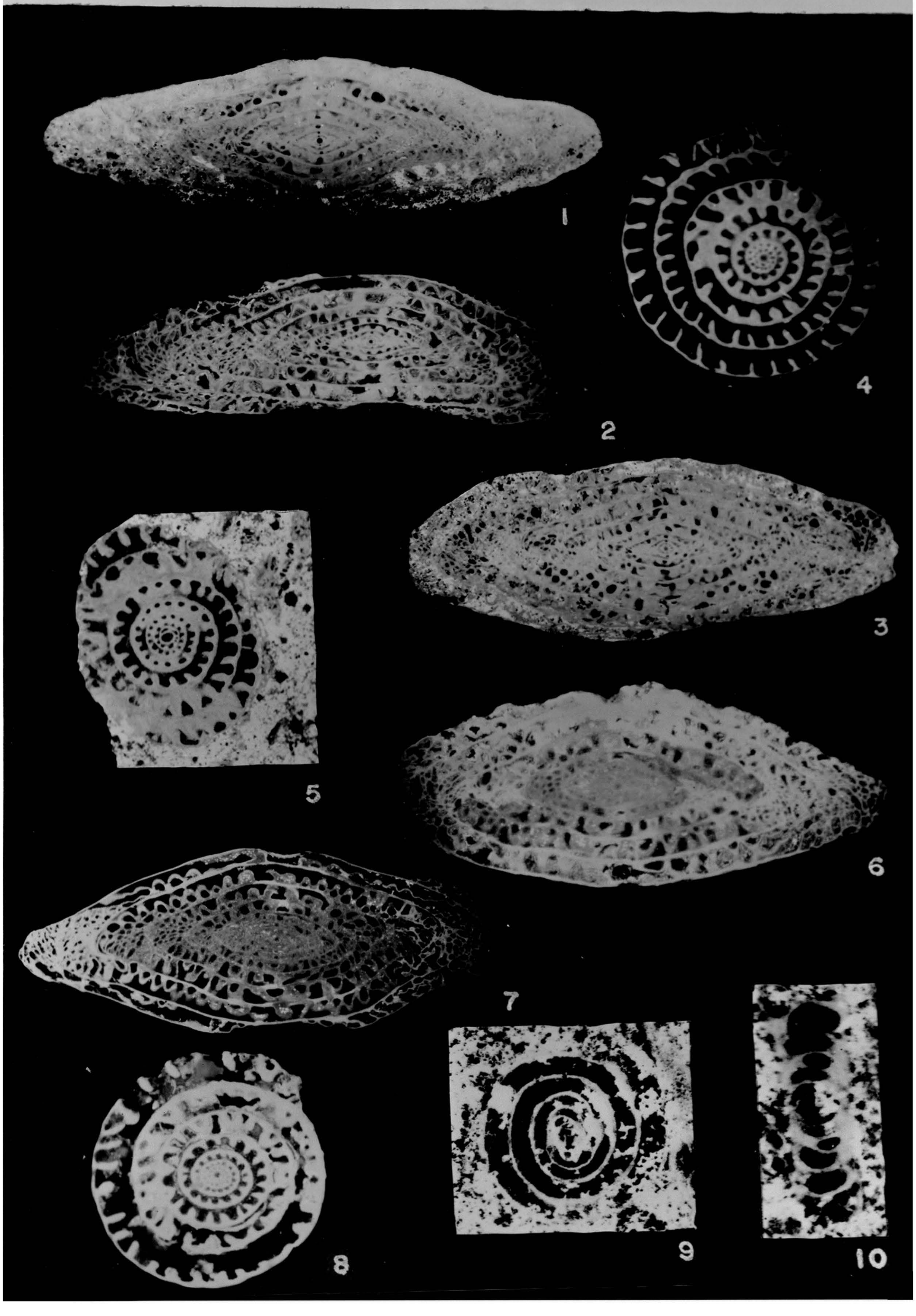


PLATE 4



Explanation of Plate 4

Figs. 1-5: *Fusulina* new species B. Ardmore limestone, station 8 (Vernon County, Missouri); stations 14 and 16, (Boone County, Missouri). (Page 69.)

1. Axial section, length 7.12 mm. 2. Axial section, length 6.48 mm. 3. Axial section, length 6.80 mm. 4. Sagittal section, greater diameter, 1.62 mm. 5. Sagittal section, greater diameter, 1.38 mm. (Figures 1, 3, and 5, were found at station 8; figs. 2 and 4 were collected at station 14.) (Figs. 1-5 are numbered in Table 10 as specimens, 1, 3, 2, 7, and 8, respectively.)

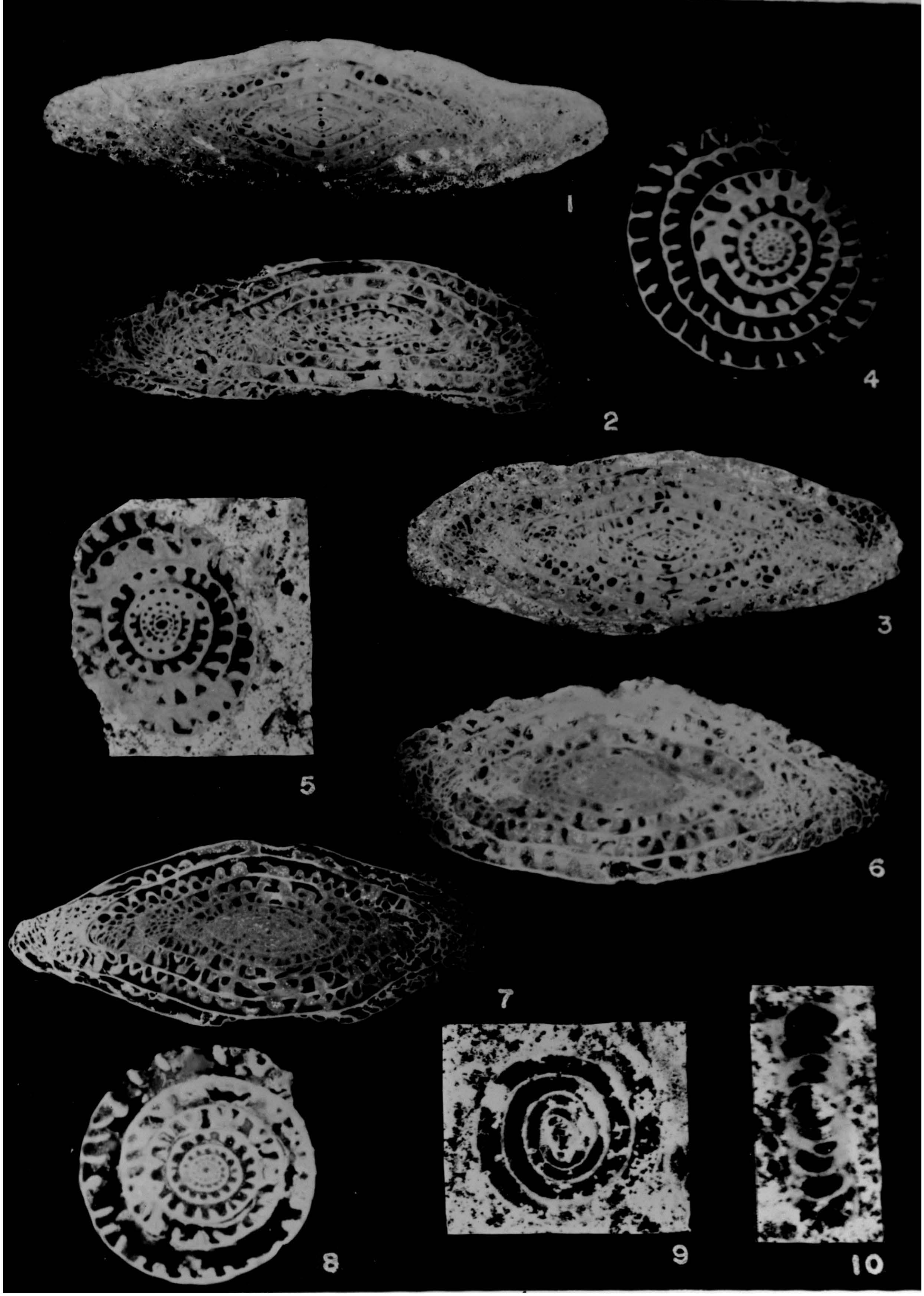
Figs. 6-8: *Fusulina* species B new variety. Ardmore limestone, station 14 (Boone County, Missouri). (Page 72.)

6. Axial section, length 5.00 mm. 7. Axial section, length 6.48 mm. 8. Sagittal section, greater diameter 1.64 mm. (Figs. 6-8 are numbered in Table 11 as 4, 2, and 7, respectively.)

Figs. 9-10: *Hemigordius* cf. *regularis* Plummer. Ardmore limestone, station 8 (Vernon County, Missouri). (Page 74.)

9. Median section, greater diameter 0.42 mm. 10. Vertical section, thickness 0.11 mm; greater diameter 0.34 mm. (Figs. 9 and 10 are numbered in Table 12 as specimens 8 and 7 respectively.)

PLATE 4



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In January, 1947, college training at the College of the City of New York was resumed. He graduated in January, 1949, with a B. S. in Science (Geology) and enrolled as a graduate student at the Missouri School of Mines and Metallurgy in September, 1949.