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STUDIES OF AMERICAN FUSULINIDS

By M. L. THOMPSON



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PALEONTOLOGICAL CONTRIBUTIONS

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STUDIES OF AMERICAN FUSULINIDS

M. L. THOMPSON

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ABSTRACT

This report is divided into three parts. Part I considers the ecology, distribution, morphology, evolutionary trends, phylogeny, and stratigraphic zonation of the family Fusulinidae. Evidence of the habitat of the fusulinids is briefly outlined, their shell structures and terminology are reviewed, and the major and minor evolutionary trends in development of their shells are discussed. The major trends in the evolution of the fusulinid shell are discussed under (1) increase in size of the shell; (2) change in shape of the shell in a direction from discoidal to elongate fusiform; (3) development of a more highly complex wall structure; and (4) development of irregularity or fluting of the septa. Also, several other evolutionary trends are recognized among some branches of the family. The phylogeny of the family is discussed and illustrated. The major stratigraphic fusulinid faunal zones in America are described as Zone of *Millerella*, Zone of *Profusulinella*, Zone of *Fusulinella*, Zone of *Fusulina*, Zone of *Triticites*, Zone of *Pseudoschwagerina*, Zone of *Parafusulina*, and Zone of *Polydioxodina*. The Tethyan Permian in the Eastern Hemisphere has two faunal zones above the Zone of *Parafusulina*, designated as the Zone of *Verbeekina-Neoschwagerina* and the Zone of *Yabeina*.

Part II considers the classification of the family Fusulinidae. Six subfamilies, 47 or 48 genera, and one subgenus are recognized. All divisions to genera are described and compared in detail, and all genotypes are illustrated.

Part III concerns the fusulinids and stratigraphy of the Lower Pennsylvanian? and lower Middle Pennsylvanian rocks of southern New Mexico and extreme western Texas. Three previously known species of *Millerella* are described and illustrated from the Lower Pennsylvanian? of this region. The largest fauna of the *Profusulinella* and *Fusulinella* faunal zones so far reported from America is described and illustrated from lower Middle Pennsylvanian rocks of this region. The fauna includes abundant *Millerella*, an unnamed form of *Nankinella*, two new species of *Staffella*, one new species of *Eoschubertella*, one previously described form of *Pseudostaffella*, six new species and one unnamed species of *Profusulinella*, one previously described species, five new species, and one unnamed species of *Fusulinella*, and one new species questionably referred to *Fusulina*. Most previously described American members of *Profusulinella* and *Fusulinella* are illustrated for comparison.

FOREWORD

American fusulinids have been studied by many workers during the past 90 years, but their stratigraphic value for correlation of the Pennsylvanian and Permian rocks of the United States has become more fully appreciated during the last 25 years. Fusulinids are exceedingly abundant in Pennsylvanian rocks in 17 of the states and less abundant in at least 6 additional states. They are also abundant in Permian rocks in 12 states and less abundant in at least 3 states. However, it is evident that only a small part of the American Pennsylvanian and Permian fusulinids has been described. This report includes studies of the Early Pennsylvanian fusulinids from southern New Mexico and western Texas. The area of New Mexico and extreme west Texas is of major importance in the study of American Pennsylvanian fusulinids, for it is near the southern end of the Ancestral Rocky Mountains that partly separated the Pennsylvanian seas of the midcontinent region from those of the western states. Similar studies are to be made of

the fusulinids from other large stratigraphic units of this same region and of units to the east and west. As an introductory phase to these studies, the first two parts of this report consider some of the broader aspects of the family Fusulinidae. Part I discusses the ecology, distribution, morphology, evolutionary trends, phylogeny, and stratigraphic zonation of the family. Part II concerns the classification of the family. Part III describes the prolific fusulinid faunas from the lower part of the Pennsylvanian of New Mexico and extreme western Texas.

Many individuals and organizations have contributed help during the preparation of this report and some are specifically mentioned on later pages. Thanks are due especially to Dr. R. C. MOORE for suggestions and constructive criticisms of the entire report. Financial aid in completing this report was given by the Graduate Research Committee of the University of Wisconsin from funds furnished by the Wisconsin Alumni Research Foundation.

PART I

ECOLOGY, DISTRIBUTION, MORPHOLOGY, EVOLUTIONARY TRENDS,
PHYLOGENY, AND STRATIGRAPHIC ZONATION OF FUSULINIDS

INTRODUCTION

The foraminifers of the family Fusulinidae have been studied for about 120 years, and during this time many dozen workers have contributed to our knowledge of the stratigraphic distribution, shell structure, taxonomy, and evolution of members of the family. Fusulinids had their beginning in latest Mississippian time, but the last members seemingly did not survive to the end of the Permian. During this relatively short time interval, the family developed into many biologic branches; and 47 or perhaps 48 genera and one subgenus, grouped in 6 subfamilies, are recognized. Almost 1,000 species have been referred to these genera. Many of the generic and subfamily groups occur together, and it is evident that the family developed simultaneously along several lines of evolution.

In regard to well-preserved entire specimens, the fusulinids outnumber the fossil fauna of any other single type of invertebrates in the Pennsylvanian and Permian of many areas. In many of these areas, well-preserved entire specimens of fusulinids probably exceed in number the combined faunas of all other types of invertebrates. The fusulinids were very sensitive to their physical environment and are closely restricted to certain lithologic units of the Pennsylvanian and Permian. Although fusulinids are exceedingly abundant in some stratigraphic units and may compose more than half the bulk of the rock, they are found in many places associated with few other types of fossils. In numerous stratigraphic levels in the Pennsylvanian and Permian, the same general types of invertebrate faunas immediately precede and immediately follow the zones in which prolific fusulinids are found; this order of faunal occurrences is especially noticeable in central United States.

Fusulinids have been recognized in more than 80 distinct stratigraphic units throughout the Pennsylvanian of New Mexico. Many of these fusulinid-bearing units occur over areas of hundreds of square miles. About an equal number of fusulinid-bearing units have been found in the Pennsylvanian of the northern midcontinent region and in Texas. In the midcontinent region, some of the fusulinid-bearing units are distributed over even larger geographic areas than those in New Mexico, and some of them seem to be continuous with the New Mexico units out from the edges of the Pennsylvanian land areas of the Rocky Mountain region. Although fusulinids are abundant and occur in many widespread zones

in the Permian of the United States, most of the Permian fusulinid faunas are more restricted in their distribution than those of the Pennsylvanian, seemingly due largely to the physical nature of the Permian seas.

ECOLOGY

Considerable evidence indicates that fusulinids were uncommonly sensitive to their physical surroundings. They were restricted to offshore open-water environments, their shells occurring most commonly in limestones or highly calcareous shales and less commonly in sandstones. Also, fusulinids are not found indigenous in coarse clastics or in close association with evaporites. In the Permian of the Texas-New Mexico area, certain limestones can be traced laterally from areas in which fusulinid faunas are prolific to areas characterized by brackish-water types of faunas, and still further to areas where the limestones grade into dolomites and evaporites. The fusulinids disappear laterally in the section at great distances from the regions of evaporites. Also, fusulinids are not found in direct association with fossil forms of invertebrates of the types that live today in brackish-water or near-shore environments. Fusulinids occur abundantly in sandstones at some localities. Several such occurrences are found in upper Desmoinesian sandstones of southern Oklahoma and northern Texas. Fusulinids have been found at a few places in these sandstones concentrated in the troughs of undulating structures interpreted as ripple marks, but it is not certain that these shells are indigenous in the ripple marks.

At some localities, thick limestones contain abundant fusulinids having highly elongate shells, most of which are oriented in the same direction. One such occurrence is in the Permian of Timor where oriented shells of fusulinids compose more than 50 percent of great thicknesses of limestone. Similar occurrences of oriented fusulinid shells are found in some Pennsylvanian and Permian limestones of America. This orientation of the shells of fusulinids suggests that strong submarine currents occurred in these localities.

The most convincing evidence of the offshore open-water habitat of the fusulinids is furnished by studies of the sedimentary cycles in the Pennsylvanian of the northern midcontinent region. MOORE (1936) divided the complete Pennsylvanian sedimentary cyclothem into 10 units, the lower two of which and the uppermost one of which are of con-

tinental origin. The intervening seven units are of marine origin, and fusulinids occur most abundantly in the middle unit of this marine part of the cyclothem. The fusulinids lived offshore in the most open shallow sea environment, and they penetrated continental basins farthest when the seas reached their greatest advancement. The fusulinid-bearing unit at any given place is underlain by rocks of the advancing sea and is overlain by rocks of the retreating sea. The sedimentary cycle in the Permian Wolfcampian of Kansas, Oklahoma, and Nebraska differs somewhat from that in the Pennsylvanian (MOORE *et al.*, 1934) but, as in the Pennsylvanian cyclothem, the fusulinids occur in and near the central part of the marine phase of the sedimentary cycle.

DISTRIBUTION

Fusulinids are almost world-wide in their geographic distribution and have been found on all continents except Antarctica. The most northern occurrence in the Eastern Hemisphere is on Spitzbergen (Svalbard), and the most southern occurrence is in Northwest Australia. They are distributed in the Western Hemisphere from northeast Greenland on the north to Bolivia on the south. Fusulinids occur in Pennsylvanian and Permian rocks on many of the Arctic Islands and throughout most of the north-south distance across European Russia; in the Viséan of Germany; in the Pennsylvanian of Spain; in the Permian of the Carnic Alps, Velebit Mountains of Yugoslavia, Sicily, Aegean Islands of Greece, and Crimea. They have been reported only from Egypt and Tunis in Africa. In Egypt they occur in the Pennsylvanian, and in Tunis they occur in the Upper Permian.

Fusulinids are exceedingly widespread in Asia and in the islands of the Indian and Pacific Oceans. They occur in the Pennsylvanian of Mongolia, China, Japan, and possibly French Indo-China; and in the Permian at numerous localities in the eastern part of the Eastern Hemisphere, including Pamir, Armenia, Iran, Turkey, Syria, Afghanistan, Caracorum, northern India, Malaya, Siam, French Indo-China, western, southern, and northern China, extreme eastern Siberia, Japan, the East Indies Islands from Sumatra to Timor, and Northwest Australia.

In the Western Hemisphere, fusulinids occur in the Pennsylvanian over large areas of the United States from Pennsylvania on the east to Nevada on the west. Undescribed collections of lowermost Middle Pennsylvanian age are known from South America. Permian fusulinids are even more widespread than Pennsylvanian forms and are known throughout much of far western United States, the Rocky Mountain area, south-central United States, and the midcontinent region. Outside the United States, Permian fusulinids occur in western Canada, Greenland, Alaska, across much of northern Mexico, Central America, Brazil, Venezuela, Colombia, Peru, and Bolivia.

It is evident that fusulinids occur over a large part of the present land areas of the world. As these organisms seemingly were unusually sensitive to their physical surroundings, it may be assumed that the climates of the world during Pennsylvanian and Permian times were more uniform than today.

MORPHOLOGY

GENERAL CONSIDERATIONS

The fusulinids are referred to the order Foraminifera and are therefore assumed to have been one-celled animals. As with many of the foraminifers, the individual shells of fusulinid species are remarkably similar in almost all respects. Externally, the shells of many species bear close resemblance. Internally, however, the shell structures may be markedly different among different forms, and extreme members of the family differ greatly in internal shell structures. The shell structures of primitive forms are relatively simple, but those of some of the most highly developed forms are among the most complex of the foraminifers. The fusulinids occur geologically only a short time after the earliest foraminifers having unquestionable calcareous shells, and the fusulinids died out considerably before the development of the prolific foraminiferal faunas of the Mesozoic, which are dominated by groups having calcareous shells. Most of the calcareous as well as arenaceous types of other foraminifers are classified on the basis of external shell structures, but classification of the fusulinids is based largely on internal shell structures that generally can be determined only from thin or polished sections. The few other groups of Foraminifera that are classified largely on the basis of internal shell structures, such as the camerinids and orbitoids, occur near the upper part of the geologic section, and the terminology applied to their shell structures is not applicable to the shell features of the fusulinids, and conversely. Although some terms applied to the fusulinid shell structures are also used for other foraminifers, much of the terminology used in describing the fusulinid shell is restricted to this family.

Some of the structural features of the fusulinid shell can be interpreted from external observations, but many are completely internal. Two sections cut through the beginning chamber reveal most internal features of the shell. One of these is cut along the axis of coiling and is called the **axial section**. The other is cut at right angles to the axis of coiling and is called the **sagittal section**. The terminology applied to sections cut through areas other than these two depends on the direction of orientation and position. A section cut normal to the axis of coiling but not through the beginning chamber is termed a **parallel section**. One cut parallel to the axis of coiling but not through the beginning chamber is termed a **tangential section**. Sections cut

in directions not parallel to the axis of coiling or normal to it are referred to as **oblique sections**. For thorough observation of all structural features of a species, it is necessary to study numerous axial and sagittal sections and numerous parallel, tangential, and oblique sections cut through different parts of the shell and at various angles. It is also desirable to observe the external nature of the shell.

An external view of the fusulinid shell shows a relatively smooth surface broken by shallow closely spaced **external furrows**. These furrows extend from end to end of the shell and mark the tops of the partitions between the chambers, termed **septa**. Adjacent external furrows come together as they reach the axial poles. The surface is interrupted by an abrupt wall, termed the **antetheca**, that forms the front wall of the last chamber and which is punctured by numerous small openings, called **septal pores**. In many fusulinids the antetheca is arcuate anteriorly, or is plane. In others it is folded or corrugated into uniformly spaced waves. The corrugation is more pronounced in the lower part of the antetheca than in its upper surface.

Thin sections of the fusulinid shell reveal highly complicated internal structures, all of which are considered in classification and identification of species. The beginning chamber of most forms is spherical to subspherical in shape, and several coils or volutions of chambers are developed about it. The antetheca does not possess an aperture, and accordingly the cell depended on the septal pores for communication with the exterior of the shell. Communication between adjacent chambers of the interior of the shell was aided by the resorption of a **tunnel** at the base of the septa in the central part of the shell of many fusulinids, and by the resorption of several tunnels or small circular **foramina** at the base of the septa throughout the length of the shell in others. Ridges of dense calcite, **chomata**, are built along the margins of the single tunnel in most fusulinids, and ridges of dense calcite, **parachomata**, are developed between adjacent foramina in forms having multiple foramina. Seemingly simultaneously with the formation of the chomata or parachomata and with the excavation of the tunnel or foramina, deposits of dense calcite, **axial fillings**, are developed in the axial regions of some fusulinids. The internal surfaces of the chamber of many fusulinids, particularly of the subfamily Fusulininae, are lined with a layer of dense calcite formed at or near the same time as that in which the tunnel is excavated, and near the time the chomata and axial fillings are deposited. This lining of the chambers comprises layers designated as **tectoria**.

The wall above the chamber is referred to as the **spirotheca** because of its spiral arrangement. In primitive forms it consists of a thin dense primary layer, the **tectum**, which is later covered above and below by layers of tectoria. In more advanced forms, the tectum is supplemented by various other

layers, including a transparent layer, the **diaphanotheca**, or a thick layer of honeycomb structure, the **keriotheca**. Each chamber has only a front and top wall of its own, for it uses the front wall of the preceding chamber as its posterior wall and the tops of the chambers in the preceding volution as its floor. The structure of the spirotheca plays an important part in classification and differentiation of the fusulinids. Ridges that are termed **septula** extend down from the lower surface of the spirotheca in the subfamily Neoschwagerininae so as to subdivide the chambers partly.

PROLOCULUS

All the fusulinids are multi-chambered, and the chambers can be divided into the first chamber, the **proloculus**, and the chambers of the coiled part of the shell. In most fusulinids the proloculus is spherical to subspherical in shape and the proloculi of conspecific specimens generally are closely similar in size. Some forms have a proloculus only a few microns in diameter, whereas that of others is slightly more than 1 millimeter in diameter. Although the proloculus of most forms is spherical, or nearly so, in some it is irregularly subspherical or even irregularly rectangular in shape. Almost all forms possessing irregular proloculi are large, are highly developed biologically within their respective subfamilies, and have large proloculi. Although the irregular proloculi are much larger than the average size of those for the entire family, some individual specimens of a given species characterized by large proloculi may have a spherical proloculus, or one that is ellipsoidal, rectangular, or somewhat unsymmetrically irregular (Pl. 13, figs. 1, 2). DUNBAR & HENBEST (1942) and others have discussed the shape of the proloculus of the fusulinids and have proposed several hypotheses as to origin of its spherical to subspherical shape. One of these suggests that the cell around which the proloculus was formed may have had a different surface tension than fluids outside the area of the proloculus, which would tend to give the cell a globular form and produce a spherical proloculus. The smaller the fluid globule, the more nearly spherical should be its shape, and this accords with the more nearly spherical shape of small proloculi as compared with the larger ones. It should be pointed out, however, that specimens of several forms having abnormally large proloculi may possess almost perfectly spherical proloculi. It can not be demonstrated that the proloculus of the fusulinids enclosed the entire embryonic cell, the nucleus, or an area of multiple nuclei. MYERS (1935, 1936) has observed the formation of the proloculus in several living Foraminifera. In some, the proloculus surrounded the embryonic cell, in others it surrounded the nucleus of the cell, and in still others it surrounded a budlike protrusion on the side of the cell. The **beginning chamber**, or beginning part of the shell of many other animals, is spherical to sub-

spherical in shape. The cause of the spherical shape of this beginning chamber, or beginning stage, of the shell in multi-cellular animals is not known, but it may be similar to that which developed the spherical proloculus of most fusulinids.

The wall of the proloculus is dense and uniform throughout its thickness, and in general structure it resembles closely that of the dense wedge-shaped layer of the septa of some forms. Its structure does not resemble that of the walls of the immediately following chambers, except in forms in which the walls of these chambers are composed of a single thin layer and the proloculus also has a wall composed of a single thin layer. The proloculus wall in most fusulinids is thicker than that of the beginning chamber of the coiled part of the shell.

The proloculus wall is broken by a single circular opening, called **proloculus aperture**, that opens into the first chamber of the coiled part of the shell. The aperture of the proloculus in some specimens has a simple unmodified margin that is continuous with the surface of the proloculus wall (Pl. 13, fig. 4). In some specimens the margin of the aperture is bordered by a short tubelike structure that extends into the proloculus (Pl. 22, fig. 1). In many other specimens the aperture is not bordered by a tubelike structure, but the surface of the wall immediately surrounding the aperture is depressed, and the aperture is at the base of a shallow funnel (Pl. 13, figs. 5, 6).

Scattered specimens of many species of fusulinids contain two proloculi, around each of which one or more volutions of normal-appearing chambers are developed, and around both of which a normal set of spirally arranged chambers is seen. Rare specimens contain three proloculi. The full size of these specimens is not noticeably different from that of other conspecific associated specimens having a single proloculus. Specimens provided with double proloculi have been illustrated by many workers since those illustrated by STAFF in 1909. Double or treble proloculi do not seem confined to any particular group of fusulinids but have been observed more commonly among the Fusulininae and Schwagerininae. Several hypotheses as to why some shells contain two or three proloculi have been suggested. The most generally accepted idea is that young individuals joined to develop as one individual, but the cause for such union is not known. It may have been for mutual benefit under conditions of adverse food supply, or the union may have been merely an accident caused by close crowding of embryonic forms, such as may occur during encystation.

Dimorphic reproduction among the fusulinids has been postulated by many workers, and attempts have often been made to demonstrate the presence of microspheric forms (sexual generation) and megalospheric forms (asexual generation). In many of the cases cited, all gradations in the size of the proloculi have been found in a single suite of specimens, and the range of volume of the proloculi is no

greater than the range in size of other features in specimens having equal-sized proloculi. Some of the most convincing evidence of dimorphism among fusulinids has been presented by DUNBAR, SKINNER, & KING (1936), based on studies of *Parafusulina*. Giant individuals having minute proloculi and highly asymmetrical early volutions occur associated with smaller individuals that bear large proloculi and different internal shell structures. The giant specimens are rare among relatively abundant smaller specimens. Giant specimens of *Parafusulina* possessing minute proloculi do not show a distinct single tunnel, but associated smaller specimens provided with large proloculi have a well-developed tunnel. DUNBAR & SKINNER (1937) have described giant specimens of several forms of *Polydiexodina* that contain minute proloculi and asymmetrical early volutions, and these are associated with more abundant smaller specimens that have large proloculi and symmetrical volutions. The smaller specimens possess multiple tunnels, but the giant specimens lack tunnels. These giant individuals have tunnel-like paths, however, that penetrate the septal walls and provide for internal communication. Rare specimens having minute proloculi and highly asymmetrical early volutions have been found associated with abundant normal-appearing specimens of species of *Fusulina* and of *Triticites*. The outer parts of the shells of these two types seem identical in other respects. It is supposed by some that the specimens characterized by minute proloculi represent the microspheric generation and the more abundant specimens that bear large proloculi represent the megalospheric generation. The preponderance of the type of specimens considered to be the asexual generation is noticeable. Only one type of shell has been identified for most species of fusulinids. It is not certain that the fusulinids display dimorphism.

CHAMBERS

The proloculus aperture opens into the first chamber of the coiled part of the shell. The first coiled chamber of most specimens is smaller in cross section than the proloculus, but it is distinctly elongate in the direction of the axis of coiling of the outer volutions. In some specimens having an unusually large proloculus, the aperture opens into a somewhat irregular chamber that almost completely surrounds the proloculus. This large irregular chamber generally does not contain as large a volume as that of the proloculus, and its walls conform in structure more closely to the walls of the succeeding chambers (Pl. 22, figs. 1, 5). In some specimens, the first chamber of the coiled part of the shell is much larger than that of the immediately succeeding chamber.

Beyond the proloculus, the fusulinid shell is composed of numerous chambers coiled about the proloculus in such a fashion that the axis of coiling in most forms is the greatest diameter of the shell, and this is commonly defined as length of the shell.

Similarly, the greatest diameter at right angles to the axis of coiling is commonly defined as the width of the shell. In some, the length of the shell in the axis of coiling is about equal to the width, and in others the axis of coiling is the shortest diameter. Most all chambers of the coiled part of shell are much shorter in the direction of coiling than their width measured parallel to the axis of coiling. The chambers are widest in the center of the shell and are reduced to zero width at the poles. Starting with the first few chambers of the first volution, the chambers gradually increase in height. This increase is almost uniform throughout most of the shell in many fusulinids, but chambers of the last one or two volutions of gerontic individuals of most forms are lower than those of the immediately preceding volutions. In forms of some genera, particularly of *Pseudoschwagerina* and *Paraschwagerina*, the chambers of the first few volutions are low, in the following one or two volutions their heights increase rapidly, and the outer volutions are highly inflated. However, the last one or two volutions of gerontic individuals of these genera decrease in height slightly. In a few aberrant genera, such as *Codonofusiella* and *Nipponitella*, the inner volutions increase in height gradually, but the outer volutions are uncoiled and highly flared or subrectilinear.

Most specimens of all genera of Schubertellinae have minute proloculi and the first one to three volutions are tightly coiled, their axis of coiling being at large angles to the axis of coiling of the outer volutions. The first part of this asymmetrically coiled part of the shell is slightly evolute, and it does not attain a form ratio of unit value. Early members of the Fusulininae also have highly asymmetrical early volutions, particularly members of *Pseudostaffella* and early members of *Profusulinella*. The cause of this asymmetrically coiled nature of the juvenile shell is not known. The asymmetrical coiling of the juvenile part of the giant specimens associated with *Parafusulina* and *Polydiexodina*, discussed by DUNBAR, SKINNER, & KING (1936), is seemingly similar to that in the more primitive forms of *Profusulinella* and forms of the Schubertellinae. However, the specimens of Schubertellinae distinguished by asymmetrical coiling are not large, and many such forms are not associated with specimens having symmetrical early volutions and markedly larger proloculi. There is no evidence that these primitive fusulinids which exhibit minute proloculi and asymmetrical early volutions represent the microspheric generation of dimorphic forms.

ANTHETHECA AND SEPTA

The anterior wall of the last chamber, the antetheca, becomes the septum between the last two chambers when an additional chamber is developed. In primitive forms of *Millerella*, the antetheca is curved anteriorly immediately below its top and is curved posteriorly near its base, resulting in septa

that are strongly arcuate. In most of the more highly developed forms of the subfamily Ozawainellinae, the antetheca is plane and perpendicular to the outer wall of the chamber. Also, members of the Verbeekinae and Neoschwagerininae have perpendicular plane antetheca and septa. With the exception of *Pseudostaffella* and very primitive forms of *Profusulinella*, the septa of members of the subfamily Fusulininae are corrugated or fluted to some extent. The fluting in primitive forms is confined to broad undulations in the extreme polar regions and to the basal part of the septa. In more highly developed forms, the plication of the septal walls progressively moves from the poles toward the center of the shell and progressively moves up toward the tops of the septa. The salient of the fold in the antetheca corresponds in position to the re-entrant in the fold of preceding septum. In forms in which the septa are closely spaced or in which the fluting is sufficiently strong, adjacent septa are brought in contact at these points, resulting in enclosed areas, **chamberlets**, at the base of the chambers that open upward. In primitive forms of Fusulininae the fluting is sufficiently intense to bring adjacent septa in contact only at their lower margins and only in the extreme polar regions where the chambers are shortest. Primitive forms of Schwagerininae, such as *Triticites*, also have septal fluting developed only in the extreme polar regions. Highly developed forms of Fusulininae and of Schwagerininae have closely and highly fluted septa throughout the length of the shell, and the fluting brings the septa in contact at opposing folds even above the tunnel. In some members of Schwagerininae, such as many forms of *Paraschwagerina* and most forms of *Pseudofusulina*, the septa are plicated to the top of the septa. In many forms of these genera, the fluting forms chamberlets that extend more than half the height of the chambers. In highly developed forms of *Schwagerina* and all forms of *Parafusulina* and *Polydiexodina*, the salient fold of the fluting extends forward a great distance and the antetheca or septum of the following chamber bends downward near to or even behind the greatest forward projection of this salient. Therefore, the re-entrant of the later antetheca or septum is impounded against the salient of the preceding septum, as illustrated in the accompanying diagram (Fig. 1). In the polar regions of many forms of *Parafusulina*, the salient extends forward as much as the combined length of the following two chambers.

In forms of *Parafusulina* and *Polydiexodina*, the extended salients, combined with the impounded re-entrants of the following septum, produce a tunnel-like structure running transverse to the axis of coiling at each crest and trough of the fluting in the antetheca. Interruptions formed by the downward turned edge of septal salients in the earlier volutions are resorbed or excavated so as to form a continuous tunnel-like path throughout the earlier part

of the shell; this path is termed **cuniculus** by DUNBAR & SKINNER (1937). The cuniculi are bordered by the edges of opposing salients and reentrants to give the appearance of septa running transverse to the axis of coiling. The bordering walls of the cuniculi are highly sinuous in primitive forms that have only moderately fluted septa. They are almost straight in forms having intensely fluted septa (Pl. 13, fig. 9).

DUNBAR & SKINNER (1931) were the first to observe the cuniculi in *Parafusulina* and *Polydiexodina*. The structure of the cuniculus has been discussed further by DUNBAR & HENBEST (1942). It was suggested by these workers, and later by THOMPSON (1946), that foramina are developed by the upturned edges of the salients in the antetheca. Further observations seem to demonstrate that the salients in the antetheca do not form foramina, but they turn downward to the top surface of the preceding volution. The lower margins of the salients are later resorbed to develop the continuous tunnel-like cuniculus. In the earlier parts of the shell of *Parafusulina*, only the margins of the salients remain along the borders of the cuniculi (Pl. 13, fig. 9). It is evident that excavation of the cuniculi developed into the auxiliary tunnels of *Polydiexodina* by coalescence of several cuniculi. The necessity of widening of the passageways seemingly was due to the extreme length of shells of *Polydiexodina*.

The antetheca of the shell contains numerous septal pores (Pl. 13, fig. 10). So far as can be determined, none of the fusulinids had an aperture or for-

amina in the antetheca; they depended largely or entirely on the septal pores for external communication. The antetheca of many fusulinids is fluted, and it has seemed quite impossible to determine the total number of septal pores in the antetheca. The relative abundance of septal pores is judged to have no connection with the stage of evolution of the individual. Whether the number of septal pores is constant among individuals of a species is not known, but there is a suggestion that the more highly fluted types of fusulinids have more abundant septal pores than those with less fluting.

Primitive fusulinids characterized by a *Profusulinella*-type spirothecal structure have a septal structure almost identical to that of the spirotheca. All evidence indicates that the spirotheca and the antetheca were deposited simultaneously, for, of tens of thousands of sections of fusulinids examined, none has a partly completed shell for the last chamber. The antetheca of the last chamber of primitive Ozawainellinae, primitive Schubertellinae, and primitive Fusulininae is composed only of the tectum, which seems identical in structure, except for septal pores, to the tectum of the spirotheca. Both the anterior and posterior surfaces of the septa are later covered by tectoria, seemingly simultaneous with the development of the tectorial lining of the chamber, with the development of the chomata, and with the development of the axial fillings, if axial fillings are present.

In highly developed genera of Fusulininae, including *Fusulinella*, *Fusulina*, and *Wedekindellina*,

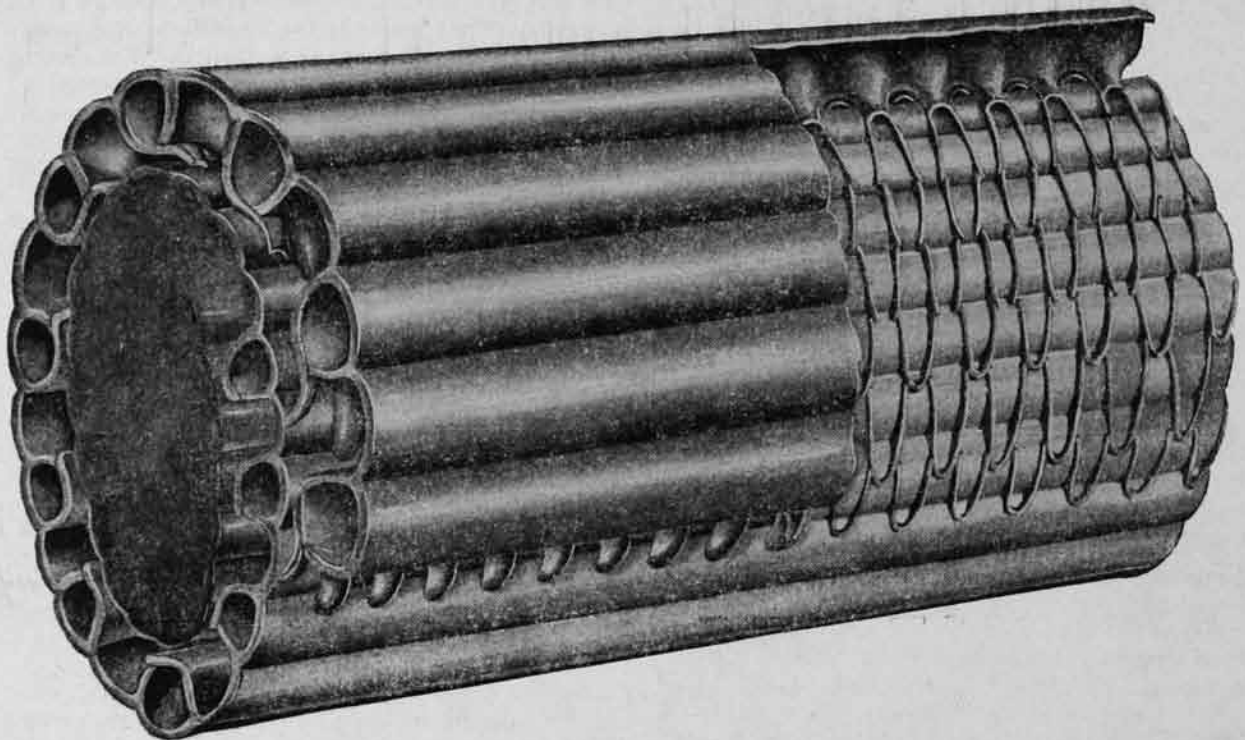


FIGURE 1.—Interpreted development of cuniculi in *Parafusulina* and *Polydiexodina*.

the tectum and diaphanotheca of the spirotheca are deflected downward to form the septum, but the diaphanotheca decreases in thickness rapidly downward from the top of the septum. Also, the diaphanotheca of the spirotheca of the following chamber extends a short distance down the anterior side of the septum. The development of the tectoria on the septa of these genera is similar to that of the more primitive genera, discussed above. However, the tectoria of the more highly developed forms of *Fusulina* are thin and discontinuous or even absent.

The tectum of the spirotheca of Schwagerininae is deflected downward to the base of the antetheca. The keriotheca of the spirotheca of members of this subfamily extends only a short distance down the septa. At the point of downward deflection of the tectum at the top of the antetheca, a dense layer is developed on the posterior side of the tectum in most forms; it seems to wedge in between the anterior edge of the keriotheca and the tectum. This wedgelike structure, which extends to the base of the antetheca with gradually decreasing thickness, has been termed the **pycnotheca**¹ by DUNBAR & HENBEST (1942). The structure of the pycnotheca is similar to that of the wall of the proloculus, that is, dense and uniform. The uniformity of the pycnotheca is broken only by the septal pores. The keriotheca does not resemble closely the pycnotheca, and there seems to be a sharp line of demarcation where they come in contact. The pycnotheca is thickest immediately above the tunnel and thins toward the poles. In many forms of Schwagerininae that have thin septa, the pycnotheca is so tenuous that it can not be distinguished from the thin tectum, or it is absent. In other schwagerinids, the pycnotheca is distinctly thick just below its upper surface but can not be distinguished from the tectum in the lower part of the septum. It has been suggested that the pycnotheca developed from the keriotheca, but its structure strongly suggests that it was formed by the thickening of the tectum.

The antetheca of members of the subfamilies Verbeekininae and Neoschwagerininae is formed by the downward deflection of the tectum of the spirotheca. In forms with thick spirotheca, the keriotheca of the spirotheca extends down both sides of the septa almost to their base, and keriothecal structures can be observed almost to the base of the septa (Pl. 18, fig. 7). In genera having thin keriotheca, such as *Verbeekina*, this layer extends only a short distance down both sides of the septum (Pl. 16, fig. 11).

The lower margins of the septa of many fusulinids, as seen in sagittal sections above the tunnel or above the foramina, are distinctly thicker than the upper part of the septa, resulting in a pendant-shaped cross section. Their cross section is not pendant-shaped in the outer few chambers, how-

ever. This thickening of the lower margins of the septa is due largely, if not entirely, to deposits similar to the chomata and tectoria that are laid down during or shortly after excavation of the tunnel or foramina.

SPIROTHECA

The wall above the chamber is termed the spirotheca (spiral wall). The structure of the spirotheca, which furnishes one of the most reliable criteria for differentiation and classification of many of the fusulinids, is highly complicated, and its evolution has been determined within many branches of the family. The anterior-posterior profile of the top of the spirotheca of most forms turns downward sharply immediately adjacent to the septa, resulting in distinct external septal furrows. The upper surface across the central part of the chamber of most forms conforms closely with the curvature of the volution.

The spirotheca of the most primitive genus, *Millerella*, is composed of a central thin dense layer, the tectum, and adjoining less dense but thicker structureless layers, the **upper tectorium** above and the **lower tectorium** below. The spirothecal structure of most early Middle Pennsylvanian genera is similar to that of *Millerella*. This type of structure is best developed in *Profusulinella* and is referred to as a *Profusulinella*-type of wall. A transparent layer, the diaphanotheca, is developed below the tectum in forms more highly advanced biologically than *Profusulinella*, resulting in a four-layered spirotheca. This sort of spirotheca is referred to as a *Fusulinella*-type of wall. The spirotheca in the outer part of the last volution of mature and submature specimens of *Millerella*, *Profusulinella*, and other primitive forms is composed of a single thin layer. It is evident that the tectoria are deposited later, and that the primary spirothecal structure is composed of a single layer, the tectum. In forms of *Fusulinella*, *Fusulina*, and other genera having a *Fusulinella*-type of spirothecal structure, the last few chambers of both mature and immature individuals have a spirotheca composed of the tectum and the diaphanotheca. Seemingly the primary structure of the spirotheca of these forms is composed of a tectum and a diaphanotheca. The tectoria are of later or secondary origin, developed contemporaneously with the chomata and axial fillings and with the excavation of the tunnel.

The spirotheca of the Schwagerininae is composed of a tectum and a lower thicker layer, the keriotheca. Such spirothecal structure is referred to as a *Triticites*-type of spirotheca. The keriotheca is so named because of its supposed honeycomblike structure.

Although it is evident that the entire spirotheca of a chamber was deposited simultaneously with the septa, it seems clear that the spirotheca continued to grow after completion of its original form. The keriotheca of the last chamber is thinner in most shells than in the immediately preceding chambers.

1. This term, spelled pyknotheca by DUNBAR & HENBEST, is here changed to pycnotheca, in accordance with approved transliteration of the Greek root words.

In submature specimens the keriotheca of the last chamber is thinner than that of the same part of the shell in mature specimens. Thus, the keriotheca seemingly increased in thickness as the shell developed.

Thin sections of the keriotheca show numerous dark lines normal to its surfaces, and these dark lines are separated by larger transparent areas. Sections cut tangent to the surface of the spirotheca show that the transparent areas are somewhat irregular to circular in outline and are surrounded by the darker thin areas (Pl. 13, fig. 8). The transparent areas are called **alveoli**. Most students have interpreted the alveoli as cell-like openings in the keriotheca and the darker thin zones as the enclosing walls of the openings. The keriotheca of many Schwagerininae is divisible into a lower area composed of coarse alveoli and an upper area of small alveoli (Pl. 13, figs. 7, 8). Several smaller alveoli of the upper area are replaced by a single large alveolus below, into which they grade.

GUBLER (1934, 1935) has interpreted the keriotheca as a masonry-like structure, in which the alveoli are coarse crystals of calcite cemented with a more fine-grained calcite impregnated with organic material, the latter less transparent material serving as "mortar." The tectum was interpreted by GUBLER as composed of fine-grained calcite and included organic material.

The spirotheca has been judged by most other workers to be porous. The alveoli decrease in size upward and at least part of them in some forms seem to pass through the tectum. Many thin sections of specimens show fine clear areas that pass through the upper surface of the spirotheca, as indicated in figures published by HAYDEN (1909), THOMPSON (1936d), DUNBAR & SKINNER (1937), DUNBAR & HENBEST (1942), and THOMPSON (1946). Some illustrations (DUNBAR & SKINNER, 1937; DUNBAR & HENBEST, 1942) indicate that fine rodlike transparent structures penetrate the entire wall and even continue through the chomata. These have been interpreted as pores. It must be pointed out that several features of the schwagerinid wall structure leave doubt that the wall was originally porous. Innumerable specimens possessing coarse alveoli reveal no pores passing through the tectum of the outer surface of the spirotheca, even in the last few chambers. In fact, such specimens are far more numerous than those that show possible porelike structures passing through the outer surface of the spirotheca. Spirothecal porosity has not been demonstrated in any specimen of many fusulinid species. Secondary deposits may account for the absence of pores in the tectum of inner volutions, but there is no obvious reason why pores should not show through the tectum in the outer few chambers. Many illustrations indicating porosity of the spirotheca reveal obvious resorption of the upper surface of the spirotheca which has occurred with the de-

velopment of cuniculi or tunnels. This is especially true of *Polydiexodina* and probably of *Parafusulina*.

HENBEST (1937) has stained numerous types of fusulinids and has observed structures of the spirotheca that suggest porosity. Stained specimens of Fusulininae reveal porelike structures that pass through all layers of the spirotheca and through the chomata. As the tunnel is well developed immediately adjacent to the chomal deposits, the necessity for such openings is not obvious. Also, the tunnel is developed when the tectoria are deposited.

The diaphanotheca of some highly developed forms of Fusulininae show a finely striated structure which seems comparable to the alveoli of the Schwagerininae. Most of the Fusulininae do not show a porous structure, but the pores may be too small to observe. Pores have not been observed in the tectum of fusulinids having a *Profusulinella*-type of spirotheca, even in species represented by abnormally large mature shells. It seems important that in large specimens of *Sumatrina* the spirotheca is composed of a single thin layer, but pores have not been observed even in the outer part of the shell.

The porosity of the spirotheca has been especially stressed in recent years by WHITE (1932), DUNBAR & SKINNER (1937), and DUNBAR & HENBEST (1942). The imperforate nature of the spirotheca was especially stressed by GUBLER (1934, 1935). DUNBAR & SKINNER presented the following three points to refute GUBLER's postulate that the alveoli represent clear calcite cemented with finer grained calcite bearing organic material. (1) The crystallographic orientation of the calcite in several adjacent alveoli of at least some specimens corresponds to the orientation of the calcite immediately on the inside of the chamber, indicating that the alveoli were filled with calcite at the same time the inside of the chamber was filled during fossilization. Therefore, the alveoli seemingly were open spaces during the life of the animal and they were filled with calcite coincidentally with filling of the inside of the chamber. (2) The tectum shows dark and light bands, indicating that its structure somewhat resembles keriothecal structure and that the tectum is not a homogeneous layer on which the calcite prisms of the keriotheca were formed, as postulated by GUBLER. (3) DUNBAR & SKINNER observed in deformed specimens from Nevada that at points of compression of the keriotheca the dark lines of the keriotheca are close together and at points of tension the dark lines are much farther apart. This suggests that the alveoli were compressible in the compressed areas, and they were points of weakness in areas of tensional stresses. Therefore, the alveoli seemingly were hollow spaces during this early period of deformation and before complete fossilization.

As pointed out by DUNBAR & SKINNER, the alveoli of all fusulinids are smaller in diameter than the thickness of most thin sections, and consequently it is difficult to observe the crystallographic structure of the materials in a single alveolus. Some fusulinid

shells collected from surface samples have hollow chambers, but shells have not been observed that also have hollow alveoli. Many fusulinid shells have been studied in which the inside of the chambers are filled with chalcedony, but the alveoli in the shells seem filled with calcite and lack chalcedony.

The more primitive members of both Neoschwagerininae and Verbeekininae have a spirotheca in which the lower layer contains alternating dark and less dense areas that resemble closely the structure of the keriotheca of the Schwagerininae. The less dense tubelike features are referred to as alveoli. In the Verbeekininae, the alveoli are about normal to the surfaces of the spirotheca but are more easily identified near the lower surface. In primitive members of the Neoschwagerininae, the keriotheca is thicker than in the Verbeekininae, and the alveoli are slightly broader. Also, in Neoschwagerininae the keriothecal structure extends to the base of the septula. In forms of *Neoschwagerina* having a thick keriotheca, the alveoli diverge as the base of the septula is approached. In some forms this divergence seemingly occurs without the introduction of additional alveoli, and both the alveoli and intervening dark areas merely increase in width. The structure of the septula has been diagrammatically illustrated by many workers, including SCHWAGER (1883), STAFF (1910), DEPRAT (1912b, 1913, 1914), LEE (1933), and GUBLER (1935). The addition of alveoli in the lower part of the septula has not been indicated in any of these illustrations. Axial sections of *Yabeina katoi* from Akasaka, Japan, indicate that the transverse septula in some parts of the shell, especially near the poles in the outer volutions, contain four or five alveoli in this upper area and may have three or four short alveoli added in their lower areas where the alveoli fan out to the edges of the septula. This does not prove that alveoli are added in the lower part of the septula, for alveoli extending down from the tectum may intersect the plane of the thin section near their lower ends and merely seem to pinch out between the alveoli that follow the plane of the section down from the tectum.

Thin dense diaphragm-like partitions that extend across the chambers of *Pseudofusulina* at various angles and in various parts of the chambers are here termed **phrenothecae** (*phrenos*, diaphragm, *theca*, wall) (Pl. 12, figs. 1, 2). The structure of the phrenotheca resembles that of the tectum and seemingly is broken at irregular intervals by small openings similar to the septal pores. The phrenothecae are concave upward in some parts of the chambers and are concave downward in other parts. Most commonly, their edges are attached to the septa, but they may be attached to the floor or roof of the chamber. In forms such as *Pseudofusulina heucoensis* DUNBAR & SKINNER, having less well developed phrenothecae, they are confined to the lower

part of the chambers and are best developed in the region of the tunnel. That they are primary parts of the shell structure is indicated by their occurrence in all specimens of some species collected from widely separated localities. Phrenothecae occur in most if not all species of *Pseudofusulina*, but are found only rarely in species of *Schwagerina*, as defined in this paper. At some localities shells of *Pseudofusulina* contain abundant phrenothecae, but numerous associated shells belonging to other genera, such as *Pseudoschwagerina* and *Schwagerina*, lack them. Therefore, it seems that phrenothecae must have been developed by some biologic structures or conditions in *Pseudofusulina* that are not common to the associated forms of other genera. Their function and origin are not known, but hypotheses are discussed in description of the Family Fusulinidae in Part II.

SEPTULA

The lower surface of the spirotheca of members of Neoschwagerininae contain ridges, septula, that hang down into the chambers. The septula of primitive members are transverse to the axis of coiling, but highly developed members have two sets of septula, one of which is transverse and the other parallel to the axis of coiling. Septula transverse to the axis of coiling are termed **transverse septula**, and those parallel to the axis are termed **axial septula**.

The septula of *Cancellina* are represented by broad short downward protrusions of the keriotheca that correspond in position with the parachomata on the base of the chamber. The alveoli of the keriotheca of this genus extend to the base of the septula without obvious divergence (Pl. 18, fig. 6). The parachomata are in contact with the septula immediately adjacent to the septa, where the parachomata are highest and the septula are longest. The septula are very broad and short in the center of the chamber, and the parachomata are low. The transverse septula of other Neoschwagerininae are long and reach the tops of the parachomata completely across the chambers, except for a small circular opening in the center of the chamber above the parachomata. The alveoli of the keriotheca continue to the base of the transverse septula in *Neoschwagerina* and *Yabeina*, and the alveoli diverge outward as they approach the base of the septula. In many sections it seems that alveoli may have been added in the lower part of the septula between the diverging alveoli that extend from the tectum of the keriotheca (Pl. 20, fig. 3). Short transverse septula, termed **secondary transverse septula**, occur above the foramina in the outer volutions of *Yabeina* and throughout the shell of higher forms. These secondary transverse septula resemble the primary transverse septula in all respects except that they are shorter and narrower. As septula are added, the individual primary septulum, as well as

secondary septula, become narrower. The transverse septula of highly developed fusulinids, such as *Lepidolina* and *Sumatrina*, are very thin and do not contain recognizable alveoli.

Axial septula are not present in *Cancellina*; they first appear in the outer volutions of *Neoschwagerina*. In *Afghanella*, *Sumatrina*, *Yabeina*, and *Lepidolina*, several axial septula are introduced between the septa. The axial septula of *Yabeina* and *Lepidolina* are irregular in length, and their lower margins do not reach the tops of the chambers of the preceding volution. The axial septula of *Afghanella* and *Sumatrina* are short and uniform in length. The upper part of the chambers is divided by the transverse and axial septula into numerous rectangular cubicles.

The structure of the septula of the more primitive forms of Neoschwagerininae, such as *Cancellina* and *Neoschwagerina*, resembles closely that of the keriotheca between the septula. In *Yabeina*, the width of the septula corresponds closely to the thickness of the keriotheca. The spirotheca of *Lepidolina* consists of a single dense layer and the septula are composed of a single dense layer without any recognizable alveoli. Also, the spirotheca of *Sumatrina* is composed of a very thin dense layer, and the alveoli are very thin.

Some paleontologists have suggested that the thin dense septula of highly developed neoschwagerinids are formed by isolation of the walls of alveoli, and that the cubicles between opposing pairs of septula are comparable in structure to the alveoli of more primitive forms. The evolutionary trend of the neoschwagerinids indicates that reduction in the thickness of the septula corresponds to reduction in the thickness of the spirotheca and that the septula are not the bounding walls of enlarged alveoli.

Both the structure and shape of the septula differ considerably among the Neoschwagerininae. The septula of *Yabeina* and *Lepidolina* are variable in length and are sinuous to irregular in shape, but the sinuosity is not regular or uniform. Both the transverse and axial septula of *Sumatrina* are of uniform length, and they are spaced regularly in both directions. The septula of the inner volutions of *Afghanella*, *Sumatrina*, and *Lepidolina* are thicker in their lower margins than near their upper margins. However, the septula in the outer few chambers of these genera are of about the same thickness throughout their heights, and it seems evident that the thick lower margins of the septula of earlier volutions are developed by secondary deposits.

The biologic cause or purpose of the septula is problematical. It has been suggested that they serve as strengthening supports for the shell. However, the first fusulinids to develop septula have a ratio of shell material to open chamber space that is far in excess of most other fusulinids, as well as of many other shell-bearing animals. Furthermore, the fusulinid shell seemingly was filled with cell substance of the animal throughout its development,

and there is no evident source of stresses on the shell. Also, the spirotheca of *Sumatrina* is exceedingly thin and fragile but the septula are shorter and do not seem capable of giving as much support for the shell as those found in more primitive forms having much thicker and stronger walls.

TUNNEL AND FORAMINA

So far as has been demonstrated, the only communication between the inside of the fusulinid shell and the exterior is by means of the numerous septal pores in the antetheca. After the shell developed a few chambers beyond the antetheca of a given chamber, communication with earlier parts of the shell was facilitated by resorption of the lower surface of the septum so as to form a single opening, the tunnel, several widely spaced openings, **multiple tunnels**, or a series of small closely spaced elliptical openings, foramina. About the same time as the development of these openings at the base of the septa, the fusulinid laid down dense deposits of calcite in several parts of the shell. In forms having a single tunnel, ridges of dense calcite, the chomata, were deposited at the sides of the tunnel. Dense deposits similar in structure to the chomata completely lined the inside of the chambers of members of Fusulininae and of primitive members of Ozawainellinae and Schubertellinae. These linings form the tectoria of the spirotheca and septa in forms having a *Profusulinella*- and *Fusulinella*-type of wall structure. Dense deposits, called **axial fillings**, completely fill the chambers in the polar regions of *Wedekindellina*, highly developed forms of *Fusulina*, and all forms of *Quasifusulina*.

Primitive members of Schwagerininae have a single tunnel and massive chomata but no other type of secondary deposits. Highly developed members of the subfamily have small or indistinct chomata and heavy axial fillings. The most highly developed genus of the subfamily, *Polydiexodina*, has multiple tunnels which lack bordering chomata, and the axial fillings are well developed.

Foramina occur in all members of the Verbeekinae and Neoschwagerininae, and all members have parachomata developed to some extent between adjacent foramina. The parachomata of *Eoverbeekina* are poorly developed and extend only a short distance from the septa in the outermost volutions of mature specimens. The parachomata are discontinuous in the earlier volutions of *Verbeekina* but extend completely across the chambers in the outer volutions of mature specimens. All species of more advanced genera have parachomata developed completely across the chambers. Axial fillings occur in some advanced forms of both subfamilies. Also, secondary deposits cover the septa and some parts of the surfaces of the spirotheca of many forms.

The secondary deposits are best developed in chambers having a tunnel or foramina, which seems to mean that these structures are related in origin.

The excavated shell material may have been used to form the secondary deposits. Many specimens have secondary deposits that are too massive to have been obtained entirely from the excavated tunnel or foramina, and accordingly part of the deposits must have come from other sources. The upper tectorium of many forms occurs on the floor of the tunnel, and it must have been partly formed after the excavation of the tunnel. This theory is further supported by the absence of secondary deposits in chambers into which the tunnel does not extend.

With few exceptions, most secondary deposits resemble one another closely in structure. In *Yangchienia*, a clear layer occurs above the tectum of the spirotheca and is overlain by a thick layer of dense calcite similar to the tectoria of other fusulinids. Neither of these upper layers occurs on the floor of the last chamber; obviously, they are deposited as secondary layers on the floor of the chambers. The chomata of many fusulinids are stratified in structure, indicating that they were laid down by stages.

The tunnel and foramina of fusulinid shells were developed by resorption of the lower parts of the septa, for they do not occur in the antetheca at any stage of growth of the individual. The only logical explanation of their development is that they furnished means of communication between earlier chambers, which may have been more needed after the septal pores were partly sealed by secondary deposits on the septa. The purpose served by the secondary deposits is not known.

EVOLUTIONARY TRENDS

GENERAL CONSIDERATIONS

The fusulinid shell seems to have changed in structural features more rapidly than has been recognized in most other large groups of fossils. That the shell structures of the fusulinids changed both rapidly and markedly is made evident by comparing *Millerella* from the basal Pennsylvanian with complex forms from the Permian, such as *Yabeina* and *Polydioxodina*. At first glance these extreme members of the family bear little resemblance, but most of the changes that took place in the shells of forms intermediate between the simple and the complex can be identified in the relative geologic order in which they occurred. During their relatively short geologic span, 6 subfamilies, about 48 genera, and almost 1,000 species developed.

Many evolutionary trends of the fusulinids can be distinguished with assurance, but it should be stressed that much is yet unknown concerning details of the development within the family. The fusulinids had their beginning near the end of the Mississippian Period, and only one genus is recognized in oldest Pennsylvanian rocks. Very shortly after the beginning of Pennsylvanian time, however, three subfamilies represented by six genera and many species have been recognized in both the East-

ern and Western Hemispheres. Therefore, the fusulinids developed along several lines of evolution rather early in their history.

In many provinces that contain abundant fusulinid faunas distributed through great thicknesses of rocks, the fusulinids are so closely spaced in stratigraphic sequence that one may observe almost continuous changes taking place within certain groups of the family. Among many large groups, changes in the shell structure are not only of identical nature but they are found to appear in the same relative geologic order in widely separated areas throughout both hemispheres. In addition, there are widely dissimilar groups of fusulinids that show progressive changes in the same order but at widely different geologic times. Some branches of the family reached ultimate stages of development along certain lines in early Pennsylvanian time, others reached similar stages in early Permian time, and still others did not reach similar stages until late Permian. Therefore, it seems evident that many of these changes were due to evolutionary trends inherent within the family.

Some gradual changes in shell structure of fusulinids in some areas may have been due largely to introduction of more favorable environmental conditions; other changes originating in other areas may represent adaptation to gradually developing adverse conditions. Whatever may have been the causes of some changes in shell structures, there are certain types of progressive alteration that took place in almost all groups of the family, regardless of locality or geologic time. Some of these major changes are summarized below.

(1) The shell became larger. The most primitive fusulinids are minute in size and measure only a fraction of a millimeter in maximum diameter. Almost all highly developed fusulinids are relatively large; indeed, the volume of some advanced forms exceeds that of the most primitive fusulinids by several thousand times.

(2) The shell changed in shape from discoidal to spherical, fusiform, or elongate subcylindrical. The most primitive genus of fusulinid is discoidal; the axis of coiling of its slightly evolute shell is the shortest diameter through the proloculus. Except for two late aberrant genera, all other fusulinids have involute shells. The length of the axis of coiling of most of them increased more rapidly than other diameters of the shell, and most groups developed greatest diameter of the shell along the axis of coiling.

(3) The shell walls became more complex. The most primitive genus has a thin simple wall structure. Later fusulinids have thicker walls of more complex structure, except in several later aberrant genera which contain thin structureless walls.

(4) The antetheca and septa tended to become fluted. The antetheca and septa of primitive fusulinids are straight, but many highly developed fu-

sulinids have antetheca and septa that progressively become more irregular or highly fluted.

These general trends are common to most fusulinids. Many other progressive developments of the shell structures were restricted to parts of the family. Some of the more important of these are (1) development of septula in the Neoschwagerininae; (2) reduction of the chomata in the Fusulininae and later in the Schwagerininae; (3) development of parachomata both in the Verbeekininae and Neoschwagerininae; and (4) development of axial fillings in the Fusulininae, later in the Schwagerininae, and still later in the Verbeekininae and Neoschwagerininae. Some of these changes seem to mark definite evolutionary trends, but others probably reflect a combination of other factors and do not define evolutionary trends.

SIZE

The primitive members of all subfamilies and nearly all genera are smaller than most of the highly developed members. The size of individuals of most types of animals is partly dependent on local environmental conditions, such as food supply, and the average size of mature specimens in one locality may be somewhat different from the average size of mature specimens in another locality. Therefore, a small difference in size alone is not considered a basis for specific differentiation. There is no pronounced increase in shell size among most members of some fusulinid subfamilies. Primitive Schubertellinae were minute (0.4 to 1.3 mm maximum diameter) and so were most Late Permian members (1.3 to 3.0 mm maximum diameter).

Primitive members of the Fusulininae are minute in size (as small as 0.5 to 0.9 mm in maximum diameter), but most late forms are relatively large (as large as 12 mm in maximum diameter). Marked increase in size is especially noticeable among the Schwagerininae, from early *Triticites* (2 to 3 mm) to very large *Polydixodina* and *Parafusulina* (as large as 60 mm); the relative size increase in this subfamily, however, is no greater than that of the Fusulininae. Early Neoschwagerininae, such as *Cancellina*, are small (about 3 mm), but late members, such as *Yabeina*, are large (at least 16 mm).

Although the general trend of fusulinids was toward increase in size of the shell, some forms seemingly developed from slightly larger ancestors.

SHAPE

The classification of fusulinids is based partly on shape of the shell, even though external form, taken alone, is not sufficient for the recognition of many genera. The most primitive fusulinid is discoidal in shape, and the general trend of most later fusulinids is toward a longer axis of coiling. The general shell profile of *Millerella* to advanced members of *Fusulina* is shown diagrammatically in Figure 2. Ozawainellinae progressively changed from a discoidal, slightly evolute shell (*Millerella*) to a spheri-

cal or irregular elongate shell (*Sphaerulina* and *Rausserella*). Schubertellinae evolved from an ellipsoidal shell (*Eoschubertella*) to a very elongate fusiform or irregular shell. Fusulininae developed from a subspherical shell (*Pseudostaffella*) to a highly elongate fusiform to irregular shell (*Fusulina* and *Quasifusulina*). Out of the fusiform shell of primitive *Triticites*, Schwagerininae produced the highly elongate subcylindrical shell of *Parafusulina* and *Polydixodina*. Most early Verbeekininae are subspherical in shape, but very advanced forms, such as *Pseudodoliolina*, are elongate-ellipsoidal in shape. The genus *Brevaxina* has a subspherical shell and strongly umbilicate axial regions, its development and shape being inharmonious to the general trend among fusulinids. The most primitive form of Neoschwagerininae is inflated-ellipsoidal in shape; advanced forms are elongate-subcylindrical to strongly inflated-fusiform in shape. Some of these subfamilies, particularly the Verbeekininae and Neoschwagerininae, possibly are biphyetic, and the similarity of internal structures, as well as shape of the shell, may indicate parallel development.

Although the general tendency among fusulinids was toward development of an elongate shell, possible reversals can be pointed out. A few forms of Schwagerininae, particularly of *Triticites* in the Pennsylvanian and *Pseudoschwagerina* in the Permian, have mature shells that are subspherical in shape. The inner volutions of *Pseudoschwagerina* have far greater diameter along the axis of coiling, and it is solely the outermost volutions that control the subspherical shape of the mature shell. The subspherical or inflated forms of *Triticites* occur stratigraphically above elongate forms, but it can not be demonstrated that the former were derived from the latter.

The genus *Brevaxina* has a short axis of coiling and umbilicate axial regions. Other members of Verbeekininae are spherical in shape or elongate in the direction of the axis of coiling. Evolutionary trends within this subfamily are obscure; probably the assemblage is biphyetic, *Eoverbeekina* and *Verbeekina* having come from one ancestral form and *Brevaxina*, *Misellina*, and *Pseudodoliolina* having come from another.

SPIROTHECA

Rather definite trends in evolutionary development of the spirotheca are seen among fusulinids. These trends took slightly different paths and rates of change in different divisions of the family. The spirotheca of the most primitive fusulinid, *Millerella*, was originally formed above the last chamber as a single thin dense layer. With growth of additional chambers in an individual, this thin layer was covered above and below by secondary layers of tectoria. The evolutionary trend of most fusulinids was to develop a thicker primary wall. The secondary deposits are not present in many specialized forms.

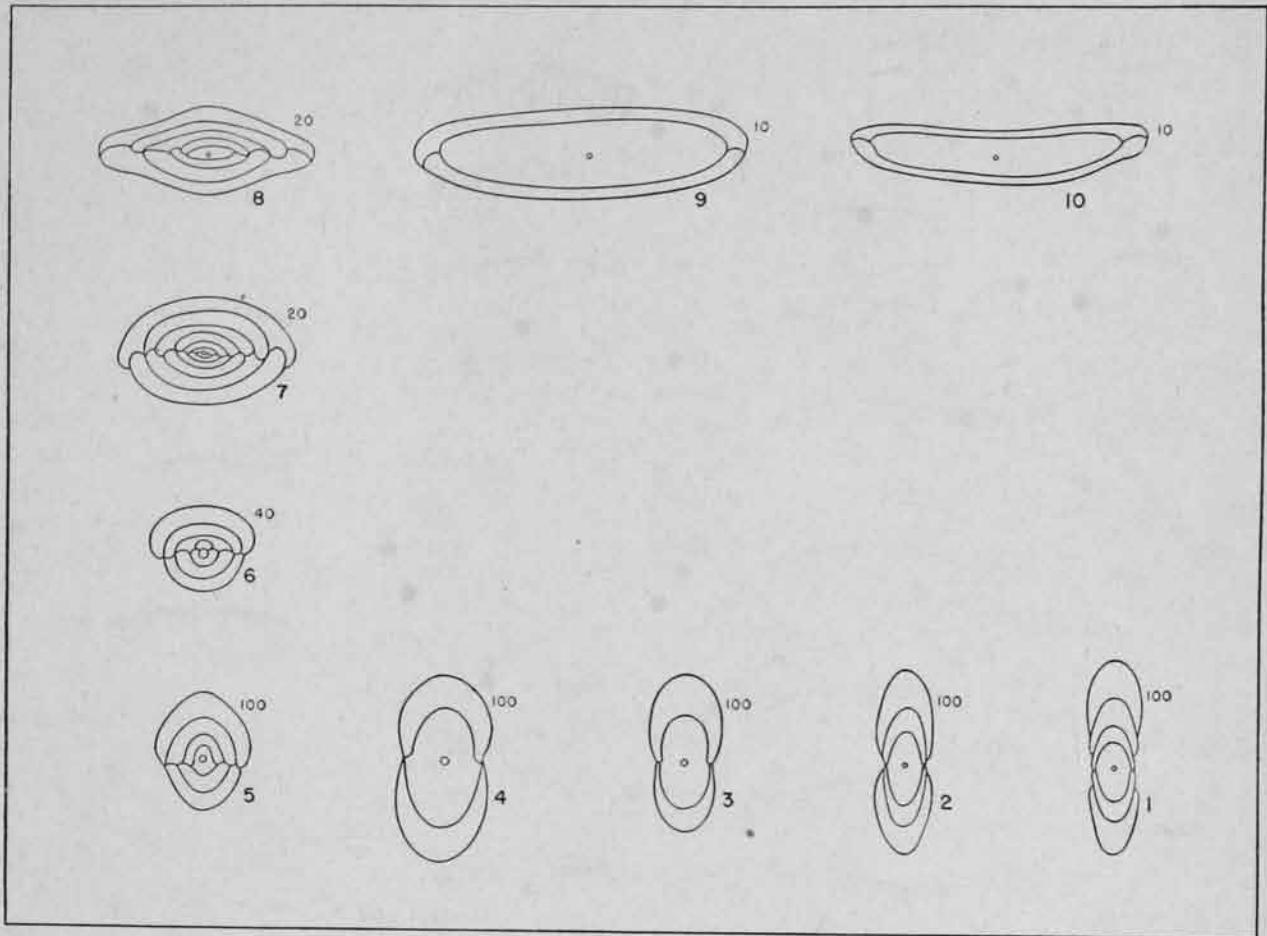


FIGURE 2.—Development of shell shape and size of Ozawainellinae to Fusulininae. 1, *Millerella marblensis*, Marble Falls limestone; 2, *M. pressa*, Kearny formation; 3, *M. pinguis*, Kearny formation; 4, *M. circuli*, Belden formation; 5, *M.?* n. sp., Amsden formation; 6, *Eoschubertella gallowayi*, Boggy formation; 7, *Profusulinella regia*, n. sp., Apodaca formation; 8, *Fusulinella acuminata*, Fra Cristobal formation; 9, *Fusulina mysticensis*, Worland limestone; 10, *F. eximia*, Cooper Creek limestone. (Numbers refer to relative magnifications of outline drawings.)

Among Ozawainellinae, the spirotheca developed from the simple structure of *Millerella* to a wall composed of a thin indistinct upper primary layer (tectum), a lower less dense primary layer (diaphanotheca), and secondary layers of upper and lower tectoria. Some advanced forms of the subfamily seem to have a spirotheca composed only of a tectum and a relatively thick diaphanotheca.

Primitive Schubertellinae have a spirotheca like that of *Millerella*. Highly developed forms have a spirotheca composed of a tectum and a relatively thick lower clear layer, but Late Permian members of the subfamily have a spirotheca throughout the shell that is composed of only a thin dense layer. The evolution of the wall of Schubertellinae is diagrammatically shown in Figure 3.

The evolution of the spirotheca of the Fusulininae seems to be similar to that of the Schubertellinae, but changes took place geologically much more rapidly than in the Schubertellinae. The three-

layered spirotheca of *Pseudostaffella* and *Profusulinella* developed into the four-layered spirotheca of *Fusulinella*. This type of spirothecal structure characterizes all forms of *Fusulina*, with gradually increasing thickness of the diaphanotheca and decreasing thickness of the upper and lower layers. In advanced forms of *Fusulina*, such as *F. cylindrica*, the diaphanotheca is thick and has a structure somewhat like that of the keriotheca of higher forms—the upper tectorium is absent and the lower tectorium is discontinuous. The later forms of Fusulininae, such as *Quasifusulina* and *Gallowainella*, have a thin spirotheca. *Gallowainella* has a spirotheca seemingly composed of a single dense thin layer. This general trend is shown diagrammatically in Figure 3 and illustrated also on Plate 1. The peak of development of the subfamily is in Desmoinesian time, but advanced genera range into the Permian Period.

Schwagerininae were introduced in the lower Mis-

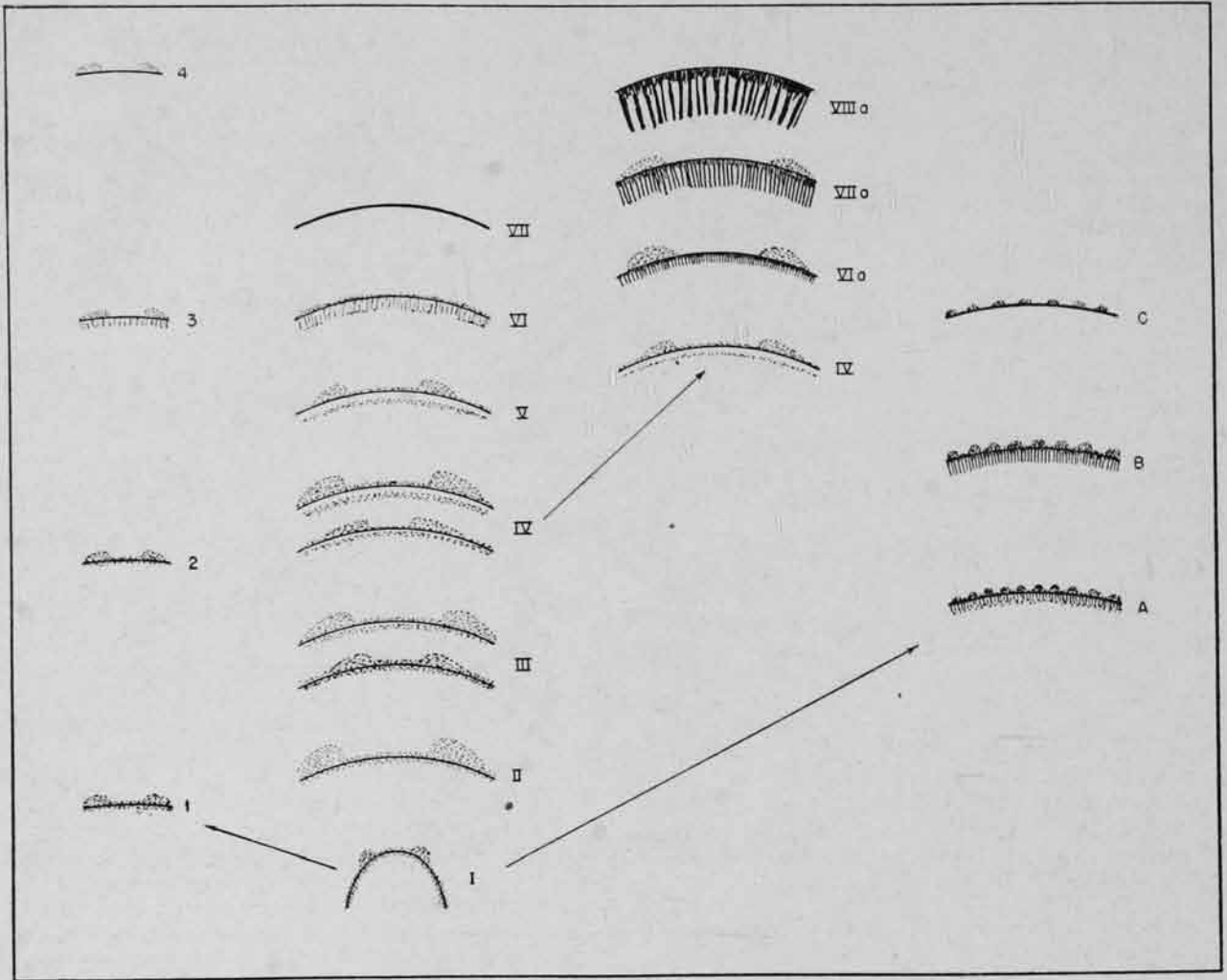


FIGURE 3.—Evolution of the spirotheca of Schubertellinae, Fusulininae, Schwagerininae, and Verbeekininae. Roman numerals denote specimens shown on Plate 1.

1-4.—Schubertellinae.

1, Primitive *Eoschubertella*; 2, highly developed *Eoschubertella*; 3, typical *Schubertella*; and 4, highly developed *Schubertella*.

I.—*Millerella*.

II-VII.—Fusulininae.

II, *Profusulinella regia*; III, *Fusulinella? primaeva*; IV, *Fusulinella juncea*; V, *Fusulina*, n. sp. (intermediate); VI, *Fusulina cylindrica*; VII, *Gallowainella* (idealized).

VIa-VIIIa.—Schwagerininae.

VIa, *Triticites irregularis*; VIIa, *Triticites moorei*; VIIIa, *Schwagerina afghanensis*.

A-C.—Verbeekininae.

A, *Verbeekina verbeeki*; B, *Misellina*; C, highly developed *Pseudodoliolina*.

sourian of America by *Triticites*. Although the ancestral form of *Triticites* is not definitely known, seemingly it was a form closely allied to *Fusulinella*. The spirotheca of *Triticites* is composed of a tectum and a thick keriotheca having clearly visible alveoli. The structure of the spirotheca remained the same in later members, but the keriotheca increased in thickness and the alveoli became coarser. The schwagerinid spirotheca is shown diagrammatically in Figure 3 and illustrated on Plate 1.

The evolution of the spirothecal structure of the Verbeekininae and Neoschwagerininae was somewhat similar to that of the Schwagerininae, except that late genera of both subfamilies possess spirotheca composed of only a single dense layer. This general trend is shown diagrammatically in Figure 3.

It seems evident the evolutionary development of the spirotheca of the fusulinids was toward a thickening of the lower primary layer, the diaphanotheca or keriotheca. All major groups followed the same

general pattern of evolution of the spirotheca independently and at different times, and this trend seems to have been inherent within the entire family.

ANTHETHECA AND SEPTA

The antetheca and septa of the most primitive fusulinids are unfluted from end to end. They are also unfluted throughout the shell in all members of the Ozawainellinae, Verbeekinae, and Neoschwagerininae. Septal fluting developed at different rates in the Schubertellinae, Fusulininae, and Schwagerininae. The septa of primitive Schubertellinae are unfluted. A few highly developed Permian forms of Schubertellinae have septal fluting developed throughout the length of the shell. The septa of Schubertellinae remained unfluted for a long time and never reached a high stage of development, even in the upper Permian. The septa of the most primitive Fusulininae (*Pseudostaffella*) are unfluted throughout the length of the shell. *Profusulinella* has septa fluted only in the extreme polar regions. Septal fluting developed rather rapidly and uniformly in the Fusulininae, from *Pseudostaffella* without septal fluting to upper Desmoinesian *Fusulina* with highly fluted septa throughout the length of the shell, and still further to Upper Pennsylvanian *Quasifusulina* with closely fluted septa. The development of septal fluting in Schwagerininae was rapid. In America, Schwagerininae was first developed in the early part of Late Pennsylvanian time and is represented by *Triticites* having septa fluted only in the polar regions. Before middle Late Pennsylvanian time the septa of some forms were fluted throughout the length of the shell. *Triticites* is first known in the midcontinent region in the upper Bethany Falls limestone, but the forms there are not the most primitive of the genus. More primitive forms of *Triticites* are known from the middle Oquirrh formation of the Wasatch Mountains of Utah and from the lower part of the Upper Carboniferous as designated by RAUSER-CERNOUSOVA, BELJAEV & REITLINGER (1940) in the Samara Bend area of Russia. Highly evolved Permian members of the subfamily (*Parafusulina* and *Polydixodina*) have intensely fluted septa throughout the length of the shell.

Evolution of septal fluting closely parallels that of the shape of the shell. Septal fluting is not developed in groups having discoidal or spherical shells, such as the ozawainellids, verbeekinids, and neoschwagerinids. It first began to form in other groups after the shell assumed a fusiform shape, and reached its highest development in subcylindrical shells. In genera that acquired a fusiform shell only after the shell structures had become very complex, as in *Sumatrana*, septal fluting was never developed.

OTHER TRENDS

Septula.—The appearance and progressive modification of septula in Neoschwagerininae comprise one of the most definite evolutionary developments

among the fusulinids, but septula are restricted to this subfamily. Their development can be traced from the short broad transverse septula of *Cancellina* to the elongate set of broad transverse septula and simple axial septula of *Neoschwagerina*, and still further to the complex sets of transverse and axial septula of *Yabeina* and *Lepidolina*. *Afghanella* and *Sumatrana* contain complicated sets of transverse and axial septula, but the position of these genera within the subfamily is not definitely known. The complexity of their septula does not accord with their geologic occurrence associated with primitive forms of the subfamily, such as *Cancellina* and *Neoschwagerina*. Their ancestral forms are not known.

Chomata.—The chomata of fusulinids having a single tunnel changed with their progressive development, but it is not certain that the changes took definite trends. The chomata of many primitive forms of Fusulininae are massive and large, and the tectoria are correspondingly thick. As the subfamily became more advanced, the chomata became less massive and the tectoria became thinner. In late members of the subfamily the chomata are feebly developed in the innermost volutions and are absent or indistinct in the outer part of the shell. The subfamily Schwagerininae experienced a similar reduction in the chomata. This general reduction in the massiveness of the chomata in late Fusulininae and late Schwagerininae is in reality a reversal of their development in early members of the family, which had small chomata; the chomata gradually became more massive as the early fusulinids evolved.

Parachomata.—Structure features that are progressively developed in the Verbeekinae, and well defined in all members of the Neoschwagerininae, are the parachomata. These are feeble in the outer volutions of *Eoverbeekina* and occur only adjacent to the septa of inner volutions of *Verbeekina* but extend across the chambers of the outer volutions. Advanced forms of Verbeekinae have distinct parachomata throughout the shell.

Axial fillings.—Dense deposits of calcite occur in the axial regions to some extent in all subfamilies except the Ozawainellinae. They are best defined in late members of most of the other five subfamilies. Heavy axial fillings occur in *Wedekindellina* near the middle of the stratigraphic range of the Fusulininae, but it seems probable that *Wedekindellina* is a specialized member of an early branch of the subfamily. The appearance of heavy axial fillings in late forms of Fusulininae and Schwagerininae coincides with reduction of the chomata. Both these features are of secondary origin, and when one is well developed the other is absent or feeble. Axial fillings are inconspicuous in late forms of the Verbeekinae and Neoschwagerininae.

It has been stated by some workers that the development of axial fillings is not constant even

among conspecific specimens. Observations do not bear out these statements. It is difficult to cut axial sections exactly along the axis of coiling, and in forms having thin zones of axial fillings many axial sections fail to intersect these fillings. Accordingly, one may not realize the presence of axial fillings in such specimens unless they are observed during the sectioning procedure. Critical observations of many forms indicate that axial fillings are about equally massive in all conspecific specimens.

PHYLOGENY

The phylogeny of the fusulinids is interpreted from a combined view of their stratigraphic occurrence and progressive changes of their shell structures. Many of the fusulinids are so closely spaced stratigraphically that it is possible to observe details of progressive development, and their phylogeny can be interpreted with considerable assurance.

Some other groups are most common in relatively isolated localities, and their exact stratigraphic relationships to fusulinids of other areas are not well understood. In such cases it is necessary to rely largely on the degree of similarity of shell structures. The genus *Misellina*, for example, which represents the early part of one branch of the subfamily Verbeekinae, does not have a recognized closely similar ancestor, and its relationship to other members of the Verbeekinae is doubtful. The ancestors of *Afghanella* and *Sumatrana* are likewise open to question. Both resemble other members of the Neoschwagerinae in many respects, but obviously they have reached a stage of evolution far in advance of associated primitive members of the family, such as *Cancellina* and *Neoschwagerina*.

The phylogeny and stratigraphic distribution of the family Fusulinidae are diagrammatically represented in Figure 4.

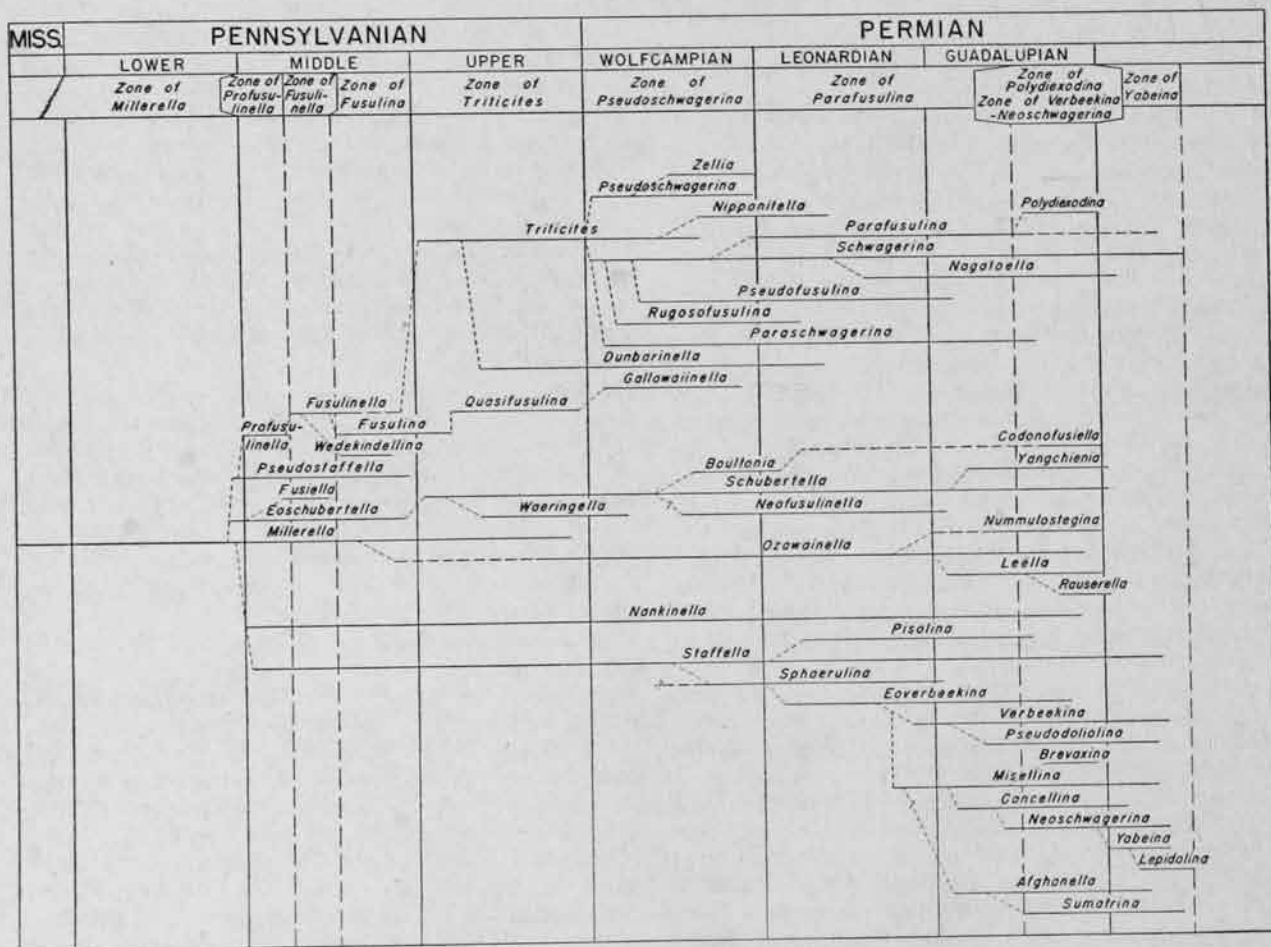


FIGURE 4.—Phylogeny and stratigraphic zonation of Fusulinidae.

STRATIGRAPHIC ZONATION

GENERAL CONSIDERATIONS

Comparison of fusulinid faunas from many localities in America, Europe, and Asia indicates that most larger groups developed along closely similar biological trends and in approximately the same stratigraphic order in all areas. Species have been found very useful as index fossils for stratigraphic correlations in local areas, but the ranges of genera must be employed for interregional as well as intercontinental correlations. Many of the primitive generic groups have long stratigraphic ranges in both hemispheres and are not recognized to be of much value for correlation. The stratigraphic ranges of some more highly specialized genera seem to be closely similar in all areas where studied in America, and their stratigraphic limits seem to be approximately the same in the Eastern Hemisphere. At least it can be demonstrated that the stratigraphic ranges of these genera in Europe and Asia are in the same order as in America.

An outstanding problem in the correlation of American fusulinid faunas with those of the Eastern Hemisphere, which is not yet satisfactorily solved, concerns the Guadalupian *Parafusulina*-*Polydiexodina* faunas of America and the Upper Permian faunas of verbeekinids and neoschwagerinids of the Eastern Hemisphere. The latter faunas are fairly well restricted to a narrow belt that extends west-east from northern Africa and southern Europe across southern Asia into northwestern North America. They are best developed in the Upper Permian of the Tethys Sea. LEE (1939) has shown that primitive forms of these faunas first appear in the lower Chihhsia limestone of China, which contains a typical *Parafusulina* assemblage described by CHEN (1934b). Advanced forms of verbeekinids and neoschwagerinids are found in the Maokou limestone, stratigraphically above the Chihhsia limestone. The magnitude of time separating these two limestones is not known. The *Polydiexodina* fusulinid fauna of the American Upper Permian may represent time corresponding to the hiatus between the Chihhsia and Maokou limestones, or overlapping part of the *Verbeekina*-*Neoschwagerina* span of the Eastern Hemisphere. Perhaps the answer to this problem will come from further studies in China, Japan, or some area in southern Asia.

Fusulinid faunal zones are defined by the predominance of generic groups or restriction of their stratigraphic range. As indicated on the accompanying diagram (Fig. 4), recognized zones are designated: (1) Zone of *Millerella*, (2) Zone of *Profusulinella*, (3) Zone of *Fusulinella*, (4) Zone of *Fusulina*, (5) Zone of *Triticites*, (6) Zone of *Pseudoschwagerina*, (7) Zone of *Parafusulina*, (8) Zone of *Polydiexodina* = (?), (9) Zone of *Verbeekina*-*Neoschwagerina*, and (10) Zone of *Yabeina*.

ZONE OF MILLERELLA

Millerella is the only genus of fusulinids found in Upper Mississippian (Chesterian) and Lower Pennsylvanian rocks in North America, and that part of the section is referred to as the fusulinid Zone of *Millerella*. The genus ranges into post-Lower Pennsylvanian deposits of North America, which are excluded from the Zone of *Millerella* because they carry more advanced forms of fusulinids also. *Millerella* is known from Europe and probably from Asia, but its range there is not known.

ZONE OF PROFUSULINELLA

The genus *Profusulinella* is restricted in America to rocks of early Middle Pennsylvanian age, and that part of the section is referred to as the Zone of *Profusulinella*. In sections of the northwest Urals and Samara Bend of Russia, *Profusulinella* is associated with fusulinids similar to those found in the Pennsylvanian beds of North America. Also, the *Profusulinella*-bearing part of the section in Europe is overlain by rocks containing a fusulinid fauna that in broader aspects resembles the fusulinid assemblage occurring immediately above the Zone of *Profusulinella* in America. A similar occurrence of *Profusulinella* is found in the Pennsylvanian rocks of China. It is therefore evident that the Zone of *Profusulinella* is represented in both hemispheres.

ZONE OF FUSULINELLA

The upper part of the lower Middle Pennsylvanian succession in North America is dominated by faunas of *Fusulinella* and is termed the Zone of *Fusulinella*. Although *Fusulinella* has a stratigraphic range higher in the section, the higher fusulinid faunas that contain *Fusulinella* are dominated by the genus *Fusulina*, and the top of the Zone of *Fusulinella* is placed in America just below the lowest occurrence of *Fusulina*. *Fusulinella* is widespread in Europe and Asia, and it occurs in rocks stratigraphically above the Zone of *Profusulinella*, at least in areas where *Profusulinella* has also been recognized.

ZONE OF FUSULINA

The genus *Fusulina* occurs throughout upper Middle Pennsylvanian rocks of North America above the Zone of *Fusulinella*, and that part of the section is referred to as the Zone of *Fusulina*. The lower boundary of the zone coincides with the top of the Zone of *Fusulinella*. The range of *Fusulinella* overlaps into the Zone of *Fusulina* in Europe as it does in America. The upper stratigraphic limit of *Fusulina* in Europe seems higher than in America, for *Fusulina* is reported to be associated with *Triticites* in the Samara Bend region and in central Russia. Furthermore, the highest forms of *Fusulina* in Russia are more advanced biologically than the highest forms of *Fusulina* in North America. Therefore, the range of *Fusulina* in Eu-

rope probably includes more of the stratigraphic section than in North America. *Fusulina* is widespread geographically in China, and its upper and lower limits in both North and South China seem to be late Middle Pennsylvanian in age.

ZONE OF TRITICITES

The genus *Triticites* dominates the fusulinid faunas of the Upper Pennsylvanian series in North America, and that part of the section is referred to as the Zone of *Triticites*. This zone is distributed from Nevada in the west to Ohio in the east and contains some of the most prolific fusulinid faunas of North America. Rocks referable to the Zone of *Triticites* have not been recognized in Central or South America or with certainty in Asia. Rocks referable to the Zone of *Triticites* are widespread in central Russia, but they may be equivalent in age only to the lower part of the American Zone of *Triticites*. All evidence indicates that *Triticites* reached its greatest development in North America, and its extreme limits as well as intermediate forms are best known here. The upper limit of the Zone of *Triticites* corresponds to the base of the Permian, as defined in North America, but the range of the genus *Triticites* extends into Lower Permian rocks.

ZONE OF PSEUDOSCHWAGERINA

The genus *Pseudoschwagerina* (*Schwagerina* of most authors prior to 1936) is considered by most paleontologists as an index to the Lower Permian. The genus ranges throughout most of the Wolfcampian in North America, and accordingly these rocks are designated as the Zone of *Pseudoschwagerina*. Until recently, the lowest known occurrence of *Pseudoschwagerina* in the Wolfcampian of the midcontinent region was in the Grenola formation, about 300 feet above the base of rocks considered Permian. Undescribed specimens of *Pseudoschwagerina* now have been obtained in the Americus limestone of Kansas (about 200 feet above the base of Wolfcampian strata in this region). *Pseudoschwagerina* is common in uppermost Wolfcampian rocks in the Hueco Mountains of Texas.

The so-called *Schwagerina* limestones of reports on Asia, Europe, and America are really *Pseudoschwagerina* limestone; the use of fossil names for rock units is not good practice, as demonstrated by the erroneous use of *Schwagerina* for so many years.

Rocks of the Zone of *Pseudoschwagerina* occur in many widely separated areas, including the Arctic Islands of the Eastern Hemisphere, European Russia, Austria, Iran, Darwas, Sumatra, China, Japan, French Indo-China, much of central and western United States, Peru, Bolivia, and possibly Greenland.

ZONE OF PARAFUSULINA

The genus *Parafusulina* overlaps slightly the upper stratigraphic limits of *Pseudoschwagerina*, but in North America it dominates the fusulinid faunas of Leonardian and lower Guadalupian strata.

This part of the American Permian is referred to as the Zone of *Parafusulina*. In the Western Hemisphere, rocks referable to the Zone of *Parafusulina* occur in Colombia, Venezuela, Guatemala, southern and northern Mexico, western Texas, southern New Mexico, California, Oregon, and possibly Alaska. The distribution of *Parafusulina* in the Eastern Hemisphere is not well known, due in a large part to the lack in illustrations of early reports of thin sections that are necessary to recognize the genus. Many species of *Parafusulina* may have been described but from available information they can not be referred to that genus with certainty. However, *Parafusulina* has been recognized in the Carnic Alps, Salt Range of India, southern China, Japan, Karakorum, and possibly the western edge of the Ural Mountains.

ZONE OF POLYDIEXODINA

The genus *Polydiexodina* is restricted in North America to rocks of late Guadalupian age that are referred to as the fusulinid faunal Zone of *Polydiexodina*. This zone immediately overlies the Zone of *Parafusulina* in North America. However, *Polydiexodina* has not been found in the Eastern Hemisphere immediately above rocks containing *Parafusulina*. In southern China, rocks bearing typical faunas of the Zone of *Parafusulina* are overlain by rocks that carry a Tethys Sea type of fauna, including *Verbeekina*. In Afghanistan, *Polydiexodina* occurs associated with *Verbeekina* and several early members of Neoschwagerininae, including *Neoschwagerina*. Therefore, it seems possible that the Zone of *Polydiexodina* in America is equivalent in age to at least part of the Tethyan Zone of *Verbeekina-Neoschwagerina*. *Polydiexodina* occurs in Darwas, Burma, Iran, and perhaps in the Aegean Islands of Greece. In the Aegean Islands, a questionable form of *Polydiexodina* is associated with a typical fauna of the Zone of *Verbeekina-Neoschwagerina*.

ZONE OF VERBEEKINA-NEOSCHWAGERINA

The lower part of the Tethys Sea fusulinid faunas of the Eastern Hemisphere is typified by the genera *Verbeekina* and *Neoschwagerina*, and that part of the stratigraphic section is referred to as the Zone of *Verbeekina-Neoschwagerina*. Rocks referable to this zone are widespread in a relatively narrow belt extending from the Mediterranean area of southern Europe across southern Asia to Japan and Australia. Rocks that contain a lower Tethyan fusulinid fauna have been discovered at many localities in this area, including Sicily, Greece, Pamir, Karakorum, Afghanistan, French Indo-China, western and southern China, Sumatra, northwestern Australia, and Japan.

The stratigraphic relationship between this faunal zone in the Eastern Hemisphere and the Zone of *Polydiexodina* in America is not known. The association of *Polydiexodina* with *Verbeekina* and *Neo-*

schwagerina in Afghanistan and possibly in Greece, and the occurrence of *Verbeekina* faunas stratigraphically above typical *Parafusulina* faunas in southern China, strongly suggest that the Zone of *Polydiexodina* in America is at least partly equivalent in age to the Zone of *Verbeekina-Neoschwagerina*.

Ammonoids indicate that the Sosio beds of Sicily are early Guadalupian (Word) in age (MILLER, 1933). The Sosio beds contain several fusulinid genera that occur in other areas in the Zone of *Verbeekina-Neoschwagerina*, and therefore it seems probable that this Tethys Sea faunal zone is in part slightly older than the Zone of *Polydiexodina* in America.

ZONE OF YABEINA

The genus *Yabeina* occurs in some of the highest fusulinid-bearing Permian rocks in the Eastern Hemisphere and has been found in British Colum-

bia, Washington, and Oregon in the Western Hemisphere. *Yabeina* has been identified at numerous localities in the Eastern Hemisphere, including Tunis, Crimea, South China, French Indo-China, and Japan. At several places *Yabeina* is known to occur stratigraphically above faunas of *Verbeekina* and *Neoschwagerina*. Furthermore, the biologic stage of development of *Yabeina* and *Lepidolina* suggests that they are younger than early *Neoschwagerina*. Rocks of Late Permian age that contain faunas of *Yabeina* and *Lepidolina* are referred to the Zone of *Yabeina*. It seems probable that the Zone of *Yabeina* represents the youngest fusulinid-bearing rocks in the Eastern Hemisphere, and that the family Fusulinidae became extinct in the narrow belt of Tethys that extended from Oregon in North America, westward across the northern Pacific region to southern Asia, and farther west at least to Tunis in the Mediterranean area.

PART II

CLASSIFICATION OF FAMILY FUSULINIDAE

INTRODUCTION

Modern classifications of Fusulinidae began with that by OZAWA in 1925, and include those by DUNBAR & CONDRA (1928), OZAWA (1928b), YABE & HANZAWA (1932), GALLOWAY (1933), DUNBAR (1933b), DOUTKEVITCH & KHABAKOV (1934), GUBLER (1935), DUNBAR & SKINNER (1937), DUNBAR (*In* CUSHMAN, 1940), and DUNBAR & HENBEST (1942). These classifications differ especially in the limits allowed for subfamily and generic groups. Two extremes may be mentioned. GUBLER (1935) recognized only 2 subfamilies and 13 genera, but DUNBAR & HENBEST (1942) recognized 4 subfamilies, 35 genera, and 3 subgenera. The classification here proposed recognizes 6 subfamilies, 47 or perhaps 48 genera, and 1 subgenus.²

Sixty-one generic or subgeneric names have been proposed for the family. Of all the generic or subgeneric names proposed, eight are considered synonyms and five are homonyms. As pointed out above, shells of members of the family have a wide range in maximum size from less than 0.4 mm to more than 60 mm. Most have a maximum diameter of 2 to 10 mm, however. All forms have numerous chambers coiled around the proloculus or beginning chamber. The axis of coiling is the largest diameter of most forms, and the shell is fusiform in shape. However, two groups are spherical to subspherical, and another is discoidal in shape, with the axis of coiling the shortest diameter. Most of the fusulinids are involute and planispiral. Members of one genus, *Millerella*, are slightly evolute; and members of two aberrant genera, *Codonofusiella* and *Nipponitella*, are irregularly uncoiled during gerontic stages of growth.

The shell is planispiral throughout growth of most highly evolved members of the family. Some primitive forms have asymmetrical inner volutions and planispiral outer volutions. Occasional specimens of some advanced groups have asymmetrical early volutions.

The beginning chamber or proloculus of most fusulinids is spherical to subspherical in shape, but some advanced forms have irregular proloculi. The chambers increase in size gradually among most members. Among some, particularly the genera *Pseudoschwagerina* and *Paraschwagerina*, the chambers increase in size gradually during the first one to four coils and then rapidly increase in height. The chambers of gerontic individuals of most genera decrease in height slightly in the last volution, re-

sulting in slightly more tightly coiled outer volutions.

The shell is calcareous, and there is no single aperture. The front wall or antetheca is coarsely perforated by septal pores. Secondary deposits close the pores of the septa after the shell develops a few chambers beyond, and the lower parts of the septa are resorbed to form singular or multiple tunnels or foramina for communication with early chambers. Dense calcite is deposited secondarily as chomata along the tunnel and as filling in axial regions. No fusulinid is known that does not have secondary deposits to some extent. The presence of a secondarily resorbed tunnel or foramina and of secondary deposits in the form of chomata or parachomata and axial fillings distinguishes the family.

The shells of most fusulinids are calcareous, but those of some genera now included in the family, such as *Staffella s. s.* and *Nankinella*, are replaced by secondary mineralization. However, associated shells of fusiform and more typical fusulinids are, in many cases, not replaced by secondary mineralization. This suggests that some groups referred to the family may not have had the same original shell composition as that of *Fusulina*, the type genus of the family.

Practically all *Pseudofusulina* and a few *Schwagerina* and *Parafusulina* have thin dense structureless layers that cut irregularly across the chambers, hang down like diaphragms or curtains, and completely divide the chambers. These thin layers ("false walls") are named **phrenothecae** above. Their origin is problematical. DUNBAR & SKINNER (1937) suggested that they may have been formed on top of the protoplasm in the chambers at times when the animal partly withdrew from the shell. It should be pointed out that the phrenothecae are present most commonly in highly inflated and loosely coiled specimens. It seems logical that specimens having such spacious shells may not have completely filled the shell at all times. In other words, they outbuilt their growth. It also seems plausible that adverse climatic conditions or food supply may have caused the cell to decrease in size so that it could not completely occupy all the shell formerly built. Therefore, the phrenothecae may have been deposited as protective coverings around vital parts of the cell. On the other hand, it should be pointed out that many fusulinids with even more spacious shells than *Pseudofusulina* seldom if ever possess phrenothecae, even where associated with *Pseudofusulina* having abundant phrenothecae.

2. See Addendum, p. 67.

The septa have a composition similar to that of the spirotheca, but they may differ markedly in structure from that of the spirotheca. The septa of most fusulinids are about normal to the overlying wall or spirotheca, but those of early members of the family are arcuate anteriorly, or extend forward at small angles. The septa of Ozawainellinae, Verbeekinae, and Neoschwagerininae are almost plane. The septa are plane in primitive genera of the other three subfamilies but are undulate or fluted in more advanced genera. Septula are confined to the Neoschwagerininae. *Cancellina* has a set of transverse septula. More advanced genera of the subfamily have transverse septula and primary and secondary axial septula.

SUBFAMILY OZAWAINELLINAE THOMPSON
& FOSTER, 1937

The subfamily Ozawainellinae THOMPSON & FOSTER (1937) includes fusulinids having a minute shell, short axis of coiling, involute or evolute shell, slightly extended or umbilicate axial regions, and angular to rounded periphery. Most members of this subfamily have a discoidal shape and angular periphery during some stage of growth. Some have a discoidal juvenile shell and a subspherical mature shell. The shells are planispiral throughout growth, excepting those of one late Permian genus of an aberrant nature referred with question to this subfamily. The tunnel is low, and its path is straight. Chomata are developed throughout most of the shell. In some it is high, asymmetrical, and broad; in others it is poorly developed. The walls or spirotheca of primitive genera are composed of the tectum, covered above and below by much thicker but less dense layers of tectoria. The septa of these primitive genera have the same structure as the spirotheca. A clear layer, the diaphanotheca, is introduced below the tectum in more advanced genera. The spirotheca of some of the most advanced genera is composed only of a tectum and a lower less dense layer, the diaphanotheca.

The test of several genera of this subfamily is calcareous and is identical to that of members of the typical subfamily Fusulininae. However, the tests of all known forms of *Nankinella*, *Staffella*, *Sphaerulina*, and *Pisolina* are completely replaced by secondary mineralization of chert or carbonates. Therefore, the original shell composition of these genera is not known.

Primitive members of this subfamily are considered ancestral to Schubertellinae, Fusulininae, and Schwagerininae. Highly developed members of the subfamily seem to be ancestral to Verbeekinae and perhaps Neoschwagerininae.

As would be expected, genera and species of Ozawainellinae have long stratigraphic ranges, and few are good index fossils. Members of the subfamily are known from rocks of late Mississippian (Ches-
terian) age to the highest fusulinid-bearing part of the Permian.

GENUS MILLERELLA THOMPSON, 1942

Plate 2, figures 1-3; Plate 23; Plate 24

GENOTYPE.—*Millerella marblensis* THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 405-407, pl. 1, figs. 3-14 (Holotype illustrated by fig. 5, pl. 1).

Millerella THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 404, 405.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 92.—THOMPSON, 1944, Kansas Geol. Survey, Bull. 52, p. 419, 420.—THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 44-49.

Fusulinella [part] of authors prior to 1925. [Not MÖLLER, 1877.]

Staffella [part] of authors.

Orobias [part] GALLOWAY & HARLTON, 1928, Jour. Paleontology, vol. 2, p. 348, 349.—GALLOWAY & RYNIKER, 1930, Oklahoma Geol. Survey, Circ. 21, p. 14, 15.—HARLTON, 1933, Jour. Paleontology, vol. 7, p. 11.—GALLOWAY, 1933, Manual Foraminifera, p. 396, 397. [Not d'EICHWALD, 1860.]

Ozawainella [part] THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 114, 115.

The shell of the genus *Millerella* THOMPSON is minute, discoidal, and possesses a short axis of coiling and narrowly rounded to subangular periphery. It is planispiral throughout growth. The inner three to four volutions are involute and outer volutions are slightly to distinctly evolute. One primitive undescribed species from basal Middle Pennsylvanian rocks of Texas is completely uncoiled in the last few chambers. More advanced forms are only slightly evolute in the outer part of the last volution. All known forms are minute in size and measure less than 1.0 mm in maximum diameter. Most forms are less than 0.5 mm in maximum diameter. The form ratio of axial length to maximum diameter is small, being 0.2 to 0.6. The spirotheca is composed of a tectum and upper and lower tectoria; in the outer few chambers it is composed only of the tectum. The tunnel is high and narrow, and its path is straight throughout the shell. Chomata are asymmetrical and broad. The septa of primitive forms are convex anteriorly above tunnel but are more strongly convex in polar regions. The septa of highly evolved forms are plane and normal to the spirotheca above the tunnel but are slightly convex in the polar regions. The shell expands uniformly. The periphery of the inner volutions of all forms are rounded, but it is subangular in the outer volutions of some forms.

Millerella can be distinguished from other closely similar genera by the discoidal shape of the shell and the evolute development of the outer volutions. It is closely similar to *Ozawainella*, but it can be distinguished from that genus especially by its evolute outer volutions and its rounded periphery, at least in parts of the shell.

Nummulostegina SCHUBERT is too poorly known for close comparison. In any case, so far as known, the shell of *Nummulostegina* is involute.

Millerella is known in America from rocks of latest Mississippian and Pennsylvanian ages. It is ex-

ceedingly abundant in Lower Pennsylvanian and in lower Middle Pennsylvanian rocks, is less common in upper Middle Pennsylvanian rocks, and is rare in Upper Pennsylvanian rocks. The geographic and stratigraphic distribution of *Millerella* in Europe and Asia is not well known. However, it is present in the Huanglung limestone of China. Specimens have been observed associated with *Profusulinella aljutovica* RAUSER-CERNOUSSOVA and *Pseudostaffella compressa* RAUSER-CERNOUSSOVA in rocks of lower Middle Pennsylvanian age in well samples from Samara Bend, Russia.

GENUS OZAWAINELLA THOMPSON, 1935

Plate 2, figures 14-16

GENOTYPE.—*Fusulinella angulata* COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 74, 75, 132, 133, pl. 2, figs. 12-14, 16-18, 20, 21, 35 (All of holotype). [Not pl. 2, figs. 4-11, 26, 34.]

Ozawainella THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 114, 115.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 132, 133.—DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 599, 600.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 139.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 76, 77.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 489 (footnote).—TORIYAMA, 1944, Japanese Jour. Geology and Geography, vol. 19, no. 1, p. 69.—TORIYAMA, 1945, Japanese Jour. Geology and Geography, vol. 20, no. 1, p. 3.

Fusulinella [part] COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 131-134, and authors prior to 1925. [Not MÖLLER, 1877.]

Staffella [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 24.—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 131.—LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., vol. 9, p. 117.—DOUTKEVITCH, 1934, Inst. Géol. Naph., Mém., sér. A, vol. 55, p. 17.

Ozawaina [part] LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 13.

Orobias [part] GALLOWAY & HARLTON, 1928, Jour. Paleontology, vol. 2, p. 348, 349.—GALLOWAY, 1933, Manual Foraminifera, p. 396.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 14.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 60. [Not d'EICHWALD, 1860.]

The shells of *Ozawainella* THOMPSON are minute in size and discoidal in shape. They have a sharply angular periphery and are planispiral and involute throughout. Mature shells are composed of five to ten volutions and have maximum diameters of 1 mm for smaller forms and 2 to 4 mm for larger forms. The form ratio of axial length to width of the genotype and other highly discoidal species is 0.25 to 0.70. The umbilical area is convex. The lateral slopes are steep and flat in many species, including the genotype. The spirotheca of most forms is thin, being composed of a tectum and thin less dense upper and lower tectoria. Some large forms have thicker walls that seem to have four layers as in *Fusulinella*, but most of these are highly replaced by secondary mineralization and the spirothecal structure can not be determined with certainty. Septa are numerous. In some forms they are normal

to spirotheca above the tunnel, while in others they extend forward at small angles. In the polar regions, the septa are arcuate, at least in some forms. Septa are plane. The tunnel path is straight. Chomata are asymmetrical and are developed throughout most of shell.

The genus *Ozawainella*, as thus defined, includes a rather large variety of forms and may be polyphyletic. Some species included in the genus, such as *Ozawainella huecoensis* DUNBAR & SKINNER, have shell material that is entirely replaced by secondary mineralization. These forms are associated with numerous schwagerinids that are not replaced by secondary mineralization, suggesting that the original shell structures may not have been the same. Other *Ozawainella* occur in similar rocks but are not replaced, further suggesting that the two types of forms referred to this genus had different original shell structures and may not be congeneric.

The characteristics by which this genus may be distinguished from closely similar genera of this subfamily are the angular periphery throughout the shell, the involute shell, and the more or less uniform profile of all volutions. Several forms of *Millerella* attain an angular periphery near maturity. However, they do not have angular periphery in the earlier parts of the shell and the shell becomes evolute at maturity.

The genus *Nankinella* LEE is not well understood, but the genotype has discoidal early volutions with angular periphery and subdiscoidal outer volutions having rounded periphery. Fusulinids having sharply angular early volutions and rounded periphery in later volutions, as well as forms having rounded periphery in early volutions and angular periphery in later volutions, are being included in the genus *Nankinella*. Many forms of *Nankinella*, including the genotype, are umbilicate.

LEE (1927) proposed *Ozawaina* as a provisional name for a subgenus of *Fusulinella*, as *Fusulinella* was defined by LEE at that time. *Ozawaina* was to apply to the lenticular forms of *Fusulinella*, should the necessity later arise. No species was mentioned by LEE and hence no type was designated. GALLOWAY (1933) designated *Nummulina antiquior* ROULLIER & VOSINSKY (1849) as the genotype of *Ozawaina* LEE. *N. antiquior* is also the genotype of *Orobias*, which automatically made *Ozawaina* a synonym of *Orobias*. *Orobias* seemingly is not a fusulinid.

Ozawainella has a wide geographic distribution and is known from America, Europe, and Asia. It is best developed in the Permian of America and Asia. The distribution of *Ozawainella* in rocks of Pennsylvanian age is not well known. It is reported from the Pennsylvanian of Russia and Japan. Several species that may prove to be referable to *Ozawainella* have been described from the Pennsylvanian of America. Thin sections have not been illustrated of most of them, however, and their in-

ternal structures are not known. *Ozawainella* possibly has a stratigraphic range throughout the Pennsylvanian of European Russia.

GENUS NANKINELLA LEE, 1933

Plate 2, figures 10-13; Plate 25, figures 13-16

GENOTYPE.—*Staffella discoides* LEE, 1931, Geol. Soc. China, Bull., vol. 10, p. 286, 287, pl. 1, figs. 1, 1a (Holotype here designated as specimen illustrated by LEE as fig. 1, pl. 1). [Not *Nankinella orbicularis* LEE, 1933 (DUNBAR & SKINNER, 1937).]

Nankinella LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 14-16.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 19.—DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 560.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forams Fossil Fauna U. S. S. R., Vol. 6, Permian, p. 32.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 143.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 77.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 489.

Fusulinella [part] of authors prior to 1925.

Staffella [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 24.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 14.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 140.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 73 (1927).—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 131.

Ozawaina [part] LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 13.

Orobias [part] GALLOWAY, 1933, Manual Foraminifera, p. 396, 397, [Not *Orobias* EICHWALD, 1860.]

All species of the genus *Nankinella* LEE are small. Their shells are discoidal and planispiral throughout, possessing a short axis of coiling and convex or umbilicate axial regions. Mature specimens of eight to fourteen volutions are as large as 6.5 mm in maximum diameter. In some forms the periphery is broadly angular throughout the shell. In others, the first three to four volutions have narrowly rounded periphery, but the outer volutions have broadly angular periphery. The genotype is poorly known; illustrations indicate that thin sections of the type specimens are not centered or well oriented. The periphery of the inner volutions of the genotype seem sharply angular, but the outer volutions have a more rounded periphery. LEE seemingly had a different concept of the genus when he proposed it, for, although he designated *Staffella discoides* as the genotype, his description indicated that he considered the periphery was angular at maturity. However, the genus must be based on the poorly known genotype and not on some better understood species now referred to the genus.

The type specimens of *Staffella discoides*, the genotype, are highly replaced by secondary mineralization, and their detailed shell structures are not easily determined. LEE's illustrations indicate that the walls are relatively thick; and, as LEE pointed out, the diaphanotheca, if such is present, can not be distinguished easily from the inner layer. The tunnel is narrow, and its path is straight. Septa

are numerous, unfluted, and extend forward slightly. Chomata are low and highly asymmetrical.

All known species of *Nankinella* are so highly replaced by secondary mineralization that the detailed structure of the wall and septa can not be determined. Also, the type specimens of the genotype are too poorly oriented to determine with certainty the form of the shell. Therefore, the genus is partly interpreted from species other than the genotype. As here interpreted, *Nankinella* is distinguished from *Ozawainella* by the more inflated shell, relatively longer axis of coiling, less sharply angular periphery throughout the shell, and umbilicate axial zones of *Nankinella*. *Ozawainella* has sharply angular periphery throughout the shell and is not umbilicate.

As based on LEE's illustrations of the genotype, *Nankinella* is similar to *Staffella*, and they may be synonymous. The genotypes of both have discoidal early volutions and outer volutions with more rounded periphery. As interpreted here, however, *Nankinella* has more nearly angular outer volutions.

Species referred to *Nankinella* are widespread geographically and are common in the Permian of Europe, Asia, and America, and in the Pennsylvanian of America and European Russia. The most primitive American forms here referred to the genus are in the Marble Falls limestone of central Texas, and in basal Middle Pennsylvanian rocks of western Texas and southern New Mexico. Forms have been referred to *Nankinella* from the Paseo Hondo formation (Leonardian) of Central America, and congeneric forms are known from the Wolfcampian of western Texas and southern New Mexico. In Asiatic and European Russia, *Nankinella* ranges throughout the Pennsylvanian and Permian, including such forms as *Nankinella preobrajenskyi* (DOUTKEVITCH) in the Pennsylvanian of the western side of the Middle Urals and *Nankinella caucasica* DOUTKEVITCH from the Darwas series of Darwas. The genotype is from the Chihhsia limestone of the Nanking Hills, China.

GENUS STAFFELLA OZAWA, 1925

Plate 2, figures 4-9; Plate 25, figures 1-12

GENOTYPE.—*Staffella moellerana* THOMPSON, 1935 = *Fusulinella sphaerica* MÖLLER, 1878, Acad. Sci. St.-Petersbourg, Mém., VII^e sér., tome 25, no. 9, p. 114-117, pl. 5, figs. 6a-6d, pl. 15, figs. 3a, 3b (Holotype here designated as specimen illustrated by MÖLLER as fig. 3a, pl. 15). [Not *Fusulina sphaerica* ABICH, 1858.]

Staffella (emend.) THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 407-411.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 490, 491.

Staffella [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 24.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 14.—LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 13.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 73 (1927).—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 131.—LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 114.—GALLOWAY, 1933, Manual Foraminifera, p.

397.—SILVESTRI, 1933, Istit. Geol. R. Univ. Padova, Mem., vol. 10, p. 13.—DOUTKEVITCH, 1934, Oil Geol. Inst., Trans., ser. A, vol. 36, p. 14-42.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 60, 61.—THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 113-117.—DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 597.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 34.—RAUSER-CERNOUSSOVA and BELJAEV, 1940, Geol. Oil Inst., Trans., new ser., fasc. 7, p. 35.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 76.

Fusulina [part] authors prior to 1878.

Fusulinella [part] authors prior to 1925.

All shells of the genus *Staffella* OZAWA are small, subspherical, planispiral, and umbilicate at maturity, possessing a rounded periphery and an axis of coiling that is less than the width. Mature shells contain six to twelve volutions, and some specimens measure 3 to 4 mm in maximum diameter. The proloculus is relatively small. Early volutions are discoidal, possessing a subangular or narrowly rounded periphery. The shell is umbilicate throughout growth, including all volutions except possibly the first to third. The tunnel is low, and its path is straight. Chomata are low and highly asymmetrical. The shell material of all species is highly replaced by secondary mineralization; therefore its original composition is not known. The spirotheca of some better preserved specimens seems to contain four layers, consisting of a tectum, a diaphanotheca, and upper and lower tectoria. Replacement is so nearly complete in most specimens that the original wall structure is obscure. The septa are numerous and are unfluted throughout the shell.

As in all species of *Nankinella* LEE and *Pisolina* LEE and most species referred to *Ozawainella* THOMPSON, the shells of all known species of *Staffella* seemingly have been completely replaced by secondary mineralization, and their detailed wall structures are obscure. Therefore, it can not be demonstrated that all forms here referred to *Staffella* have the same detailed spirothecal and septal structures. MÖLLER (1878) illustrated the type specimens of *Staffella moellerana* THOMPSON as having a four-layered spirotheca as in *Fusulinella*. However, it has been observed in numerous fusulinids with a three-layered spirotheca that if the specimens are replaced by secondary mineralization, the spirotheca may seem to have four layers. This may result from different stages of replacement. In general, the walls of Lower Pennsylvanian forms referred to *Staffella* are thinner than those from the Permian.

Species of *Staffella* may be distinguished from other closely similar genera by their planispiral shell, discoidal inner volutions, umbilicate axial regions, low broad chomata, broadly rounded periphery of outer volutions, and small proloculus. *Pisolina* LEE has a spherical shell of about the same shape throughout all volutions, only slightly if at all umbilicate polar regions, unusually large proloculus, and narrow and highly asymmetrical but

well defined chomata. LEE stated that *Pisolina excessa* LEE, the genotype of *Pisolina*, has a tectum and ill-defined keriotheca; but it is not certain from LEE's illustrations or descriptions that the wall structure of *Pisolina* is greatly different from that of *Staffella*.

Staffella can be distinguished from *Nankinella* by the more rounded periphery at maturity and more deeply umbilicate axial regions of the former. These genera are commonly associated from the basal Pennsylvanian to the Upper Permian, and their preservation generally is about the same. They seem to be closely related biologically.

For many years Pennsylvanian fusulinids now referred to *Pseudostaffella* THOMPSON were referred to *Staffella*. However, *Pseudostaffella* does not seem to be closely related biologically to *Staffella*. Their only major point of similarity is that mature shells of both are subspherical. The inner volutions of most *Pseudostaffella* are coiled at large angles to the outer volutions. Also, the chomata of *Pseudostaffella* are relatively much more massive and broader, their proloculi are relatively larger, and the shells of mature specimens are smaller. The original shell composition of these genera seemingly was markedly different.

LEE (1933) pointed out at the time he proposed *Eoverbeekina* that it may in reality be a synonym of *Staffella*. In general size, shape, and shell development the type species of these genera do seem closely similar. However, many forms that have been studied closely from the Pennsylvanian and Permian resemble the genotype of *Staffella* but do not contain foramina as found in *Eoverbeekina*.

Staffella is widespread in rocks of early Middle Pennsylvanian to Late Permian age. They are known from America in rocks of earliest Middle Pennsylvanian and Leonardian ages. In European Russia, representatives of *Staffella* are abundant in rocks of Pennsylvanian age. The genotype is from the Upper Permian Arax sediments (Djulfa beds) of Armenia and Azerbaijan. Unnamed congeneric specimens have been illustrated from the Middle Permian of Kweichow, China.

GENUS *PISOLINA* LEE, 1933

Plate 3, figures 15, 16

GENOTYPE.—*Pisolina excessa* LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 19, 20, pl. 3, figs. 3, 3a, 3b (Holotype here designated as the specimen illustrated by LEE as fig. 3b, pl. 3).

Pisolina LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 19, 20.—DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 561.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 35.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 143.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 76.

The genus *Pisolina* LEE has a small shell that is almost perfectly spherical, possessing rounded or only slightly depressed polar regions. Mature shells

of seven to eight volutions measure 3 to 4 mm in diameter. The form ratio is about the same throughout growth of the shell. The spirotheca is thin and its structure was described by LEE as composed of a tectum and an ill-defined keriotheca. The spirotheca as observed from illustrations of the genotype seems to have the same structure as in most other Permian members of the subfamily. The proloculus is extremely large; its maximum diameter measures about 1 mm. The tunnel is singular and its path is slightly irregular. Chomata are well defined, low, and highly asymmetrical. The septa are straight.

Only two forms of this genus have been described: *Pisolina excessa* LEE, the genotype, from the lower Wushan limestone of southern China, and *P. abichi* DOUTKEVITCH from the Djulfa beds of Armenia. The shells of both these species seemingly have been completely replaced by secondary mineralization, and the true structure of the wall is difficult to determine.

Pisolina closely resembles *Sphaerulina* LEE in general external features. However, the early portions of the shells of these genera are quite different. In *Sphaerulina*, the proloculus is minute, the early three to four volutions are discoidal, and the spirothecal structures seem to be different. *Pisolina* differs from *Staffella* in the spherical shape of the shell throughout growth of the individual and the large proloculus of the former.

Pisolina is known only from the Permian of Asia.

GENUS SPHAERULINA LEE, 1933

Plate 3, figures 11-14

GENOTYPE.—*Sphaerulina crassispira* LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 17, pl. 1, figs. 2-2b, 3a (Holotype here designated as the specimen illustrated by LEE as fig. 3b, pl. 1).

Sphaerulina LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 16, 17.—DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 560.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 143.

The genus *Sphaerulina* LEE is based entirely on the genotype. The shell is small, spherical, and planispiral throughout growth. Mature shells of ten volutions measure about 2 mm in diameter. The proloculus is minute. The first three to four volutions are discoidal; later volutions have broadly rounded periphery. The axial regions are convex in earlier volutions but are slightly umbilicate at maturity. The tunnel is singular. Chomata are low and highly asymmetrical. The spirotheca was originally described as composed of tectum and finely alveolar keriotheca. The septa are unfuted.

LEE states that the spirotheca is composed of a tectum and keriotheca having fine alveoli. However, the shell is highly replaced by secondary mineralization; therefore, details of shell structure can not be determined with certainty.

Sphaerulina resembles *Pisolina* in general size and shape. However, *Sphaerulina* has a smaller pro-

loculus, a discoidal early shell, and possibly a different spirothecal structure. *Sphaerulina* is difficult to distinguish from *Staffella*. Their spirothecal structures may be different. LEE mentioned that secondary tunnels or foramina occurred at the base of the septa in the last few chambers of *Sphaerulina*, suggesting that *Sphaerulina* may in reality be a synonym of *Eoverbeekina*. LEE observed the close similarity between *Eoverbeekina intermedia* LEE, the genotype of *Eoverbeekina*, and *Staffella moellerana* THOMPSON, the genotype of *Staffella*, and he suggested that they may be congeneric. It is possible that *Sphaerulina crassispira* and *Staffella moellerana* may be congeneric.

Sphaerulina is represented by only one species, the genotype, from the Permian at Kweichow, China.

GENUS LEËLLA DUNBAR & SKINNER, 1937

Plate 3, figures 6-10

GENOTYPE.—*Leëlla bellula* DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 604, 605, pl. 46, figs. 1-15 (Holotype here designated as the specimen illustrated by DUNBAR & SKINNER as figs. 5, 14, pl. 46).

Leëlla DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 603.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 139.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 77.

The shells of the genus *Leëlla* DUNBAR & SKINNER are minute and inflated fusiform to ellipsoidal, possessing a straight axis of coiling. The axis of coiling is the shortest diameter in the inner two to four volutions and the periphery is narrowly to broadly rounded. The axis of coiling in the outer two to three volutions is the largest diameter, and the periphery is very broadly rounded. The change from a discoidal first volution to a fusiform mature shape is uniform. The septa are numerous and unfuted throughout the length of the shell. The septa extend forward at a small angle. The spirotheca is composed of tectum, diaphanotheca, and upper and lower tectoria. The tunnel is singular and its path is straight. The chomata are highly asymmetrical and broad, having steep tunnel sides and low poleward slopes. The chomata extend almost to poles in the inner volutions of the genotype.

The genus *Leëlla* is assigned with question to the subfamily Ozawainellinae. As pointed out by DUNBAR & SKINNER (1937, p. 603), *Leëlla* is closely similar to *Sphaerulina* except that the outer volutions of *Leëlla* are fusiform.

Leëlla is similar to *Rauserella* in many respects. However, the inner discoidal part of the shell of *Rauserella* is coiled at a large angle to the coiling of the outer irregularly fusiform volutions. The mature shape of *Rauserella* is irregular and that of *Leëlla* is uniform. Also, the spirothecal structures of these two genera may be different.

Only two species of *Leëlla* are known, and both are from the upper Guadalupian series of Texas.

GENUS *RAUSERELLA* DUNBAR, 1944

Plate 3, figures 1-5

GENOTYPE.—*Rauserella erratica* DUNBAR, 1944, Geol. Soc. America, Special Paper 52, p. 37, 38, pl. 9, figs. 1-8 (Holotype illustrated by fig. 1, pl. 9).

Rauserella DUNBAR, 1944, Geol. Soc. America, Special Paper 52, p. 37.

The genus *Rauserella* DUNBAR is based on a fusulinid that is irregularly coiled in the outer volutions of mature specimens. The shell is minute and irregularly fusiform, possessing an irregular axis of coiling. Mature specimens of five volutions measure about 3 mm long and 1 mm wide. The inner three to four volutions are planispiral, possessing a short axis of coiling and narrowly rounded periphery. Beyond the third to fourth volution, the axis of coiling changes position rapidly and irregularly. The outer volutions of the shell tend to become fusiform, and their axis of coiling is highly elongate. The rapid change of position of the axis of coiling results in an irregularly fusiform mature shell. The septa are unfluted throughout the shell. The original diagnosis indicated, "The wall is thin, and its structure obscure; in the outer volutions it appears to consist of tectum and diaphanotheca, but in the inner volutions the wall is thickened by a nearly clear epitheca and the tectum is a thin median layer." (DUNBAR, 1944, p. 37.) The tunnel is singular, and its path is straight in the inner discoidal volutions and irregular in the outer volutions. The chomata are low and narrow in the inner volutions but are indistinct in the outer irregular volutions.

Rauserella resembles *Leëlla* in several respects, especially in that the inner volutions are discoidal, the mature shell is small, and the septa are unfluted. The aberrant nature of the irregularly coiled mature shell suggests that *Rauserella* was developed from *Leëlla*. Also, the spirothecal structures of these forms may be identical. One of the major differences is the irregular coiling of *Rauserella*.

Rauserella is assigned with question to the subfamily Ozawainellinae. The planispiral discoidal inner volutions of both *Rauserella* and *Leëlla* seem to demonstrate that they were derived from a discoidal to subspherical form like some of the typical ozawainellids, and the aberrant nature of *Rauserella* indicates that it is near the end of the life history of that particular group. As there is no other proposed subfamily of fusulinids in which either can be placed without question, I am tentatively referring them to Ozawainellinae.

The genotype and only known species of *Rauserella* is from rocks of upper Guadalupian age in northern Mexico and Texas. Congeneric forms have been reported from the Permian fusulinid Zone of *Verbeekina-Neoschwagerina* of Nagato, Japan. (Note by SKINNER in DUNBAR, 1944, p. 38.)

GENUS *NUMMULOSTEGINA* SCHUBERT, 1907

Plate 2, figures 17, 18

GENOTYPE.—*Nummulostegina velebitana* SCHUBERT, 1908, K. K. Geol. Reichs., Wien, Jahrb., Band 58, p. 377, fig. 4 (Illustrated specimen here designated as holotype).

Nummulostegina SCHUBERT, 1907, K. K. Geol. Reichs., Wien, Verh., Jahrg. 1907, No. 8, p. 212.—SCHUBERT, 1908, K. K. Geol. Reichs., Wien, Jahrb., Band 58, p. 377.—CUSHMAN, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 209, 210.—CUSHMAN, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 196, 197.—THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 114.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 559.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 138.—CUSHMAN, 1940, Foraminifera, p. 217.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 75, 76.

Orobias [part] GALLOWAY & HARTLON, 1928, Jour. Paleontology, vol. 2, p. 348, 349.—GALLOWAY, 1933, Manual Foraminifera, p. 396, 397.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 60. [Not d'EICHWALD, 1860.]

The genus *Nummulostegina* was proposed by SCHUBERT (1907) for a form described the following year (SCHUBERT, 1908) from the Permian of "Nord-dalmatien, Österreich," Yugoslavia. All available data indicate that the genotype has a planispiral discoidal shell of five or six volutions that is about 0.8 mm long and 1.4 mm wide. Most internal features of the shell are unknown. SCHUBERT's illustrations are drawings of external views and his description gives little information concerning the inside of the shell other than septal counts. SCHUBERT (1908) mentioned, however, that the internal parts of the shells of his specimens were highly recrystallized. As mentioned above, many ozawainellids have highly recrystallized shells.

Nummulostegina probably is a fusulinid. SCHUBERT and later CUSHMAN (1928, 1933) considered it a camerinid. CUSHMAN (1940) and DUNBAR (1940) referred it to the camerinids and fusulinids, respectively, in the same publication. If *Nummulostegina* is a fusulinid, it probably is referable to the subfamily Ozawainellinae and may be synonymous with some other genus here referred to the subfamily. For the present, however, its status is uncertain. Dr. FRANZ KAHLER is now restudying SCHUBERT's specimens of the type species.

SUBFAMILY *SCHUBERTELLINAE* SKINNER, 1931

Schubertellinae was suggested by SKINNER (1931) as a possible subfamily of fusulinids to include a minute form he described from the Pennsylvanian of Oklahoma as *Schubertella gallowayi* SKINNER. *Schubertella gallowayi* was later placed in the genus *Eoschubertella* THOMPSON. *Eoschubertella* is recognized to be closely similar to *Schubertella* and to several other genera of minute fusulinids. They form such a closely compact and distinct part of the family Fusulinidae that they are placed in a distinct subfamily, for which SKINNER's suggested

name is used. It is realized that certain genera referred to Schubertellinae are more or less transitional between Schubertellinae and the more primitive Ozawainellinae, and certain others are more or less transitional between Schubertellinae and Fusulininae. However, most members of Schubertellinae compose a distinct branch of fusulinids and are not transitional in nature between typical members of Ozawainellinae and typical members of Fusulininae. Schubertellinae seemingly was derived from Ozawainellinae in early Middle Pennsylvanian or possibly late Lower Pennsylvanian time, and Fusulininae developed from Schubertellinae early in the geologic history of the latter.

All members of this subfamily are minute, and most of them are elongate fusiform, having irregular to straight axis of coiling, irregular to convex lateral slopes, and form ratios of 1.3 to 3.5. The proloculus is minute. The chambers increase in height somewhat uniformly. The first one or two volutions of most forms are coiled at a large angle to the outer volutions. The spirotheca of primitive forms are composed of a tectum and upper and lower tectoria. Some advanced members have a spirotheca composed of a tectum, a diaphanotheca, and upper and lower tectoria. A few high Permian schubertellids have a spirotheca composed of a single thin dense layer, but those of some advanced forms are composed of a tectum and a lower thicker less dense layer. The septa of primitive members are straight throughout the length of shell. The septa of some more advanced forms are fluted in the polar regions but are straight across the central part of the shell. In two genera, *Boultonia* and *Codonofusiella*, the septa are fluted throughout the length of the shell. The tunnel is singular. Chomata are low in primitive forms but are exceedingly massive and broad in some advanced forms.

It is not certain that all genera here referred to Schubertellinae are from the same ancestral stock. *Eoschubertella* seemingly gave rise to *Fusiella*, which in turn gave rise to *Waeringella*. *Eoschubertella* also gave rise to *Schubertella*, which in turn gave rise to *Yangchienia* and *Neofusulinella*, and possibly to *Boultonia* and *Codonofusiella*. *Codonofusiella* is interpreted to be an aberrant genus of the subfamily. The relationship of *Leëlla* and *Rauserella* to the schubertellids is uncertain. Evidence indicates that they developed from some late member of the subfamily Ozawainellinae, and they are referred to that subfamily.

As would be expected of primitive forms, schubertellids have long geologic ranges, occurring from rocks of lower Middle Pennsylvanian age to the youngest fusulinid-bearing part of the Permian Period. Very few members of the subfamily are now considered good index fossils, but forms of several genera, including *Yangchienia* and *Schubertella*, may prove to be of stratigraphic value. So far members of this subfamily have not been extensively

studied, possibly due to their minute size in association with larger fusulinids. Future studies will doubtless show that many species of the schubertellids are more limited stratigraphically than now recognized.

GENUS EOSCHUBERTELLA THOMPSON, 1937

Plate 4, figures 1, 2, 16, 17; Plate 28, figures 1-3

GENOTYPE.—*Schubertella lata* LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 111, pl. 6, figs. 9-11 (Holotype here designated as the specimen illustrated by LEE & CHEN as fig. 9, pl. 6).

Eoschubertella THOMPSON, 1937, Jour. Paleontology, vol. 11, p. 123, 124.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 563, 564.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 142.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 77, 78.

Schubertella [part] GALLOWAY & RYNIKER, 1930, Oklahoma Geol. Survey, Circ. 21, p. 22, 23.—LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 109, 110.—SKINNER, 1931, Jour. Paleontology, vol. 5, p. 256, 257.—GALLOWAY, 1933, Manual Foraminifera, p. 397, 398.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 16.—DOUTKEVITCH, 1934, Inst. Géol. Naph., Mém., sér. A, vol. 55, p. 34, 35. [Not STAFF & WEDEKIND, 1910.]

Fusulinella [part] THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 298-300.—THOMPSON, 1936, Jour. Paleontology, vol. 10, p. 104, 105. [Not MÖLLER, 1877.]

The genus *Eoschubertella* THOMPSON contains a large group of minute fusulinids that resemble the juvenile stages of some *Profusulinella* and *Fusulinella*. The shell is minute, ellipsoidal to highly inflated fusiform, and loosely coiled. Mature specimens of three to five volutions are 0.4 to 1.3 mm long and 0.3 to 0.7 mm wide, having form ratios slightly greater than unit value. The first one or two volutions of most forms are slightly irregularly coiled at large angles to the coiling of outer volutions. The polar regions are rounded to bluntly pointed. Septa are unfluted. The tunnel path is irregular. Chomata are low and asymmetrical. The spirotheca is composed of a tectum and thin upper and lower tectoria.

Eoschubertella superficially resembles *Schubertella*. However, the spirotheca of the former is composed of a tectum and upper and lower tectoria, whereas that of the latter is composed of a tectum and a diaphanotheca. Also, the shell of *Eoschubertella* is more highly ellipsoidal and more loosely coiled than that of *Schubertella*. *Eoschubertella* differs from *Fusiella* in several respects. *Eoschubertella* has a more highly inflated shell, a more loosely coiled shell, and is more nearly ellipsoidal in shape. *Fusiella* is elongate spindle shaped. Perhaps most important of all, *Fusiella* has axial fillings.³

Eoschubertella is abundant in Middle Pennsylvanian rocks of America and in rocks of equivalent ages in Europe and Asia.

3. DOUTKEVITCH (1934a) described a form as *Fusiella granum-oryzae* from the Pennsylvanian of eastern European Russia that seemingly does not have axial fillings. The septa of the holotype seem to be fluted in the polar regions. This form may not be referable to *Fusiella*.

GENUS **SCHUBERTELLA** STAFF & WEDEKIND,
1910

Plate 4, figures 18-26

GENOTYPE.—*Schubertella transitoria* STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Inst., Bull., vol. 10, p. 121, pl. 4, figs. 7, 8 (Holotype here designated as the specimen illustrated by STAFF & WEDEKIND as fig. 8, pl. 4).

Schubertella STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Inst., Bull., vol. 10, p. 112.—STAFF, 1912, Palaeontographica, Band 59, p. 164.—THOMPSON, 1937, Jour. Paleontology, vol. 11, p. 120, 121.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 609, 610.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 142.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 78.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 488.

Schubertella [part] DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 132.—LEE & CHEN, 1930, Nat. Research Inst. Geol., Mem., no. 9, p. 109, 110.—GALLOWAY & RYNIKER, 1930, Oklahoma Geol. Survey, Circ. 21, p. 22, 23.—GALLOWAY, 1933, Manual Foraminifera, p. 397, 398.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 16.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 58-60.

Depratella OZAWA, 1928, Cushman Lab. Foramin. Research, Contr., vol. 4, p. 9, 10.—OZAWA, 1928, Cushman Lab. Foramin. Research, Special Pub. no. 1, p. 134, 135. [GENOTYPE.—*Neofusulinella giraudi* DEPRAT, 1915 (Holotype here designated as the specimen illustrated by DEPRAT as fig. 7, pl. 1). (Not *Neofusulinella phairayensis* COLANI, 1924, as redesignated by OZAWA in 1928).]

Fusulinella [part] of authors. [Not MÖLLER, 1877.]

Neofusulinella [part] of authors. [Not DEPRAT, 1912.]

The genus *Schubertella* STAFF & WEDEKIND contains a large variable group of forms and is abundant throughout the Upper Pennsylvanian and the Permian. The shell is minute and inflated to elongate fusiform, having sharply to bluntly pointed poles. Mature specimens of most forms are less than 2 mm long and consist of four to six volutions. The form ratios of mature specimens are 1.3 to 3.0. The first one to two volutions of most forms are coiled at angles as great as 90° to the axis of the outer volutions. The outer three or four volutions are planispiral. The shell expands uniformly. The wall is composed of a tectum and a lower transparent layer. The wall in some forms has a single thin layer. Septa are numerous and are unfluted. The tunnel is singular. Chomata are asymmetrical and well developed in some forms but indistinct in others. The proloculus is minute.

The genus *Schubertella* was based on a single species, the genotype. The original description was generalized and the illustrations were idealized drawings. The detailed structures of the genotype were not understood until about 27 years later when THOMPSON (1937) studied topotype specimens from Spitzbergen. During the period from 1910 to 1937, several congeneric specimens were described from the Permian of Asia and referred to various genera, including *Fusulinella* and *Neofusulinella*. *Neofusulinella giraudi* DEPRAT was made the genotype of *Depratella* OZAWA, but it may be referable to *Schubertella*. Most of the Middle Pennsylvanian

forms now referred to *Eoschubertella* were referred to *Schubertella* prior to 1937.

Neofusulinella giraudi DEPRAT, 1915, was designated the genotype of *Depratella* OZAWA in 1928 (Pl. 4, figs. 25, 26). Later the same year, OZAWA listed *Neofusulinella phairayensis* COLANI, 1924, as the genotype of *Depratella*. Most subsequent workers have considered *Depratella* a synonym of *Schubertella*, and it is so considered here. *Depratella giraudi* resembles the genotype of *Neofusulinella*, *N. lantenoisi*, in some respects; but until type material of the latter can be restudied, it seems best to refer the genotype of *Depratella* with question to *Schubertella*.

Schubertella can be distinguished from *Eoschubertella* by their different wall structures, the more highly elongate shell of most forms of *Schubertella*, and the more loosely coiled shells of *Eoschubertella*. *Schubertella* seemingly developed from *Eoschubertella* and, as would be expected, they are closely similar. Several forms referred to *Schubertella* resemble the genotype of *Fusulinella*. However, *Fusulinella* has three layers in the spirotheca and has axial fillings.

Schubertella is widespread geographically and occurs in the Permian of the Arctic Islands, Europe, Asia, Pacific Islands, and in North, Central, and South America. Also, undescribed *Schubertella* are common in Upper Pennsylvanian rocks at several places in North America, including Kansas and Oklahoma. *Schubertella* probably is even more common in Upper Pennsylvanian and Permian rocks than now known.

GENUS **FUSIELLA** LEE & CHEN, 1930

Plate 4, figures 3-6; Plate 26, figure 6

GENOTYPE.—*Fusielia typica* LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 107, 108, pl. 2, fig. 1; pl. 6, figs. 1-6 (Holotype illustrated by fig. 1, pl. 2 and fig. 1, pl. 6).

Fusielia LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 107.—DOUTKEVITCH, 1934, Oil Geol. Inst., Trans., ser. A, vol. 36, p. 9-14, 60-65.—THOMPSON, 1934, Iowa Univ. Studies Nat. History, vol. 16, p. 280-281.—LEE, 1937, Geol. Soc. China, Bull., vol. 16, p. 80, 81.

Fusielia [part] GALLOWAY, 1933, Manual Foraminifera, p. 398.—DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 134, 135.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 567.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 140, 141.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 78, 79.

?*Boultonia* [part] LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 10-12.

The genus *Fusielia* LEE & CHEN has a minute shell that is highly elongate fusiform, having a slightly inflated to cylindrical central region. Mature specimens of five to six and one-half volutions are 1.2 to 1.8 mm long and have a form ratio of about 3. The inner one to two volutions are coiled at a large angle to the coiling of outer volutions. The height of chambers increases slowly and uniformly. The septa are unfluted throughout the

length of shell. The tunnel is singular. Chomata are asymmetrical and low. Fillings of dense calcite developed in extreme polar regions of the outer three to four volutions. The spirotheca is composed of a tectum and upper and lower tectoria.

The elongate shell, unfluted septa, and axial fillings of *Fusiella* resemble closely those of *Wedekindellina*. The spirothecal structures of these genera are different, however. *Fusiella* has a spirotheca composed of three layers, and that of *Wedekindellina* is composed of four layers. Also, the beginning volutions in *Fusiella* are highly asymmetrical, but those of *Wedekindellina* are more nearly symmetrical. *Fusiella* resembles *Waeringella* in general shape and axial fillings. They can be distinguished, however, by the septal fluting in *Waeringella*. Also, their wall structures are probably similar only superficially. Although of doubtful generic value, the shells of most *Waeringella* are larger than those of *Fusiella*.

DOUTKEVITCH (1934a) described a form from the Pennsylvanian of eastern European Russia and referred it to *Fusiella* as *F. granum-oryzae* DOUTKEVITCH. This Russian form has fluted septa and seemingly does not have axial fillings. It possibly is referable to *Boultonia*. *Boultonia rawi* LEE (1927) from the Pennsylvanian Penchi series of North China possibly is referable to *Fusiella*.

The general development of *Fusiella* strongly suggests that it is ancestral to *Wedekindellina* and also to *Waeringella*; *Wedekindellina* having developed from *Fusiella* in middle or early Middle Pennsylvanian time and *Waeringella* having developed from *Fusiella* in early Upper Pennsylvanian time.

Only two species referable unquestionably to *Fusiella* have been described: *F. typica*, the genotype, and *F. paradoxica* LEE. Both were described originally from the Pennsylvanian Huanglung limestone of China. LEE (1937) describes the genotype and mentions specimens similar to *F. paradoxica* from the Moscovian in the Donetz Basin of Russia. He pointed out, however, that his Russian specimens are not too well understood.

GENUS WAERINGELLA THOMPSON, 1942

Plate 4, figures 7-15

GENOTYPE.—*Waeringella spiveyi* THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 414-416, pl. 2, figs. 1-15 (Holotype here designated as the specimen illustrated by THOMPSON as fig. 1, pl. 2).

Waeringella THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 413, 414.

The original diagnosis and comparisons of the genus *Waeringella* THOMPSON are here quoted in full:

Shell small, fusiform to slightly irregular; poles sharply pointed; central portion inflated; mature specimens consist of eight to nine volutions and measure about 1.3 mm in width and 3.6 mm in length, with a form ratio of about 1:3; spirotheca composed of a tectum, a lower, thin, structure-

less layer and an upper layer which may correspond to the upper tectorium of other of the fusulinids; juvenarium endothroid and asymmetrical; tunnel singular with very irregular path and narrow tunnel angle; chomata narrow and of moderate height; axial fillings developed; septa numerous and essentially straight in the central portion of the shell, with fluting confined mainly to the polar regions.

Representatives of *Waeringella* resemble rather closely those of the genus *Wedekindellina* Dunbar and Henbest on the bases of general appearance, size and shape. However, the wall structures of these two genera are different and the axial fillings of *Waeringella* are not so heavy as those in *Wedekindellina*. In *Wedekindellina* the spirotheca has a distinct four-layer structure of upper and lower tectoria, tectum and diaphanotheca. Whereas in *Waeringella* the spirotheca has only two or possibly three layers; a tectum, a lower layer, and an upper layer which may represent an upper tectorium but which seems to correspond to the extended axial fillings rather than a true tectorium. In representatives of *Wedekindellina* the septa are unfluted throughout the length of the shell and the septa are curved in the extreme polar regions without any true fluting, but in representatives of *Waeringella* the septa are strongly fluted in the extreme polar regions and are broadly fluted to essentially straight in the central portion of the shell. (THOMPSON, 1942a, p. 413, 414.)

Waeringella resembles *Fusiella* somewhat closely. However, the septa of *Waeringella* are distinctly fluted in the polar regions and slightly wavy across the central part of the shell, whereas those of *Fusiella* are unfluted throughout the length of the shell. Also, the earlier volutions of *Fusiella* are more highly asymmetrical than those of *Waeringella*.

Only one species of *Waeringella* has been described. It is from the middle part of the Upper Pennsylvanian of Texas. An undescribed congeneric form is also known from the upper part of the Oquirrh formation of Utah. The genus has not been reported outside North America.

GENUS YANGCHENIA LEE, 1933

Plate 5, figures 1-7

GENOTYPE.—*Yangchienia iniqua* LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 14, pl. 1, figs. 1, 1a (Holotype here designated as the specimen illustrated by LEE as fig. 1a, pl. 1).

Yangchienia LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 14.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 18.—THOMPSON, 1935, Eclogae geol. Helvetiae, vol. 28, p. 511-517.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 569, 570.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 142, 143.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 79.—THOMPSON, 1946, Jour. Paleontology, vol. 20, p. 146, 147.

Fusulinella [part] OZAWA, 1929, Eclogae geol. Helvetiae, vol. 22, p. 47. [Not MÖLLER, 1877.]

The genus *Yangchienia* LEE is the most distinct of the subfamily. The shell is minute, is inflated fusiform, and has pointed poles. Mature specimens of seven to ten volutions are 1.4 to 3.0 mm long and 0.7 to 1.5 mm wide. The first one to three volutions have short axes of coiling that are at angles up to 90° to the axes of outer volutions. The proloculus is small. The inner volutions increase in height uniformly, but the outer two to three volu-

tions increase in height more slowly. The septa are unfluted. The spirotheca is relatively thick and is composed of a tectum and a lower transparent layer in the outer part of last volution, indicating that the primary structure of the spirotheca is composed of two layers. The spirotheca in the inner parts of the shell is composed of the tectum and the lower transparent layer, plus a basal dense layer and two layers above the tectum. The upper two layers probably are so differentiated because of stages in deposition. Both the upper and lower parts of spirotheca may be continuous with the massive chomata. The tunnel is singular. Chomata are asymmetrical and extremely massive.

Yangchienia resembles *Schubertella* in some general features. However, its wall structure is different from that of *Schubertella*, its chomata are much more massive, it contains more volutions at maturity, and it is larger in size. *Yangchienia* can be distinguished from *Neofusulinella* by its different wall structure, the fluted septa in the polar region of *Neofusulinella*, the thicker primary wall of *Neofusulinella*, and the larger size of most forms of *Neofusulinella*. Also, most forms of *Neofusulinella* are planispiral throughout, whereas the inner volutions of all *Yangchienia* are asymmetrical.

The form described by OZAWA (1927) as *Fusulinella compressa* from the Nn zone of the Akasaka limestone of Japan seemingly is referable to *Yangchienia*. OZAWA's illustrations and descriptions do not supply all desired information, however.

In addition to the genotype and this Japanese form, only two species of *Yangchienia* have been described. One of these, *Y. tobleri* THOMPSON, occurs in the Zone of *Verbeekina-Neoschwagerina* in the Aegean Islands of Greece and in the Sosio beds of Sicily. The other, *Y. haydeni* THOMPSON (= *Y. sp. CIRY*, 1941), occurs commonly in the fusulinid Zone of *Verbeekina-Neoschwagerina* in Afghanistan, associated with the genus *Polydioxodina*, and in Turkey associated with forms characteristic of the Zone of *Verbeekina-Neoschwagerina*. In China, the genotype *Y. iniqua* occurs in the upper part of the Chihhsia limestone from which *Verbeekina*, *Misellina*, *Pseudodoliolina*, and *Cancellina* have also been described. *Yangchienia* seems restricted to the fusulinid Zone of *Verbeekina-Neoschwagerina*.

GENUS NEOFUSULINELLA DEPRAT, 1912

Plate 5, figures 17, 18

GENOTYPE.—*Neofusulinella lantenoisi* DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 41, 42, pl. 7, figs. 23-25, text fig. 18 (Holotype here designated as the specimen illustrated by DEPRAT as fig. 23, pl. 7). [Not *N. praecursor* DEPRAT, 1913 (GALLOWAY & RYNIKER, 1930).]

Neofusulinella DEPRAT, 1912, Acad. Sci. Paris, Comptes rendus, tome 154, p. 1549, 1550.—THOMPSON, 1934, Iowa Univ. Studies Nat. History, vol. 16, p. 291-293.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 564, 565.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 130, 131.—THOMPSON, WHEELER, & HAZZARD, 1946, Geol. Soc. America, Mem., no. 17, p. 15, 16.

Neofusulinella [part] DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 40.—?DEPRAT, 1915, Indochine Service Géol., Mém., vol. 4, fasc. 1, p. 10-13.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 24-26.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 12, 13.

Fusulinella [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 28.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 142, 143.—GALLOWAY, 1933, Manual Foraminifera, p. 400.—DUNBAR, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 132.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 61-63. [Not MÖLLER, 1877.]

Triticites [part] DUNBAR & CONDRAS, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 61 (1927). [Not GIRTY, 1904.]

Yangchienia [part] THOMPSON, 1935, Eclogae geol. Helvetiae, vol. 28, p. 514. [Not LEE, 1933.]

The genus *Neofusulinella* DEPRAT is referred to the subfamily Schubertellinae with question. The following brief description is taken mainly from the genotype. The shell is small and inflated uniformly fusiform, having a straight axis of coiling, uniform lateral slopes, and pointed poles. The shell is planispiral throughout growth. Chomata are massive to moderate. Mature shells of six to twelve volutions are 3.6 to 6.0 mm long and 2.0 to 3.8 mm wide. The spirotheca is composed of a tectum and a lower transparent layer. However, the chomata spread onto the roofs and floors of the chambers in some forms, resulting in an apparent four-layered wall. The septa are thin, broadly wavy to fluted in extreme polar regions, and almost plane across the central part of the shell.

Neofusulinella is not well understood, and its classification has been in dispute. DEPRAT's original illustrations of the genotype, *N. lantenoisi* DEPRAT, were drawings which seemingly did not all represent well-oriented or well-preserved specimens, and the genus has remained poorly known. These specimens may be lost and the exact nature of the genotype may never be known with certainty. THOMPSON & FOSTER (1937) studied conspecific specimens from China, but these specimens are partly replaced. However, the forms here referred to *Neofusulinella* form a compact group and all have many features of close similarity.

The fluting of the septa in the axial regions, the planispiral nature of the entire shell, large shell, and less well developed chomata of *Neofusulinella* serve to distinguish it from *Yangchienia*. *Neofusulinella* may be distinguished from *Waeringella* by the axial fillings, minute size of the shell, asymmetrical early volution, and different wall structure of *Waeringella*. *Neofusulinella* is somewhat similar to *Schubertella*, from which it probably developed. However, *Neofusulinella* is larger in size, has a different wall structure, fluted septa, and a symmetrical shell throughout growth of the individual.

Several forms from the Permian of Asia and America are referred to *Neofusulinella*; these include *N. occidentalis* THOMPSON & WHEELER and *N. montis* THOMPSON & WHEELER from the McCloud limestone of California, *N. lantenoisi* DEPRAT from

the Middle Permian of French Indo-China and western China, and *Fusulinella itoi* OZAWA from the Middle Permian (?) of Japan. It is realized that this group of forms may be biphyletic.

Neofusulinella seemingly is restricted to the Permian. It is known from Wolfcampian and lower Leonardian rocks of America, from rocks of the Permian fusulinid Zone of *Verbeekina-Neoschwagerina* of French Indo-China and western China, and probably from rocks of Middle Permian age in Japan.

GENUS *BOULTONIA* LEE, 1927

Plate 5, figures 14-16

GENOTYPE.—*Boultonia willsi* LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 10, 11, pl. 2, figs. 1-4 (Holotype here designated as the specimen illustrated by LEE as fig. 1, pl. 2).

Boultonia LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, p. 10.—DUNBAR & HENBEST, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 362, 363.—GALLOWAY, 1933, Manual Foraminifera, p. 400.—THOMPSON, 1934, Iowa Univ. Studies Nat. History, vol. 16, p. 281.—DOUTKEVITCH, 1934, Oil Geol. Inst., Trans., ser. A, vol. 36, p. 61.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 568.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 141.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 79.

Schubertella [part] DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 132. [Not STAFF & WEDEKIND, 1910.]

?*Codonofusiella* DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 606, 607.

The genus *Boultonia* LEE is based solely on the genotype, from which the following generic diagnosis was derived. The shell is minute and elongate fusiform, having sharply pointed poles and straight to curving axis of coiling. Shells of mature specimens composed of four volutions measure about 1.0 mm long and 0.2 mm wide. The first volution is coiled at right angles to outer volutions. The spirotheca is composed of "tectum and osseum (diaphanotheca) which latter only rarely reveals indistinct traces of an alveolar structure but more often appears to be homogeneous and solid." (LEE, 1927, p. 10.) The septa are fluted throughout the length of the shell.

DOUTKEVITCH (1934a) describes the spirotheca of *Boultonia* as composed of a tectum and upper and lower tectoria, a wall structure similar to that of *Fusiella*. The distinguishing feature of *Boultonia* was stated by LEE to be the asymmetrical arrangement of the inner volution. The genotype is the only known representative. It is much smaller than most other fusulinid genera. *Codonofusiella* is the only genus having similar arrangement of the inner volutions, seemingly similar wall structure, similar septal fluting, and the same general size. However, *Codonofusiella* has an uncoiled gerontic stage not reported for *Boultonia*. It is probable that these genera are closely similar biologically and, if not congeneric, *Boultonia* probably is ancestral to *Codonofusiella*.

It seems that *Boultonia* and *Codonofusiella* are biologically the most highly developed members of the subfamily Schubertellinae, and that *Codonofusiella* is an aberrant member of the subfamily.

At the time LEE proposed this genus, he referred to it the genotype and *Boultonia rawi* LEE (1927) from the Pennsylvanian Penchi series of North China. *B. rawi* has unfluted septa, heavy axial filling, and is not considered congeneric with *B. willsi*. It may be referable to *Wedekindellina*, *Fusiella*, or *Waeringella*.

The genotype is from the Permian Taiyuan series of North China.

GENUS *CODONOFUSIELLA* DUNBAR & SKINNER, 1937

Plate 5, figures 8-13

GENOTYPE.—*Codonofusiella paradoxica* DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 607-609, pl. 45, figs. 1-9 (Holotype here designated as the specimen illustrated by DUNBAR & SKINNER as fig. 7, pl. 45).

Codonofusiella DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 606, 607.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 141.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 80.

The genus *Codonofusiella* DUNBAR & SKINNER is based solely on the genotype. The shell is minute. The first four volutions are tightly coiled, but the outer volution is irregularly uncoiled. Also, the first one or two volutions are coiled at a large angle to the following two or three volutions. As maturity is approached, the shell becomes loosely coiled or uncoiled. Specimens of the genotype contain four coiled volutions about 1 mm long and 0.44 mm wide. In some specimens the flaring and uncoiled part of the last volution exceeds the combined volume of all preceding volutions. The spirotheca is exceedingly thin, and its structure is not definitely known. It is reported to be composed of a tectum and a lower less dense layer. The septa are strongly fluted throughout the length of the shell, even in the flaring and uncoiled gerontic portions. The tunnel is singular, and the chomata are minute.

The first four volutions of *Codonofusiella* resemble remarkably closely the genotype of *Boultonia* in general shape and size, spirothecal structure, nature of coiling, and septal fluting. The only difference of possible generic value between the types of these genera is that the last volution of *Codonofusiella* becomes uncoiled as in the genus *Nipponitella*. This uncoiling seems to indicate an aberrant development.

The genotype of *Codonofusiella* is from the Capitan limestone and rocks of equivalent upper Guadalupian age of south-central United States. An undescribed species has been recorded from the Cache Creek series of British Columbia.⁴

4. See Addendum, p. 67.

SUBFAMILY FUSULININAE RHUMBLER, 1895

The subfamily Fusulininae as here defined contains five and questionably seven genera: *Pseudostaffella*, *Profusulinella*, *Fusulinella*, *Wedekindellina*, and *Fusulina*, and questionably *Quasifusulina* and *Gallowainella*. Although this subfamily started soon after the first members of the family, it is for the most part highly complex. It contains several members that have exceedingly short stratigraphic ranges, are widespread geographically, are exceedingly abundant, and are excellent index fossils.

With the exception of *Pseudostaffella*, all members have long axes of coiling and are fusiform to subcylindrical in shape. *Pseudostaffella* has a relatively shorter axis of coiling and is subspherical in shape. In the more primitive genera, *Pseudostaffella* and *Profusulinella*, the wall has three layers; tectum and upper and lower tectoria. In some more highly evolved genera, such as *Fusulinella*, *Fusulina*, and *Wedekindellina*, the wall is composed of four layers; tectum, diaphanotheca, and upper and lower tectoria. In advanced forms of *Fusulina*, the upper and lower tectoria are missing or are only partly developed. *Gallowainella* is considered a highly specialized and degenerate end branch of the subfamily. Its wall is composed of only a single dense layer or several thin indistinct layers.

Specimens of most forms are planispiral throughout growth. The innermost few volutions of many forms of *Pseudostaffella* and *Profusulinella* are coiled at large angles to the outer volutions, however. The tunnel is singular in all genera. Chomata are distinct in most forms, excepting advanced forms of *Fusulina* and all forms of *Quasifusulina* and *Gallowainella*. Heavy axial fillings occur in highly advanced or degenerate forms. Heavy axial fillings and massive chomata are present in *Wedekindellina*.

Septal fluting occurs in all degrees of development within the subfamily. Septa are unfluted in *Pseudostaffella*, and they are feebly fluted only in the extreme polar regions in primitive *Profusulinella*. Fluting progressively extends to the center of the shell through the evolutionary development from *Profusulinella* to *Fusulinella* and to *Fusulina*. The septa are intensely fluted throughout length of shell in *Quasifusulina* and *Gallowainella*. However, the degree of fluting observed in late forms of the schwagerinids, such as *Parafusulina* and *Polydiexodina*, is not present in *Quasifusulina* or in *Gallowainella*. The septa are unfluted in *Wedekindellina*. All forms of *Wedekindellina* have axial fillings and some forms have very heavy axial fillings.

The evolutionary development within the subfamily can be reasonably well established for most genera. *Profusulinella*, *Fusulinella*, and *Fusulina* seemingly developed in this order in Middle Pennsylvanian rocks. *Quasifusulina* and *Gallowainella* probably were developed from *Fusulina*. It is possible, however, that the latter is a degenerate form

of schwagerinid and not referable to the subfamily Fusulininae. *Wedekindellina* may have developed from some branch of *Profusulinella* during the early history of the latter. *Pseudostaffella* seemingly developed from some part of *Eoschubertella* and in turn gave rise to *Profusulinella*. It is possible, however, that *Wedekindellina* developed from *Fusiella* and that it is far removed biologically from other groups here referred to the Fusulininae. Also, *Pseudostaffella* possibly is not ancestral to *Profusulinella*. If either of the latter two possibilities is correct, Fusulininae as here defined is biphyletic and contains some genera not closely related.

All members of Fusulininae except *Quasifusulina* and *Gallowainella* are confined to rocks of Middle Pennsylvanian age. *Quasifusulina* and *Gallowainella* are the most highly evolved genera here referred to the subfamily, and, as would be expected, they occur higher geologically than other members of the subfamily. *Quasifusulina* and *Gallowainella* are not known from America. *Pseudostaffella*, *Profusulinella*, *Fusulinella*, *Fusulina*, and *Wedekindellina* are widespread in Middle Pennsylvanian rocks of North America and in rocks of similar age in Europe and Asia.

GENUS PSEUDOSTAFFELLA THOMPSON, 1942

Plate 6, figure 1; Plate 25, figures 17-25

GENOTYPE.—*Pseudostaffella needhami* THOMPSON, 1942, *Am. Jour. Sci.*, vol. 240, p. 411-413, pl. 1, figs. 15-20, pl. 3, figs. 10-14 (Holotype here designated as the specimen illustrated by THOMPSON as fig. 13, pl. 3).

Pseudostaffella THOMPSON, 1942, *Am. Jour. Sci.*, vol. 240, p. 407-411.—THOMPSON, 1945, *Kansas Geol. Survey, Bull.* 60, p. 49.

Fusulina [part] of authors prior to 1877. [Not FISCHER DE WALDHEIM, 1829.]

Fusulinella [part] of authors prior to 1925. [Not MÖLLER, 1877.]

Staffella [part] OZAWA, 1925, *Tokyo Imp. Univ., Coll. Sci., Jour.*, vol. 45, art. 4, p. 24.—OZAWA, 1925, *Tokyo Imp. Univ., Coll. Sci., Jour.*, vol. 45, art. 6, p. 14.—OZAWA, 1927, *Tokyo Imp. Univ., Fac. Sci., Jour.*, sec. 2, vol. 2, pt. 3, p. 140.—LEE, 1927, *China Geol. Survey, Palaeontologia Sinica*, ser. B, vol. 4, fasc. 1, p. 12, 13.—DUNBAR & CONDRA, 1928, *Nebraska Geol. Survey, Bull.* 2, 2d ser., p. 73 (1927).—OZAWA, 1928, *Cushman Lab. Foram. Research, Special Pub. no. 1*, p. 131.—DUNBAR & HENBEST, 1930, *Am. Jour. Sci.*, 5th ser., vol. 20, p. 363.—LEE & CHEN, 1930, *Nat. Research Inst. Geology, Mem.*, no. 9, p. 114.—ROTH & SKINNER, 1930, *Jour. Paleontology*, vol. 4, p. 347.—GALLOWAY, 1933, *Manual Foraminifera*, p. 397.—DUNBAR, 1933, *Cushman Lab. Foram. Research, Special Pub. no. 4*, p. 131, 132.—DOUTKEVITCH, 1934, *Oil Geol. Inst., Trans.*, ser. A, vol. 36, p. 14.—CHEN, 1934, *Nat. Research Inst. Geology, Mem.*, no. 14, p. 34.—THOMPSON, 1935, *Jour. Paleontology*, vol. 9, p. 113-117.—GUBLER, 1935, *Soc. Géol. France, Mém.*, new ser., tome 11, fasc. 4, no. 26, p. 60, 61.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 597.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 138.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey, Bull.* 67, p. 76, 77.

The genus *Pseudostaffella* THOMPSON is one of the most easily recognized of the minute fusulinids of the Pennsylvanian. The shell is small, is spherical to subspherical in shape, and has rounded to slightly

depressed polar regions. Mature shells of four to seven volutions are 0.5 to 1.7 mm long and 0.5 to 1.8 mm wide. The form ratio is 1.0 to 0.8. The periphery is rounded throughout the shell. In some forms, the axis of coiling of the inner volutions is at a large angle to the axis of outer volutions. The tunnel is singular, and its path is irregular. Chomata are massive and highly asymmetrical. In some forms, the chomata extend to polar regions. The spirotheca is composed of a tectum and upper and lower tectoria. The septa are unfluted throughout the length of the shell.

Pseudostaffella can be distinguished from *Profusulinella* by its short axis of coiling and sub-spherical shape. Also, the chomata of *Pseudostaffella* are relatively more massive than those of *Profusulinella*, and the septa of *Pseudostaffella* are not fluted. *Pseudostaffella* can be distinguished from *Eoschubertella*, from which it possibly was derived, by its spherical shape, more massive chomata, and generally more tightly coiled shell.

Pseudostaffella resembles *Staffella* in general shape. However, the periphery of the shell of *Pseudostaffella* is more broadly rounded throughout growth of the individual, the shell is smaller at maturity and contains fewer volutions, and the spirothecal structure probably is different. The shell material of *Staffella* is completely replaced by secondary mineralization in all known forms, even where associated in the Middle Pennsylvanian with *Pseudostaffella*. Specimens of *Pseudostaffella* are seldom replaced by secondary mineralization. Therefore, it seems probable that the original shell structure of *Pseudostaffella* was different from that of *Staffella*.

The relationship of *Pseudostaffella* to other members of the Fusulininae is problematical. In general shape, *Pseudostaffella* resembles some members of the subfamily Ozawainellinae. In size and some shell structures, it resembles members of Schubertellinae. However, in wall structure, axial arrangement, chomata development, and general shell development *Pseudostaffella* resembles early stages of primitive members of the Fusulininae. Although *Pseudostaffella* is referred to Fusulininae, it is realized to be more or less intermediate between Schubertellinae and Fusulininae.

In addition to the genotype from the Middle Pennsylvanian of New Mexico, the following forms of *Pseudostaffella* have been described from America: *Staffella keytei* ROTH & SKINNER from the McCoy formation of Colorado; *Staffella atokensis* THOMPSON from the Atoka formation of Oklahoma; *Staffella hollingsworthi* THOMPSON from the Boggy formation of Oklahoma; and *Staffella keytei* var. *maccoyensis* THOMPSON from the McCoy formation of Colorado. *Pseudostaffella* is widespread in Europe and Asia, and is represented there by at least eight species. The occurrence in Europe and Asia is similar stratigraphically to the American oc-

currence. *Pseudostaffella* seems to be restricted to rocks of Middle Pennsylvanian age throughout the world.

GENUS PROFUSULINELLA RAUSER-CERNOUSSOVA & BELJAEV, 1936

Plate 1, figure 1; Plate 6, figure 2; Plate 26, figures 1, 2, 11; Plates 27-31

GENOTYPE. — *Profusulinella pararhomboides* RAUSER-CERNOUSSOVA & BELJAEV, 1936, Acad. Sci. U.S.S.R., Trans. Polar Comm., vol. 28, p. 175, 176, 221, pl. 1, figs. 5, 6 (Holotype illustrated by fig. 6, pl. 1).

Profusulinella RAUSER-CERNOUSSOVA & BELJAEV, 1936, Acad. Sci. U.S.S.R., Trans. Polar Comm., vol. 28, p. 175, 220.—RAUSER-CERNOUSSOVA, 1938, Acad. Sci. U.S.S.R., Work. Geol. Inst., vol. 7, p. 97, 153.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 568.—THOMPSON, 1942, New Mexico School Mines, Bull. 17, p. 29, 30.—THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 40, 41.

Schwagerina [part] DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 41, 42. [Not MÖLLER, 1877.]

Fusulina [part] BEEDE & KNIKER, 1924, Texas Univ. Bull. 2433, p. 12, 13. [Not FISCHER DE WALDHEIM, 1829.]

Neofusulinella [part] LEE & CHEN, 1930, Nat. Research Inst. Geology, Mém., no. 9, p. 118. [Not DEPRAT, 1912.]

Fusulinella [part] GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 61-63.—THOMPSON, 1935, Jour. Paleontology, vol. 9, p. 295-298. [Not MÖLLER, 1877.]

Fusella [part] SKINNER, 1931, Jour. Paleontology, vol. 5, p. 255.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 140, 141.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 78, 79. [Not LEE & CHEN, 1930.]

The genus *Profusulinella* RAUSER-CERNOUSSOVA and BELJAEV is exceedingly abundant, widespread, and has a very short stratigraphic range. It is one of the best index fossils of the lower part of the Middle Pennsylvanian. The shell is small and ellipsoidal to fusiform. The axis of coiling is the largest diameter. Mature specimens of four to seven volutions are about 0.7 to 3.5 mm long and 0.5 to 1.9 mm wide. The inner one to two volutions of most forms are coiled at a large angle to the coiling of the outer volutions. The proloculus is spherical and is of moderate size. The expansion of the shell is uniform. The spirotheca is composed of a tectum and upper and lower tectoria. The tunnel is singular, and its path is slightly irregular. Chomata are asymmetrical and well developed. The septa are essentially straight throughout the length of the shell in primitive forms, and they are broadly fluted in the polar regions of more advanced forms.

Profusulinella can be distinguished from *Fusulinella* by the presence of only three layers in the spirotheca of *Profusulinella* as compared to four layers in the spirotheca of *Fusulinella*. The septa are fluted more intensely and further toward the center of the shell in *Fusulinella* and the mature shells of most *Fusulinella* are larger than those of most *Profusulinella*.

Several forms of *Profusulinella* have been referred to *Fusella*. These genera have similar wall struc-

tures, but the shells of *Fusulinella* are smaller, more highly elongate, and contain axial fillings. It seems evident that *Profusulinella* is ancestral to *Fusulinella*. *Profusulinella* occurs stratigraphically below *Fusulinella* and, so far as can be determined, these two genera do not overlap stratigraphically. Several forms, including *Fusulinella? primaeva* (SKINNER) from the basal Big Saline limestone of Texas, are gradational in development between *Profusulinella* and *Fusulinella*. A thin diaphanotheca is introduced in the spirotheca of the outermost volutions of mature specimens of these transitional forms.

Profusulinella resembles *Eoschubertella* in several respects. However, *Eoschubertella* is smaller, generally is more loosely coiled and more highly ellipsoidal, and has smaller chomata. *Profusulinella* can be distinguished from *Pseudostaffella* by the fusiform larger shells of *Profusulinella*, and by the septal fluting in the polar regions of *Profusulinella*.

The ancestral form of *Profusulinella* is not definitely known. In regard to general shape, *Profusulinella* seems to have been developed from a form like *Eoschubertella*. However, in spirothecal structure, chomata structure, and general coiling, *Profusulinella* more closely resembles *Pseudostaffella*. It seems probable that *Pseudostaffella* developed from *Eoschubertella*, and *Profusulinella* developed from *Pseudostaffella*.

Profusulinella occurs in the lower part of the Middle Pennsylvanian in southern New Mexico, extreme western Texas, central Texas, and southern Oklahoma; and is widespread in rocks of lower Moscovian age in European Russia and in the Huanglung limestone in China. Probable congeneric forms have been described from Cammon, French Indo-China, in rocks reported to be of Moscovian age. It seems likely that several other forms that are congeneric with *Profusulinella pararhomboides* have been described from other areas in Europe and Asia. However, the detailed structures of the wall of some of these forms have not been critically observed.

GENUS FUSULINELLA MÖLLER, 1877

Plate 1, figures 2, 3; Plate 6, figure 3; Plate 26, figures 3-5, 7-10, 12-13; Plates 32-38

GENOTYPE.—*Fusulinella bocki* MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII^e sér., tome 25, no. 9, p. 104-107, pl. 5, figs. 3a-3g, pl. 14, figs. 1-4 (Holotype here designated as the specimen illustrated by MÖLLER as fig. 1, pl. 14). [Not *Fusulinella struvii* MÖLLER, 1879 (STAFF, 1909).]

Fusulinella MÖLLER, 1877, Neues Jahrb. Min., Geol. und Pal., Jahrg. 1877, p. 144-146.—DUNBAR & HENBEST, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 362.—GALLOWAY, 1933, Manual Foraminifera, p. 400.—DUNBAR, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 132.—THOMPSON, 1934, Iowa Univ. Studies Nat. History, vol. 16, p. 291-296.—RAUSER-CERNOUSSOVA, 1936, Acad. Sci. U.S.S.R., Bull., Classe Sci. Math. et Nat., p. 80, 81.—RAUSER-CERNOUSSOVA & BELJAEV, 1936, Acad. Sci. U.S.S.R., Trans. Polar Comm., vol. 28, p. 180, 222.—DUNBAR & SKINNER,

1937, Texas Univ. Bull. 3701, p. 561.—RAUSER-CERNOUSSOVA & BELJAEV, 1940, Geol. Oil Inst., Trans., new ser., fasc. 7, p. 23, 73.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 140.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 77.—THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 41, 50.

Fusulinella [part] MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII^e sér., tome 25, no. 9, p. 101-104.—MÖLLER, 1879, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII^e sér., tome 27, no. 5, p. 21.—SCHELLWIEN, 1898, Palaeontographica, Band 44, p. 260, 261.—DOUVILLÉ, 1906, Soc. Géol. France, Bull., 4th sér., tome 6, p. 583, 584.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 24.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 15.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 140.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 73 (1927).—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 131, 132.—SILVESTRI, 1933, Istit. Geol. R. Univ. Padova, Mem., vol. 10, p. 30, 31.—DOUTKEVITCH, 1934, Oil Geol. Inst., Trans., ser. A, vol. 36, p. 43, 81.—DOUTKEVITCH, 1934, Inst. Géol. Naph., Mém., sér. A, vol. 55, p. 38, 40.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 61-63.—THOMPSON, 1936, Jour. Paleontology, vol. 10, p. 675.

[Not *Fusulinella* STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 486-492.—STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Inst., Bull., vol. 10, p. 112.—STAFF, 1912, Palaeontographica, Band 59, p. 164.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 6, 7, 38.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 74, 131.]

Neofusulinella [part] DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 40.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 101.—LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 16.—LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 118. [Not DEPRAT, 1912.]

The shell of *Fusulinella* MÖLLER is small and elongate to inflated fusiform and has a straight to slightly irregular axis of coiling. Mature specimens of six to nine volutions are 0.9 to 5.0 mm long and 0.6 to 2.2 mm wide. The form ratio is from extremes of 1.4 for some gibbose forms to 4.0 for some highly elongate forms. The proloculus is small and the volutions increase in height uniformly. The shell of most forms is planispiral throughout, but in some forms early volutions are slightly asymmetrical to the outer volutions. In rare specimens of some species the proloculus is minute and the first one or two volutions are coiled at a large angle to the outer volutions. The spirotheca is composed of a tectum, a diaphanotheca, and upper and lower tectoria. Septa of primitive forms are fluted in the extreme polar regions and straight across the central part of the shell. In more advanced forms, the septa are fluted in the polar regions, and the fluting extends further toward the center of shell than in more primitive forms. Chomata are massive and are highly asymmetrical.

The genus *Fusulinella* was established by MÖLLER in 1877 for a single species he was then studying from the "obern Kohlenkalk bei Krestzi, Gouvernement Twer," Russia. The following year MÖLLER (1878) described this form as *Fusulinella bocki* MÖLLER and it is the type of the genus. *Fusulinella*

has been recognized almost consistently as a valid genus since 1877, but has been interpreted in various ways. During the period from about 1909 to 1924, STAFF and others restricted *Fusulinella* to minute discoidal to spherical fusulinids, and they did not include in it fusulinids closely similar to the genotype. STAFF (1909) erroneously designated as the genotype the subdiscoidal form *Fusulinella struvii* MÖLLER (1879). During the period from 1925 to 1930 several paleontologists included in *Fusulinella* all forms now referred to *Fusulinella* as well as forms now generally referred to *Fusulina*. LEE (1927), and later DUNBAR & HENBEST (1930), discovered that the genotype of *Fusulina*, *F. cylindrica* FISCHER DE WALDHEIM, has a spirotheca closely similar in structure to that of *Fusulinella bocki*. DUNBAR & HENBEST pointed out that the major structural difference between the two genera is the more highly fluted septa of *Fusulina*. It is in this latter sense that these genera are interpreted today.

Fusulinella can be distinguished easily from *Fusulina*, for the septa of *Fusulina* are fluted throughout the length of the shell but those of *Fusulinella* are fluted only in the polar regions. Mature specimens of some *Fusulina* are much larger than those of *Fusulinella*. Also, the tectoria of late forms of *Fusulina* are very thin and discontinuous or absent, and axial fillings are developed in some forms of *Fusulina*, including the genotype.

Fusulinella closely resembles *Profusulinella*. However, the spirotheca of *Profusulinella* is composed of a tectum and upper and lower tectoria, and the spirotheca of *Fusulinella* contains a tectum, diaphanotheca, and upper and lower tectoria. The septa of primitive forms of *Profusulinella* are practically unfluted throughout the length of the shell, and they are broadly fluted only in the polar regions of advanced forms. The septa of *Fusulinella* are more narrowly fluted. Also, the mature shells of most *Fusulinella* are larger than most *Profusulinella*. *Fusulinella* can be distinguished from *Wedekindellina* by the heavy axial fillings, the more slender and elongate shell, and the unfluted septa of *Wedekindellina*.

The most primitive species of *Fusulinella* in America are in rocks of lower Middle Pennsylvanian age, and the latest forms referred to the genus without question are from rocks of the middle part of that series. However, forms that may possibly be congeneric with *Fusulinella bocki* occur in the upper part of the Middle Pennsylvanian of the mid-continent region (THOMPSON, 1945). The stratigraphic range of *Fusulinella* in China seems similar to that in America.

In 1940, RAUSER-CERNOUSOVA & BELJAEV reported several forms from a deep well on the Volga River at Samara Bend, Russia, as *Fusulinella usvae*, *F. pulchra*, and *F. schwagerinoides* associated with lower Upper Pennsylvanian types of *Triticites* and with *Quasifusulina longissima* (MÖLLER). However, the illustrations of these forms do not indicate

that they are closely similar to most American and Asiatic forms of *Fusulinella*.

GENUS FUSULINA FISCHER DE WALDHEIM, 1829

Plate 1, figures 4-8; Plate 6, figures 4-18; Plate 32, figures 7, 8; Plate 38, figures 9-13

GENOTYPE.—*Fusulina cylindrica* FISCHER DE WALDHEIM, 1829, Soc. Imp. Naturalistes Moscou, Bull., vol. 1, p. 330-331.—FISCHER DE WALDHEIM, 1837, Oryctographie (Gouv. Moscou), p. 126, 127, pl. 13, figs. 1-5.

Fusulina FISCHER DE WALDHEIM, 1829, Soc. Imp. Naturalistes Moscou, Bull., vol. 1, p. 330.—FISCHER DE WALDHEIM, 1837, Oryctographie (Gouv. Moscou), p. 126.—MÖLLER, 1877, Neues Jahrb. Min., Geol. und Pal., Jahrg. 1877, p. 141-143.—DUNBAR & HENBEST, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 362.—ROTH & SKINNER, 1930, Jour. Paleontology, vol. 4, p. 343.—GALLOWAY, 1933, Manual Foraminifera, p. 401.—DUNBAR, 1933, Cushman Lab. Foraminifera, Special Pub. no. 4, p. 134.—THOMPSON, 1934, Iowa Univ. Studies Nat. History, vol. 16, p. 298-301.—THOMPSON, 1936, Am. Jour. Sci., 5th ser., vol. 32, p. 287-291.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 562, 563.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 144.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 80.—THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 41, 59.

Fusulina [part] BRADY, 1876, Mag. Nat. History, Ann., 4th ser., vol. 18, p. 414-422.—MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII sér., tome 25, no. 9, p. 45-51.—MÖLLER, 1879, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII sér., tome 27, no. 5, p. 3.—SCHELLWIEN, 1898, Palaeontographica, Band 44, p. 238-243.—YABE, 1903, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 21, art. 5, p. 2.—DOUVILLÉ, 1906, Soc. Géol. France, Bull., sér. 4, tome 6, p. 584.—SCHELLWIEN, 1908, Palaeontographica, Band 55, p. 161-193.—DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 14.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 79.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 63, 64.

Hemifusulina MÖLLER, 1877, Neues Jahrb. Min., Geol. und Pal., Jahrg. 1877, p. 144.—MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VIII sér., tome 25, no. 9, p. 74, 75. (GENOTYPE.—*Hemifusulina bocki* MÖLLER, 1878 = *Fusulina minima* SCHELLWIEN, 1908. Holotype here designated as the specimen illustrated by MÖLLER, 1878, as fig. 2, pl. 11, and re-illustrated by SCHELLWIEN, 1908, as fig. 21, pl. 13, under *Fusulina bocki* MÖLLER. (Here reproduced as fig. 4 on Pl. 6.)

Schellwieinia [part] STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Inst., Bull., vol. 10, p. 113 (proposed as typical subgenus of *Fusulina* FISCHER DE WALDHEIM; is therefore synonym of *Fusulina*, with *Fusulina cylindrica* FISCHER DE WALDHEIM as subgenotype). [Not *Schellwieinia* of later authors.]

Fusulinella [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 24, 25.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 15.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour. sec. 2, vol. 2, pt. 3, p. 140.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 73 (1927).—OZAWA, 1928, Cushman Lab. Foraminifera, Special Pub. no. 1, p. 131, 132. [Not MÖLLER, 1877.]

Girtyina LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 24.—HENBEST, 1928, Jour. Paleontology, vol. 2, p. 76.—LEE & CHEN, 1930, Nat. Research Inst. Geology, Mem., no. 9, p. 129-132. [Not *Girtyina* STAFF, 1909.]

Girtyina [part] STAFF, 1912, Palaeontographica, Band 59, p. 164, 165. [Not *Girtyina* STAFF, 1909.]

Beedeina GALLOWAY, 1933, Manual of Foraminifera, p. 401, 402. [GENOTYPE.—*Fusulinella girtyi* DUNBAR & CONDRA,

1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 76-78, pl. 2, figs. 1-5 (1927) (here illustrated as figs. 9-12 on Pl. 6.)]

The genus *Fusulina* FISCHER DE WALDHEIM bears the oldest generic name of the family and is the source of the family name. The shell is small and inflated fusiform to subcylindrical, having bluntly rounded to sharply pointed poles and straight to irregular axis of coiling. Mature specimens of five to ten volutions are about 2.0 to 10.3 mm long and 1.0 to 3.5 mm wide. Most primitive forms are short and inflated fusiform; most more advanced forms, including the genotype, are elongate subcylindrical to elongate fusiform. The shell of most specimens of all forms is planispiral throughout growth. In some primitive forms having minute proloculi the first few volutions are coiled at a large angle to the outer volutions. The tunnel is singular. Chomata of primitive forms are asymmetrical and broad. In late forms, including the genotype, the chomata are small and axial fillings are developed. The spirotheca of primitive forms are composed of a tectum, a diaphanotheca, and thick upper and lower tectoria; the tectoria are thin, discontinuous, or absent in highly developed forms. The septa are fluted throughout the length of the shell. The fluting is relatively low and broad in primitive forms but it is narrow and extends almost to the top of the chambers in highly developed forms.

For about 48 years after its proposal by FISCHER DE WALDHEIM, the generic name *Fusulina* was applied to most fusulinids. During development of the terminology of the fusulinids, much misunderstanding of the nature of *Fusulina* arose, as the above synonymy indicates, and several synonymous generic terms were proposed. The status of some of these is still in doubt.

When FISCHER DE WALDHEIM proposed the genus in 1829, he named *Fusulina cylindrica* and *F. depressa* in that order. In 1877 and 1878, MÖLLER stated that *Fusulina cylindrica* was the typical form of the genus. Also, SCHELLWIEN (1898) indicated that *F. cylindrica* was the typical form of the genus. YABE (1903) unambiguously designated *F. cylindrica* the genotype of *Fusulina*.

Topotype specimens of *Fusulina cylindrica* from Mjatschkowa, Russia, have been studied and described by many workers since FISCHER DE WALDHEIM's time, including MÖLLER (1878), SCHELLWIEN (1908), LEE (1927), DUNBAR & HENBEST (1930), and THOMPSON (1936e, 1945). SCHELLWIEN (1898) recognized two types of fusulinids at Mjatschkowa, one with a thin wall and highly fluted septa as described above for *Fusulina*, and the other with only slightly fluted septa and thick walls composed of a tectum and keriotheca with distinct alveoli. SCHELLWIEN retained the name *Fusulina cylindrica* for the former type and for the latter type he coined the name *Fusulina simplex* SCHELLWIEN. *F. simplex* is referable to the genus *Triticites*

GIRTY (1904). In 1935, SILVESTRI studied fusulinids from Mjatschkowa and seemingly had only specimens of the thick-walled type. He was seemingly unaware of SCHELLWIEN's restriction of *F. cylindrica* to the thin-walled type having highly fluted septa, and erroneously concluded that *Fusulina* has a two-layered thick wall and only slightly fluted septa.

MÖLLER (1877) proposed the genus *Hemifusulina* for a form he was then studying from "Kohlenkalk des Gouvernements Twer, bei Prjamuchina." The following year MÖLLER (1878) described this form as *Hemifusulina bocki* MÖLLER, and it therefore is the genotype of *Hemifusulina*. SCHELLWIEN (1908) considered *Fusulina* synonymous with *Hemifusulina*. As MÖLLER (1878) had described one form as *Fusulina bocki* MÖLLER on page 54 and another form as *Hemifusulina bocki* MÖLLER on page 76, placing *Hemifusulina* and *Fusulina* in synonymy automatically made the name *Fusulina* [*Hemifusulina*] *bocki* (MÖLLER) of page 76 a homonym of *Fusulina bocki* MÖLLER of page 54. Therefore, SCHELLWIEN renamed the homonym *Fusulina minima* SCHELLWIEN. Although SCHELLWIEN gave reference under *Fusulina minima* to MÖLLER's illustrations of *Hemifusulina bocki*, he re-illustrated them and labeled them as "*Fusulina bocki* MÖLL." MÖLLER's specimens originally referred to *Hemifusulina bocki* must be considered the types of *Fusulina minima* SCHELLWIEN, and the axial section illustrated by MÖLLER (1878) as figure 2 on his Plate 11 and by SCHELLWIEN (1908) as figure 21 on his Plate 13 is here designated the holotype of *Fusulina minima* SCHELLWIEN and therefore the holotype specimen of the genotype of *Hemifusulina* (Pl. 6, fig. 4).

SCHELLWIEN's illustrations (photographs) and description of *Fusulina minima* demonstrate that it has a wall composed of a tectum, diaphanotheca, and upper and lower tectoria. The septa are strongly fluted throughout the length of the shell. The shell is planispiral throughout growth. Chomata are low but well developed. The major differences between the genotypes of *Hemifusulina* and *Fusulina* are that the shells of *F. cylindrica* are more elongate and cylindrical, the chomata are more poorly developed, and axial fillings occur in *F. cylindrica* but are absent in the genotype of *Hemifusulina*. Most American forms generally referred to *Fusulina* resemble the genotype of *Hemifusulina* more closely than they do *Fusulina cylindrica*. On the other hand, *F. cylindrica*, with its axial fillings and elongate shell, resembles the genotype of *Quasifusulina* more closely than it resembles the genotype of *Hemifusulina*.

Although realizing the possibility that both *Fusulina* and *Hemifusulina* may eventually be recognized as valid, for the present I am retaining *Fusulina* in its generally accepted sense; that is, to include both *Fusulina minima* and *Fusulina cylindrica*.

STAFF (1909) proposed the genus *Girtyina* (p.

490) for specimens which he stated were illustrated in one of SCHELLWIEN'S manuscripts as *Fusulina ventricosa*. Later in the same report (p. 506) STAFF formally introduced the name *Girtyina* as a genus, with *Fusulina ventricosa* as the genotype. In 1912, STAFF illustrated as *Girtyina ventricosa* (MEEK) specimens that are not closely similar to the form originally described by MEEK & HAYDEN. *Fusulina ventricosa* is referable to the genus *Triticites*. The form illustrated by STAFF in 1912 was later named *Fusulinella girtyi* by DUNBAR & CONDRA (1928) and is now referred to *Fusulina*. Therefore, *Girtyina* is a synonym of *Triticites*. It can not be determined with certainty what form STAFF had in mind when he proposed the name *Girtyina*, but he did unambiguously state that the genotype is "*Fusulina ventricosa* Meek."

GALLOWAY (1933) proposed the genus *Beedeina* with *Fusulinella girtyi* DUNBAR & CONDRA (1928) as genotype. *F. girtyi* (Pl. 6, figs. 9-12) is closely similar to the genotype of *Hemifusulina*, *F. minima* SCHELLWIEN (= *Hemifusulina bocki* MÖLLER, 1878), although the chomata are more strongly developed in *F. girtyi* than in *F. minima*. This feature alone is not believed to be of generic importance. Therefore, if a genus distinct from *Fusulina* is to be recognized for the forms having thin *Fusulinella*-type walls, more gibbose shells, and no axial fillings, the name *Hemifusulina* MÖLLER should be applied to them.

Fusulina, as here interpreted in a broad sense, can be distinguished from *Fusulinella* by the closely fluted septa throughout the length of the shell of *Fusulina*, the larger size of most *Fusulina*, and the axial fillings in advanced forms of *Fusulina*.

It is difficult to point out many major generic differences between *Fusulina cylindrica*, the genotype of *Fusulina*, and *Fusulina longissima* MÖLLER, the genotype of *Quasifusulina*. I have studied topotype specimens of *F. cylindrica* and specimens sent to me from Russia identified by Dr. D. RAUSER-CERNOUSSOVA as *Quasifusulina longissima*. The spirothecal structures of the two forms are almost identical. The major differences between these two species seem to be the rate of expansion of the shell, size of mature specimens, degree of development of axial fillings, and some measurable data. CHEN (1934b, p. 91) stated that *Quasifusulina* contains a "thin tectum and keriotheca with ill-developed alveolar structure; outer tectorium absent, inner tectorium sometimes gently developed." The spirotheca of *F. cylindrica* is similar to that of *Q. longissima* except that a thin upper tectorium is recognized in the former (THOMPSON, 1945, p. 446). *Q. longissima* has more massive axial fillings than those of *F. cylindrica*. All these differences probably are specific and not of generic value. However, at this time I am questionably and tentatively recognizing both genera. *Quasifusulina* as defined below differs only slightly from the genotype of *Fusulina*, but it

differs from more primitive forms of *Fusulina* (possibly referable to *Hemifusulina* MÖLLER) in that the shell is elongate cylindrical and contains heavy axial fillings.

GENUS WEDEKINDELLINA DUNBAR & HENBEST, 1933

Plate 7, figures 1-7

GENOTYPE.—*Fusulinella euthusepta* HENBEST, 1928, (= *Wedekindellina euthusepta* DUNBAR & HENBEST, 1933), *Jour. Paleontology*, vol. 2, p. 80, 81, pl. 8, figs. 6-8b, pl. 9, figs. 1, 2, 5 (Holotype illustrated by fig. 6, pl. 8).

Wedekindellina DUNBAR & HENBEST, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 134.—THOMPSON, 1934, *Iowa Univ. Studies Nat. History*, vol. 16, p. 278-282.—RAUSER-CERNOUSSOVA, 1935, C. R. (Doklady) Acad. Sci. U. S. S. R., vol. 4, (IX), p. 117-120.—THOMPSON, 1935, *Jour. Paleontology*, vol. 9, p. 304.—RAUSER-CERNOUSSOVA & BELJAEV, 1936, Acad. Sci. U. S. S. R., *Trans. Polar Comm.*, vol. 28, p. 183.—THOMPSON, 1936, *Jour. Paleontology*, vol. 10, p. 105.—(?) LEE, 1937, *China Geol. Soc. Bull.*, vol. 16, p. 78, 79.—NEEDHAM, 1937, *New Mexico School Mines Bull.* 14, p. 27.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 567.—RAUSER-CERNOUSSOVA & BELJAEV, 1940, *Geol. Oil Inst., Trans.*, new ser., fasc. 7, p. 21, 72.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 141.—THOMPSON & SCOTT, 1941, *Jour. Paleontology*, vol. 15, p. 352.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey Bull.* 67, p. 79.—THOMPSON, 1945, *Kansas Geol. Survey Bull.* 60, p. 56.

Wedekindella DUNBAR & HENBEST, 1930, *Am. Jour. Sci.*, 5th ser., vol. 20, p. 362 (GENOTYPE.—*Fusulinella euthusepta* HENBEST, 1928).—ROTH & SKINNER, 1930, *Jour. Paleontology*, vol. 4, p. 340. [*Not* SCHINDEWOLF, 1928.]

Wedekindia DUNBAR & HENBEST, 1931, *Am. Jour. Sci.*, 5th ser., vol. 21, p. 458 (GENOTYPE.—*Fusulinella euthusepta* HENBEST, 1928).—SKINNER, 1931, *Jour. Paleontology*, vol. 5, p. 259. [*Not* SCHINDEWOLF, 1925.]

Fusulinella [part] HENBEST, 1928, *Jour. Paleontology*, vol. 2, p. 80-82.—DOUTKEVITCH, 1934, *Oil Geol. Inst., Trans.*, ser. A, vol. 36, p. 43, 81. [*Not* MÖLLER, 1877.]

?*Boultonia* [part] LEE, 1927, *China Geol. Survey, Palaeontologia Sinica*, ser. B, vol. 4, fasc. 1, p. 10. [*Not including Boultonia willsi* LEE, the genotype.]

Fusulina [part] WHITE, 1932, *Texas Univ. Bull.* 3211, p. 24.—GUBLER, 1935, *Soc. Géol. France, Mém.*, new ser., tome 11, fasc. 4, no. 26, p. 63. [*Not* FISCHER DE WALDHEIM, 1829.]

The genus *Wedekindellina* DUNBAR & HENBEST has a small elongate fusiform shell that has a straight to slightly irregular axis of coiling. Mature shells of seven to thirteen volutions are about 2.0 to 5.4 mm long and 0.6 to 2.0 mm wide. The form ratio is 1.7 to 4.0. Almost all forms are long and slender. Some forms have inflated central areas, and others have an ellipsoidal profile. The proloculus is minute, and the shell is tightly coiled. Volutions increase in height slowly. The first few volutions of some forms are slightly asymmetrical. The path of the tunnel is slightly irregular in most forms. The tunnel is singular. Chomata are highly asymmetrical and broad. Axial fillings are well developed. Axial fillings occur only in extreme polar regions in primitive forms; they completely fill the chambers about half the distance from the pole to the tunnel in some more advanced forms, and extend to the tunnel borders in some forms.

Septa are closely spaced and are unfluted throughout the length of the shell. The spirotheca is composed of a tectum, a diaphanotheca, and upper and lower tectoria.

Wedekindellina can be distinguished from *Fusulinella*, to which it is most closely similar, by the unfluted septa, the presence of heavy fillings in its axial region, the slender shape of the shell, and the closely spaced septa of *Wedekindellina*. The general shape and axial fillings of *Wedekindellina* closely resemble those of *Fusiella*. However, *Fusiella* has a spirotheca composed of only three layers—a tectum and upper and lower tectoria. Also, the shell of *Fusiella* is much smaller than that of *Wedekindellina*.

The relationship of *Wedekindellina* to other members of the subfamily Fusulininae is not clearly understood. Based on general appearance, axial fillings, and unfluted septa, *Wedekindellina* seems to be a descendant of *Fusiella*. The subfamily Fusulininae as here defined may be biphyletic; one branch, including *Wedekindellina*, having been derived from *Fusiella*, and the other branch, including *Profusulinella*, *Fusulinella*, *Fusulina*, and *Quasifusulina*, having been derived from *Pseudostaffella* or from *Eoschubertella*.

Wedekindellina is widespread geographically in North America. THOMPSON & SCOTT (1941) published most localities reported up to that time. Since 1941, *Wedekindellina* has been discovered in north-eastern Utah (THOMPSON, 1945) and eastern Arizona. *Wedekindellina* is widespread in eastern European Russia (DOUTKEVITCH, 1934a; RAUSER-CERNOUSSOVA *et al.*, 1940). *Boultonia rawi* LEE from northern China may be referable to *Wedekindellina*.

Wedekindellina is confined to rocks of upper Middle Pennsylvanian age in America and Eurasia. NEWELL & KEROHER (1937) described a form from basal Missourian rocks of Kansas as *Wedekindellina ultimata*. There is some question, however, that this form is referable to *Wedekindellina*.

GENUS QUASIFUSULINA CHEN, 1934

Plate 6, figure 19

GENOTYPE.—*Fusulina longissima* MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VII^e sér., tome 25, no. 9, p. 59-61, pl. 1, fig. 4, pl. 2, figs. 1a-1e, pl. 8, figs. 1a-1c. (MÖLLER lists at the head of the specific description pl. 7, figs. 1a-1e, but the description is based on his pl. 8, figs. 1a-1c.)—SCHELLWIEN, 1908, Palaeontographica, Band 55, p. 163-165, pl. 13, figs. 15, 16. [Not pl. 13, fig. 14.] (Holotype here designated as specimen illustrated by pl. 8, fig. 1a of MÖLLER, 1878, and by pl. 13, fig. 16 of SCHELLWIEN, 1908.)

Quasifusulina CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 91-92.—CHEN, 1934, Nat. Research Inst. Geology, Mem., no. 14, p. 46.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 570, 571.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 150.—GORSKY, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U. S. S. R., vol. 5, Middle and Upper Carboniferous, p. 39.—RAUSER-CERNOUSSOVA & BELJAEV,

1940, Geol. Oil Inst., Trans., new ser., fasc. 7, p. 5.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 80, 81.

Fusulina [part] of some authors prior to 1934.

Schellwienia [part] of some authors prior to 1934.

The genus *Quasifusulina* CHEN is the most advanced unquestioned member of the subfamily Fusulininae. The shell is small and highly elongate subcylindrical, having broadly irregular axis of coiling and bluntly rounded poles. Mature shells of five to seven volutions are as large as 12.2 mm long and 2.7 mm wide. The proloculus is relatively large and is spherical to irregular in shape. In some specimens it has a maximum size of 0.6 mm. The shell is loosely coiled, and the chambers are of about the same height throughout the length of the cylindrical part of the shell. The chambers increase in height sharply in the end zones of outer volutions. The tunnel is singular, and its path is relatively straight. Chomata are poorly developed immediately adjacent to the septa, but seemingly are absent in the center of the chambers. The spirotheca is less than 50 microns thick in outer volutions, and is composed of a tectum, a lower layer that seems to be fibrous in some parts of some specimens, and thin discontinuous upper and lower layers. These upper and lower layers may be parts of axial fillings extending out from polar regions, they may be parts of the chomata, or they may be a combination of the two. The septa are intensely fluted throughout the length of the shell, and the fluting extends to the tops of the chambers. Cuniculi are developed in some Permian forms. Axial fillings occur in the polar regions of the second to the penultimate volutions. Axial fillings extend to the tunnel borders in the second and third volutions of mature specimens of some Permian Asiatic forms; they extend about half the distance to the tunnel in the second to the fourth volutions of the holotype of the genotype.

CHEN described the spirotheca of *Quasifusulina* as composed of a tectum, a keriotheca having ill-defined alveolar structure, and a partly developed tectorium. The Russian specimens which I have studied agree closely with this, except that no alveolar structure is observable and the tectorium-like layers seem poorly developed both on the top and the bottom of the spirotheca. These outer layers may correspond to parts of the axial fillings. DUNBAR & HENBEST (1942) did not observe a tectum in the spirotheca. A comparison of topotype specimens of *Fusulina cylindrica* and specimens of *Quasifusulina longissima* sent me by Dr. RAUSER-CERNOUSSOVA from Russia indicates that their spirothecal structures are closely similar, if not identical.

Quasifusulina differs from *Fusulina* (as based on the genotype *F. cylindrica*) in that the septa of *Quasifusulina* are more highly and closely fluted and the axial fillings of *Quasifusulina* are heavier. SKINNER (DUNBAR & SKINNER, 1937, p. 570) observed cuniculi developed in *Quasifusulina tenuissima*

(SCHELLWIEN) from the Permian of the Carnic Alps, but cuniculi have not been observed in *Fusulina*.

Quasifusulina differs from *Gallowainella* mainly in spirothecal structures. The spirotheca of *Gallowainella* is composed of a single thin layer in which no structures are observed. CHEN (1934a) originally described the genotype of *Gallowainella*, *G. meitiensis* (CHEN), as having a tectum and a diaphanotheca with indistinct alveoli. Later observations by CHEN & DUNBAR (DUNBAR & SKINNER, 1937, p. 571) indicate that the spirotheca is composed of a single thin layer having dark coverings above and below. Also, the axial fillings of *Gallowainella* are not as heavy as those of *Quasifusulina*, and the septa of the former are even more highly fluted.

I am placing both *Quasifusulina* and *Gallowainella* in the subfamily Fusulininae. It seems evident that *Quasifusulina* developed from *Fusulina*. The relationship of *Gallowainella* to other members of the subfamily is not clearly understood.

Quasifusulina is represented by only two described species, *Q. longissima* and *Q. tenuissima*. *Q. longissima* is known from rocks of lower Upper Pennsylvanian age of Russia, and several varieties⁵ of this form occur throughout the Taiyuan series of North China and the Chuanshan limestone of South China. *Q. tenuissima* was originally described from the Troghofel limestone of the Carnic Alps and has been reported from the Taiyuan series of North China. Therefore, *Quasifusulina* has a stratigraphic range in Europe and Asia from rocks corresponding in age to the lower part of the Upper Pennsylvanian to at least the top of the Wolfcampian series of the Permian.

GENUS GALLOWAINELLA CHEN, 1937

Plate 7, figures 8-12

GENOTYPE.—*Gallowaina meitiensis* CHEN, 1934, Geol. Soc. China, Bull., vol. 13, p. 238, 239, pl. 1, figs. 1-10 (Holotype here designated as the specimen illustrated by CHEN as fig. 1, pl. 1).

Gallowainella CHEN, 1937, (In DUNBAR & SKINNER) Texas Univ. Bull. 3701, p. 571, 572.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 149, 150.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 85.

Gallowaina CHEN, 1934, Geol. Soc. China, Bull., vol. 13, p. 237, 238. (GENOTYPE.—*Gallowaina meitiensis* CHEN, 1934.) [Not *Gallowayina* ELLIS, 1932.]

The genus *Gallowainella* CHEN has a small shell that is elongate subcylindrical to fusiform in shape and that has an arcuate axis of coiling and sharply to bluntly pointed poles. Mature shells of six to seven volutions are about 5.2 mm long and 1.5 mm wide. The proloculus is relatively large, and the shell expands uniformly. The chambers increase in height rapidly as the poles are approached. Septa are narrowly fluted for about two-thirds their

heights throughout the length of the shell. The spirotheca is composed of a single thin layer covered above and below by thin secondary layers. The spirotheca is about 20 microns thick in the outer volutions. Axial fillings are developed throughout all except the outer volution.

Gallowainella resembles *Quasifusulina* somewhat closely. As now understood, they can be distinguished by the different wall structure and lighter axial fillings of *Gallowainella*.

The relationship between *Gallowainella* and *Palaeofusulina* is not clear. Most of DEPRAT'S (1913) illustrations of the genotype of *Palaeofusulina*, *P. prisca* DEPRAT, are drawings or retouched photographs, and they indicate that the spirotheca of *Palaeofusulina* has a keriotheca with distinct alveoli. LICHAREW (1926) described as *Palaeofusulina nana* LICHAREW a form that has a thin spirotheca with indistinct alveoli. Also, COLANT'S (1924) illustrations and description indicate that the genotype of *Palaeofusulina* has an exceedingly thin wall and no discernible alveoli. Therefore, it is possible that *Palaeofusulina* has a spirothecal structure like that of *Gallowainella*. However, *Palaeofusulina* has a short highly inflated shell lacking axial fillings.

The position of *Gallowainella* in the classification of the family is uncertain. The genus was interpreted by CHEN and others to be a degenerate form of some member of the subfamily Schwagerininae. However, its general resemblance to *Quasifusulina*, which is almost certainly a highly developed member of the Fusulininae, suggests that *Gallowainella* is a degenerate form of Fusulininae.

The stratigraphic age of *Gallowainella* is not definitely known. The genotype and only known form came from the Meitein limestone and above the Lungtan coal series of South China. It may be of Middle Permian age. Therefore, its stratigraphic position may not contradict the conclusion that it possibly is a degenerate form descending from *Quasifusulina*.

SUBFAMILY SCHWAGERININAE DUNBAR & HENBEST, 1930

The subfamily Schwagerininae was proposed by DUNBAR & HENBEST in 1930 to include *Triticites* and *Schwagerina* and three genera later named *Pseudofusulina*, *Parafusulina*, and *Polydioxodina*. Since 1930, six additional genera have been recognized that are here referred to Schwagerininae: *Nipponitella*, *Dunbarinella*, *Rugosofusulina*, *Paraschwagerina*, *Pseudoschwagerina*, and *Nagatoella*. One genus described prior to 1930, *Palaeofusulina*, is questionably referred to this subfamily.

This subfamily contains a large variety of fusulinids. The members have a spirotheca composed of a tectum and a keriotheca having well-developed alveoli. The septa are fluted to some extent in all of them. The fluting of primitive members is best developed in the polar regions, but the fluting in

5. Several of these varieties undoubtedly are specifically distinct from *Q. longissima*.

highly developed members is intense completely across the shell. All forms are fusiform to sub-cylindrical fusiform in shape and have straight to slightly irregular axis of coiling. Shell is planispiral throughout all volutions, excepting the first few volutions of some specimens and the outer part of *Nipponitella*. All genera are involute excepting *Nipponitella*, which is irregularly uncoiled in the outer volutions.

The subfamily name Fusulininae was applied by STAFF & WEDEKIND (1910) for some of the same fusulinids now included in Schwagerininae. However, they misinterpreted the genus *Fusulina* and referred to it fusulinids now referred to *Schwagerina*. When the name Schwagerininae was proposed by DUNBAR & HENBEST, the generic name *Schwagerina* was applied to forms now referred to *Pseudoschwagerina*. As interpreted below, however, both *Schwagerina* and *Pseudoschwagerina* are referable to Schwagerininae.

The most primitive members of the subfamily Schwagerininae occur in the basal Upper Pennsylvanian series of America and in rocks of equivalent age in Europe and Asia. The latest members of the subfamily occur in the youngest fusulinid-bearing Permian rocks of Europe, Asia, Africa, and northwestern North America.

GENUS TRITICITES GIRTY, 1904

Plate 1, figures 9-11; Plate 8, figures 1-10;

Plate 13, figure 10

GENOTYPE.—*Miliolites secalicus* SAY, 1823, Long's Exped. to the Rocky Mtns., etc., vol. 1, p. 151.—*Triticites secalicus* GIRTY, 1904, Am. Jour. Sci., 4th ser., vol. 17, p. 234-240, text figs. 1, 2.—DUNBAR & CONDRAS, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 104-108, pl. 7, figs. 1-7, pl. 8, fig. 6 (1927).

Triticites GIRTY, 1904, Am. Jour. Sci., 4th ser., vol. 17, p. 234-240.—GIRTY, 1914, Jour. Geology, vol. 22, p. 239-242.—DUNBAR & CONDRAS, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 53-58 (1927).—DUNBAR & HENBEST, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 363.—GALLOWAY, 1933, Manual Foraminifera, p. 402, 403.—DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 135.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 64, 65.—RAUSER-CERNOUSSOVA & BELJAEV, 1936, Acad. Sci. U. S. S. R., Trans. Polar Comm., vol. 28, p. 186.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 613.—RAUSER-CERNOUSSOVA, 1938, Acad. Sci. U. S. S. R., Work Geol. Inst., tome 7, p. 106.—RAUSER-CERNOUSSOVA & BELJAEV, 1940, Geol. Oil Inst., Trans., new ser., fasc. 7, p. 6.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 145.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 81, 82.

Girtyina STAFF, 1909, Neues Jahrb. Min., Geol., und Pal., Beilage-Band 27, p. 506. [GENOTYPE.—*Fusulina cylindrica* var. *ventricosa* MEEK & HAYDEN, 1868, Philadelphia Acad. Nat. Sci., Proc., vol. 10, p. 261 = *Triticites ventricosus* (MEEK & HAYDEN).] [Not *Girtyina* STAFF, 1912; LEE, 1927; LEE & CHEN, 1930.]

Fusulina [part] STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 494, and of several authors prior to 1927.—OZAWA, 1928, Cushman Lab. Foramin. Research, Special Pub. no. 1, p. 134.—SILVESTRI, 1935, Soc. Geol. Italiana, Boll., vol. 54, p. 203-219. [Not FISCHER DE WALDHEIM, 1829.]

Schellwienia [part] STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Instit., Bull., vol. 10, p. 113.—STAFF, 1912, Palaeontographica, Band 59, p. 165.—LEE, 1927, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 1, p. 40.

?*Grabauina* LEE, 1924, Geol. Soc. China, Bull., vol. 3, p. 51-54. [GENOTYPE.—*Grabauina disca* LEE, 1924, Geol. Soc. China, Bull. 3, p. 51-54, text figs. 1a, 1b (here reproduced as figs. 9, 10 on Pl. 8. Holotype here designated as specimen illustrated by LEE as text fig. 1b).]

The genus *Triticites* GIRTY includes more North American fusulinids than any other genus. Their shells are medium to small and fusiform, having straight axes of coiling and sharply to bluntly pointed poles. Many forms have inflated central region, steep lateral slopes, and sharply pointed poles. Some are subcylindrical and have bluntly pointed poles. Larger forms of ten volutions have maximum sizes of 16 mm long and 6 mm wide, but the average sizes of most forms are much less than these figures. The shell expands uniformly. The spirotheca is composed of a tectum and a keriotheca containing distinct alveoli. The septa are fluted only in the extreme polar regions of primitive forms, but they are weakly fluted completely across the shell in more advanced forms. The tunnel is singular, and its path is straight. Chomata are distinct and highly asymmetrical. In some forms the chambers are of the same height throughout the length of the shell; in others they increase in height poleward from center of shell.

The general size, septal fluting, shape, and spirothecal structure of the early volutions of *Nipponitella* are closely similar to *Triticites*. However, the shell of *Nipponitella* becomes evolute and irregularly uncoiled in gerontic stages. *Nipponitella* seemingly is an aberrant descendant of *Triticites*. *Triticites* can be distinguished from *Dunbarinella* by the axial fillings and the intensely fluted septa of *Dunbarinella*. *Triticites* differs from *Schwagerina* principally in the intensely fluted septa throughout the length of the shell of *Schwagerina*. *Pseudoschwagerina* differs from *Triticites* especially in that the first few volutions of the former are tightly coiled as in *Triticites*, but the outer volutions are loosely coiled. The shell of mature specimens of *Pseudoschwagerina* is highly globular.

GIRTY selected *T. secalicus* (SAY) as genotype of *Triticites*, a species that is more or less intermediate between the known biologic extremes of the genus and intermediate between the upper and lower stratigraphic limits of the genus. *Triticites secalicus* occurs in the Plattsmouth limestone or in rocks of equivalent age in the middle of the Upper Pennsylvanian series over much of central United States.

Triticites probably is ancestral to all other members of the subfamily Schwagerininae. One branch of the genus gave rise to *Dunbarinella* during Upper Pennsylvanian time, another gave rise to *Schwagerina* in later Pennsylvanian or early Permian time, and still another gave rise to *Pseudoschwagerina* in early Permian time. As would be expected, late

members of the different branches of the genus differ considerably.

Several generic names have been proposed that are synonyms of *Triticites*. STAFF (1909) proposed the genus *Girtyina* and designated *Girtyina ventricosa* MEEK (= *Fusulina ventricosa* MEEK & HAYDEN, 1858) as the genotype. Two years later STAFF (1912) illustrated as *Girtyina ventricosa* [= *Fusulina girtyi* (DUNBAR & CONDRA)] a form from Illinois that is not closely similar to the form named by MEEK & HAYDEN. However, as STAFF designated the form named by MEEK & HAYDEN as the genotype, it must be assumed that he correctly understood the species, even though he later incorrectly identified it. *Fusulina ventricosa* MEEK & HAYDEN is a typical form of *Triticites*. Therefore, *Girtyina* is a synonym of *Triticites*.

LEE (1924) proposed the genus *Grabauina* with *Grabauina disca* LEE (1924) as genotype. The illustrated type specimens of *G. disca* are badly crushed and some of their features are distorted (Pl. 8, figs. 9, 10). Some specimens seem to have septa fluted throughout the length of the shell. Otherwise, their features, if restored, probably would resemble those of *T. secalicus*. *Grabauina* is questionably placed in synonymy with *Triticites*. It is possible that *Grabauina* is a valid genus of which *Pseudofusulina* DUNBAR & SKINNER is a synonym.

Triticites is widespread in Upper Pennsylvanian and Wolfcampian rocks of America, occurring from Ohio in the east to California in the west. *Triticites* is widespread in Upper Pennsylvanian rocks of European Russia. It occurs in the region of Moscow, on the west flanks of the Ural Mountains, and in the Samara Bend and Trans-Volga regions. Questionable *Triticites* are common in the basal Swine limestone of South China and are rare in the Taiyuan series of North China.

The most primitive fauna of *Triticites* in America is from the lower part of the Upper Pennsylvanian series, and the most advanced fauna is in the middle part of the Permian Wolfcampian series. The genus seemingly is as restricted stratigraphically in Europe and Asia as in America.

GENUS NIPPONITELLA HANZAWA, 1938

Plate 8, figures 12-17

GENOTYPE.—*Nipponitella explicata* HANZAWA, 1938, Imp. Acad., Proc., vol. 14, no. 7, p. 256, 257, figs. 8-16 (Holotype here designated as the specimen illustrated by HANZAWA as fig. 11).

Nipponitella HANZAWA, 1938, Imp. Acad., Proc., vol. 14, no. 7, p. 256.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 149.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 85.

The genus *Nipponitella* HANZAWA has a small shell. The first three to six volutions are elongate fusiform. The outer part of the shell is irregularly uncoiled, forming ornate subrectilinear flanges. The proloculus is spherical, and the shell expands uni-

formly during the fusiform part. The uncoiled part of the shell has a volume several times the volume of the coiled part. The spirotheca is composed of a tectum and a keriotheca bearing coarse alveoli. The tunnel is singular in the coiled part of the shell, but has not been observed in the uncoiled part. Chomata are developed in the coiled part of shell, but seem to be absent in the uncoiled part. The septa are narrowly fluted in the polar regions, but the fluting occurs only at the base of the septa in the central part of the coiled volutions. The septa are irregularly and intensely fluted in the uncoiled part of the shell.

HANZAWA reported cuniculi at the base of the septa in the coiled part of the shell. However, the small size of the coiled shell, the relatively thick spirotheca, and the unfluted upper part of the septa of the coiled part of the shell do not resemble these features of other fusulinids that have cuniculi. In many respects, the central part of *Nipponitella* resembles some highly developed forms of *Triticites*. It is possible that *Nipponitella* developed from and is an aberrant descendant of *Triticites*.

Nipponitella resembles *Codonofusiella* from the Upper Permian in regard to the uncoiled gerontic stage, but these genera resemble each other in few other ways. The structure of the spirotheca, the shape of the early volutions, and the coiling of the early volutions are entirely different.

Nipponitella is known from the Permian Maiya group of Rikuzen Province of northeastern Japan and from a boulder in river gravel of the same area.

GENUS DUNBARINELLA THOMPSON, 1942

Plate 9, figures 14-18

GENOTYPE.—*Dunbarinella ervinensis* THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 419, 420, pl. 3, figs. 1-9 (Holotype here designated as the specimen illustrated by THOMPSON as figs. 1, 4, pl. 3).

Dunbarinella THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 416-418.

Fusulina [part] of some authors prior to 1930. [Not FISCHER DE WALDHEIM, 1829.]

Schellwienia [part] of some authors prior to 1931.—LEE, 1931, Geol. Soc. China, Bull., vol. 10, p. 287. [Not STAFF & WEDEKIND, 1910.]

Triticites [part] WHITE, 1932, Texas Univ. Bull. 3211, p. 32. [Not GIRTY, 1904.]

Schwagerina [part] DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 623-627. [Not MÖLLER, 1877.]

The genus *Dunbarinella* THOMPSON is the most advanced fusulinid in the American Pennsylvanian. It has a small elongate fusiform shell containing a straight axis of coiling and pointed poles. Mature specimens of six to ten volutions are 5 to 10 mm long. The proloculus is minute. The first two to four volutions are tightly coiled, and the outer volutions expand uniformly. The tunnel is singular and narrow. The chomata form definite ridges only in the inner three to four volutions. They are discontinuous in the outer volutions. Dense calcite

fills all chambers in the axial regions excepting those of the first one or two volutions and those of the outermost volution. The spirotheca is composed of a tectum and a keriotheca that contains coarse alveoli. The septa are narrowly fluted throughout the length of the shell, and the fluting reaches the tops of chambers in the polar regions. However, closed chamberlets are formed for only about two-thirds the height of the chambers across the central part of the shell.

Dunbarinella can be distinguished from *Schwagerina* by the axial fillings, the shape of the shell, the nature of the septal fluting, and the general development of the shell of *Dunbarinella*. Heavy axial fillings, tightly coiled shell, and outline of the shell distinguish *Dunbarinella* from *Pseudofusulina*.

Several paleontologists have included *Dunbarinella* in *Schwagerina* (or synonymous genera) or in *Pseudofusulina*. *Pseudofusulina* seemingly was derived from *Triticites* shortly after the beginning of Wolfcampian time. *Schwagerina* seemingly was derived from *Triticites* at about the same time. *Dunbarinella* must have been derived from a branch of *Triticites* near the middle of Upper Pennsylvanian time. The genera *Dunbarinella*, *Schwagerina*, and *Pseudofusulina* developed along the same evolutionary trends, and many species of all three reached similar stages of development. Accordingly, many are difficult to classify.

Dunbarinella is widespread, being known from many areas of the midcontinent region, California, China, Caracorum, and European Russia. In America the most primitive forms are from the middle part of the Upper Pennsylvanian series, and the latest forms are from the lower part of the Permian. In Europe and Asia, all forms are of Permian age, and most of them are from rocks considered to be Wolfcampian in age.

GENUS *SCHWAGERINA* MÖLLER, 1877

Plate 1, figure 12; Plate 9, figures 1, 2, 5-12;
Plate 13, figures 4, 6, 7, 8

GENOTYPE.—*Borelis princeps* EHRENBURG, 1842, *Berichte Verhandl. K. preuss. Akad., Wiss. Berlin*, p. 273.—EHRENBURG, 1854, *Mikrogeologie*, pl. 37, figs. X, C, 1-4.—DUNBAR & SKINNER, 1936, *Jour. Paleontology*, vol. 10, p. 86, 87, pl. 10, figs. 1-5, 7-11 (Holotype here designated as the specimen illustrated by DUNBAR & SKINNER as fig. 9, pl. 10).

Schwagerina MÖLLER, 1877, *Neues Jahrb. Min., Geol. und Pal., Jahrg. 1877*, p. 143, 144.

Schwagerina [part] DUNBAR & SKINNER, 1936, *Jour. Paleontology*, vol. 10, p. 85, 86.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 623-627.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 145, 146.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey, Bull.* 67, p. 82.—THOMPSON & MILLER, 1944, *Jour. Paleontology*, vol. 18, p. 494.—THOMPSON, WHEELER & HAZZARD, 1948, *Geol. Soc. America, Mem.* 17, p. 17, 18. [Not MÖLLER, 1878, and authors prior to 1936.]

Fusulina [part] of authors (MÖLLER, 1878). [Not FISCHER DE WALDHEIM, 1829.]

Schellwienia [part] of authors.

Pseudofusulina [part] DUNBAR & SKINNER, 1931, *Am. Jour. Sci.*, 5th ser., vol. 22, p. 252-257. [Not including *P. huecoensis* DUNBAR & SKINNER, the genotype.]—GALLOWAY, 1933, *Manual Foraminifera*, p. 404, 405.—DUNBAR, 1933, *Cushman Lab. Foram. Research, Special Pub. no. 4*, p. 136.—CHEN, 1934, *China Geol. Survey, Palaentologia Sinica*, ser. B, vol. 4, fasc. 2, p. 50.—RAUSER-CERNOUSSOVA, 1936, *Acad. Sci., U.S.S.R., Bull., Classe Sci. Math. et Nat.*, p. 573-584.—RAUSER-CERNOUSSOVA, 1938, *Acad. Sci. U.S.S.R., Work Geol. Inst.*, tome 7, p. 132.—BELJAEV & RAUSER-CERNOUSSOVA, 1938, *Acad. Sci. U.S.S.R., Work Geol. Inst.*, tome 7, p. 177.

The genus *Schwagerina* MÖLLER has a small fusiform to subcylindrical shell that contains a straight to slightly arcuate axis of coiling and sharply to bluntly pointed poles. The proloculus is small and the shell expands uniformly. The tunnel path is relatively straight. Chomata are developed throughout most of the shell, but they are discontinuous or low in the central parts of chambers. Septa are fluted throughout the length of the shell. In primitive forms the fluting is narrow only in the lower half of the chambers; in advanced forms the fluting is narrow and high. Structures similar to the cuniculi of *Parafusulina* and *Polydiexodina* have been observed in some advanced Upper Permian *Schwagerina*. However, the forward fold of the salients was not excavated. The spirotheca is composed of a tectum and a coarsely alveolar keriotheca.

MÖLLER (1877) designated *Borelis princeps* EHRENBURG as the genotype of *Schwagerina*. It can not be demonstrated that MÖLLER had not studied specimens of *Borelis princeps* at the time he proposed *Schwagerina*. The following year, MÖLLER (1878) described a form as *Schwagerina princeps* (EHRENBURG), and for about 58 years this form was interpreted as being typical of *Schwagerina*. MÖLLER did not describe or illustrate any form at the time he proposed *Schwagerina*, but he referred a large variety of forms to the genus, in addition to *Borelis princeps*. The form described and illustrated by MÖLLER in 1878 has a spirotheca composed of a tectum and keriotheca. The shell is large and subglobular in shape, and it has a tightly coiled early stage and highly expanded outer volutions.

DUNBAR & SKINNER (1936) restudied EHRENBURG's type material of *Borelis princeps* and discovered that this form is not closely similar to the form referred to *Schwagerina princeps* by MÖLLER in 1878. *B. princeps* has an inflated subglobular shape, a spirotheca composed of a tectum and keriotheca, a shell that expands more uniformly than that of the form illustrated by MÖLLER as *Schwagerina princeps*, and septa fluted throughout the length of the shell. Therefore, DUNBAR & SKINNER proposed *Pseudoschwagerina* as a genus to include the form illustrated by MÖLLER as *Schwagerina princeps*, and they restricted *Schwagerina* to forms closely similar to *Borelis princeps* EHRENBURG. It is in this latter sense that the genus *Schwagerina* is here interpreted.

The genus *Pseudofusulina* was proposed by DUNBAR & SKINNER (1931), and *P. huecoensis* DUNBAR

& SKINNER (1931) was designated the genotype. When DUNBAR & SKINNER (1936) discovered the true nature of *Schwagerina*, they proposed to suppress *Pseudofusulina* as a synonym of *Schwagerina*. However, the genotype of *Pseudofusulina* is so markedly different from *Schwagerina princeps* that it is here proposed to recognize both *Schwagerina* and *Pseudofusulina*.

Schwagerina can be distinguished from *Dunbarinella* by the general structure of the shell of *Schwagerina*, the heavy axial fillings of *Dunbarinella*, and the nature of the septal fluting of *Dunbarinella*. *Pseudofusulina* can be distinguished from *Dunbarinella* by the large proloculus and loosely coiled shell and by the absence of or poor development of axial fillings. *Schwagerina* differs from *Nagatoella* especially in regard to the shape of the shell and the low septal fluting of *Nagatoella*. The axial fillings of *Nagatoella* are much broader than the axial fillings of forms referred to *Schwagerina*.

Schwagerina is widespread geographically in Permian rocks of North, Central, and South America, Europe, Asia, Africa, East Indies, and islands of the Arctic. The genus occurs in south-central United States from near the base of the Wolfcampian series to near the top of the Leonardian series and in the Upper Permian Zone of *Yabeina* faunas of British Columbia and Washington. In Europe, Asia, Pacific Islands, the Arctic region, and South America, the lowest occurrence of *Schwagerina* seems to correspond closely stratigraphically to the first appearance in America. In Africa, Europe, and Asia, *Schwagerina* is found in the Upper Permian fusulinid Zone of *Yabeina*.

Typical forms of *Parafusulina* were derived from elongate *Schwagerina* in the upper Wolfcampian. Many highly inflated types of *Schwagerina* have cuniculi-like arrangements of the septa. In most inflated forms, the salients in the fluting are not resorbed as in *Parafusulina*. Inflated forms having this type of septal fluting here referred to *Schwagerina* occur throughout the Permian in Europe and Asia. Many of them have been referred to *Parafusulina*. It is possible that some forms referred to *Parafusulina* from the Zone of *Yabeina* may not be congeneric with *P. wordensis*.

GENUS **RUGOSOFUSULINA** RAUSER-CERNOUSSOVA, 1937

Plate 9, figure 13

GENOTYPE.—*Fusulina prisca* (EHRENBERG) emend. MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VII^e sér., tome 25, no. 9, p. 56-59, pl. 3, figs. 1a-1c, pl. 6, figs. 2a-2c.—SCHELLWIEN, 1908, Palaeontographica, Band 55, p. 182-184, pl. 18, figs. 7-9, 11, 13, 14, 16, 17. (Selected holotype of form on which genus was defined is illustrated by MÖLLER as fig. 2a, pl. 6, and by SCHELLWIEN as fig. 8, pl. 18.) [Not (?) SCHELLWIEN, 1908, pl. 18, fig. 10.]

Rugosofusulina RAUSER-CERNOUSSOVA, 1937, Lab. Paleontology Moscow Univ. U.S.S.R., Studies Micropaleontology, vol. 1, fasc. 1, p. 9-26.—THOMPSON, WHEELER & HAZZARD, 1946, Geol. Soc. America, Mem. 17, p. 28.

(?) *Alveolina* [part] EHRENBERG, 1842, Berichte Verhandl. K. preuss. Akad. Wiss. Berlin, p. 272.—EHRENBERG, 1864, Mikrogeologie, pl. 37, fig. D 7-9.

Fusulina [part] MÖLLER, 1878, and some authors prior to 1931.

Schellwienia [part] of some authors 1909 to 1930.

Pseudofusulina [part] of authors 1931 to 1936.—RAUSER-CERNOUSSOVA, 1938, Acad. Sci. U.S.S.R., Work Geol. Inst., tome 7, p. 132.

Rugosofusulina DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 146, 147.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 82, 83.

The genus *Rugosofusulina* RAUSER-CERNOUSSOVA was distinguished from *Schwagerina* principally because of the irregular upper surface of its spirotheca. The shell is small and elongate fusiform to sub-cylindrical. The proloculus is spherical. The shell is loosely coiled and expands uniformly. Mature specimens of four to six volutions are 4 to 12 mm long and 1.6 to 3.8 mm wide. Most of the eleven Russian species or varieties originally referred to this genus have mature shells of four to five and one-half volutions, and all of them correspond closely in the total volume of the shell. Also, most forms from other areas correspond closely in volume to the Russian forms. The form ratio is about 4.3 for highly elongate forms and 1.7 for gibbose forms. The spirotheca is composed of a tectum and a coarsely alveolar keriotheca. The entire spirotheca of primitive forms is undulating or dimpled. The tectum of advanced forms is undulating or dimpled, but the lower surface of the spirotheca is smooth. In general, the entire spirotheca is irregular laterally, and the septal furrows are deeply incised. Due to the irregular nature of the spirotheca, the axis of coiling is a zone rather than a line. The septa are highly and irregularly fluted throughout the length of the shell, but the fluting of adjacent parts of the septa are not parallel. The tunnel is singular. Chomata are distinct in the inner volutions of some forms, but they are very small and discontinuous in others.

RAUSER-CERNOUSSOVA designated *Fusulina prisca* EHRENBERG emend. MÖLLER, 1878, as the genotype of *Rugosofusulina*. Therefore, MÖLLER's specimens must be included in the genotype, even though they may not be referable to the form originally named by EHRENBERG.

In the general shape of the shell, rate of expansion of the shell, nature of the septal fluting, and the broad lateral irregularities of the spirotheca, the genotype of *Rugosofusulina* resembles closely the genotype of *Pseudofusulina*. With the exception of the rugosity or dimpled nature of the spirotheca of *Rugosofusulina*, there are few if any differences of generic value between these genera. *Rugosofusulina* differs from *Schwagerina* by the rugose spirotheca, more loosely coiled shell, greater irregularity of the spirotheca, and irregularity of the septal fluting in the former.

Forms of *Rugosofusulina* are widespread in Wolf-

campian rocks of America, occurring in Texas, Oklahoma, Kansas, New Mexico, and California. RAUSER-CERNOUSSOVA (1937) referred eleven species and two varieties from European Russia to *Rugosofusulina*. The genotype has been identified by various authors from many localities in Europe and Asia, including the Carnic Alps, North China, South China, and Japan. The detailed structure of the spirotheca of the specimens referred to the genotype from these numerous localities has not been described in detail. They may not all be referable to *Rugosofusulina*. All forms referred without question to *Rugosofusulina* seemingly correspond in age to the Wolfcampian of America.

GENUS *PARASCHWAGERINA* DUNBAR & SKINNER, 1936

Plate 10, figures 1-8; Plate 14, figures 8, 9

GENOTYPE.—*Schwagerina gigantea* WHITE, 1932, Texas Univ. Bull. 3211, p. 82, 83, pl. 8, figs. 13-15.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 666-668, pl. 55, figs. 1-10 (Holotype here designated as the specimen illustrated by WHITE as fig. 13, pl. 8, and re-illustrated by DUNBAR & SKINNER as fig. 5, pl. 55).

Paraschwagerina DUNBAR & SKINNER, 1936, Jour. Paleontology, vol. 10, p. 89, 90.—KAHLER & KAHLER, 1937, Palaeontographica, Band 87, Abt. A, p. 7.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 666.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 148.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 84.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 499, 500.

Schwagerina [part] of authors, 1908 to 1936.

The genus *Paraschwagerina* DUNBAR & SKINNER contains perhaps the most variable group of species of any Permian genus. The shell is large and inflated fusiform to subglobular, possessing a straight axis of coiling and pointed to broadly rounded poles. The proloculus is minute. The first three to five volutions are tightly coiled. The outer volutions are highly inflated. The ultimate volution of mature specimens is slightly more tightly coiled than the penultimate volution. The genotype is elongated and inflated fusiform, possessing sharply pointed poles. Some forms referred to this genus are subglobular in shape, and their umbilical areas are rounded. The spirotheca is composed of a tectum and a keriotheca. The spirotheca of the genotype is relatively thick, but in some forms the spirotheca is fairly thin. The septa of the genotype are closely and highly fluted throughout the length of the shell, forming chamberlets almost to the tops of the chambers. In other forms referred by DUNBAR & SKINNER to this genus, the fluting is confined to the lower one-sixth of the chambers of the outer four volutions. The septa are highly fluted throughout the length of the tightly coiled portion of the shell. The tunnel is singular. Chomata are distinct in the tightly coiled early volutions, but they are rudimentary in outer volutions.

DUNBAR & SKINNER (1936) referred to *Paraschwagerina*, in addition to the genotype, *Schwager-*

ina alternans SCHELLWIEN, *S. yabei* STAFF, *S. kansasensis* BEEDE & KNIKER, *S. fosteri* THOMPSON & MILLER, *Fusulina dussaulti* DEPRAT, and *Schellwienia oblonga* OZAWA. Since 1936, one additional species has been described as *Paraschwagerina rouveli* THOMPSON & MILLER.

Paraschwagerina includes at the one extreme the genotype and at the other extreme *P. yabei* having fluting in the outer volutions confined to the basal margins of septa. They all have in common the tightly coiled early volutions and the highly inflated outer volutions.

Paraschwagerina resembles *Pseudoschwagerina* in many respects. They are distinguished mainly by the small proloculus, more tightly coiled early volutions, and highly fluted septa of *Paraschwagerina*. *Paraschwagerina* resembles *Schwagerina* in some ways. They are distinguished mainly by the less highly inflated outer volutions of *Schwagerina*.

The earliest American *Paraschwagerina* is from a short distance above the base of the Permian Wolfcampian series. The highest American form is from rocks of Central America considered upper Wolfcampian in age. Most forms referred to *Paraschwagerina* from Europe and Asia are Wolfcampian in age. However, *Paraschwagerina yabei* (STAFF) is from the Sosio beds of Sicily and is associated with forms of the Zone of *Verbeekina-Neoschwagerina*, including *Yangchienia*, *Verbeekina*, *Neoschwagerina*, and *Sumatrina*. All available information indicates that the Sosio beds are of Guadalupian age. Therefore, *Paraschwagerina* seemingly has a stratigraphic range from lower Wolfcampian to Guadalupian.

GENUS *PSEUDOSCHWAGERINA* DUNBAR & SKINNER, 1936

Plate 11, figures 1-10

GENOTYPE.—*Schwagerina uddeni* BEEDE & KNIKER, 1924, Texas Univ. Bull. 2433, p. 27-30, pl. 1, figs. 1, 2, pl. 4, fig. 10, pl. 6, figs. 1, 2, 4-7 (Holotype here designated as the specimen illustrated by BEEDE & KNIKER as fig. 1, pl. 6).

Pseudoschwagerina DUNBAR & SKINNER, 1936, Jour. Paleontology, vol. 10, p. 89.—RAUSER-CERNOUSSOVA, 1936, Acad. Sci. U. S. S. R., Bull., Classe Sci. Math. et Nat., p. 573-584.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 656.—KAHLER & KAHLER, 1937, Palaeontographica, Band 87, Abt. A, p. 14.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U. S. S. R., vol. 6, Permian, p. 41.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 147.—KAHLER & KAHLER, 1941, Palaeontographica, Band 92, Abt. A, p. 73.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 83, 84.—CIRY, 1943, Annales Paléontologie, tome 30, p. 14-43.—THOMPSON, WHEELER & HAZZARD, 1946, Geol. Soc. America, Mem. 17, p. 18, 19.

Schwagerina MÖLLER, 1878, Acad. Imp. Sci. St.-Petersbourg, Mém., VII^e sér., tome 25, no. 9, p. 69-71, and of authors prior to 1936. [Not MÖLLER, 1877.]

The shell of *Pseudoschwagerina* DUNBAR & SKINNER is relatively large and is highly inflated fusiform to subglobular in shape. The axis of coiling is

straight and the poles are pointed to rounded. The proloculus is spherical and is relatively large. The first one to four volutions are tightly coiled. The outer volutions are highly inflated. The ultimate volution of mature shells is more tightly coiled than the penultimate volution. The poles of the tightly coiled inner volutions are sharply pointed but those of the outer volutions are more rounded. The tunnel path is straight. Chomata are low and narrow in the inner volutions, but they are discontinuous and low in the outer volutions. The septa of the holotype are fluted throughout the shell and almost to the top of chambers. The septa are so widely spaced in the outer volutions, however, that the fluting does not form closed chamberlets to the top of the fluted part of the septa. In many species the septa are fluted only along the very basal margins of the septa, and in some forms the septa are practically unfluted throughout the length of the shell. The spirotheca is composed of a tectum and a keriotheca. It is thin in the inner volutions of most forms, but becomes relatively thick in the outer two volutions of most forms. In some forms, the spirotheca is thick in the outer three to four volutions.

The genus *Pseudoschwagerina* was divided by KAHLER & KAHLER (1937) into a typical subgenus *Pseudoschwagerina* and the subgenus *Zellia* KAHLER & KAHLER. The subgenus *Zellia* includes forms having thick spirotheca in the outer three to four volutions, feebly fluted septa, and, as reported by KAHLER & KAHLER, outer deposits on both sides of the septa. Almost all forms of *Zellia* are subspherical in shape at maturity; whereas many forms of *Pseudoschwagerina* are distinctly fusiform.

Pseudoschwagerina resembles *Paraschwagerina* more closely than any other proposed genus. Most forms of these genera may be distinguished by the more closely and highly fluted septa of *Paraschwagerina*, the more highly elongate tightly coiled early portions of *Paraschwagerina*, and the more highly elongate shell of most forms of *Paraschwagerina*, particularly of the genotype. Some specimens referred to *Paraschwagerina*, such as *Schwagerina yabei* STAFF, are highly inflated subglobular in shape and have widely spaced and broadly fluted septa. They resemble closely some forms referred to *Pseudoschwagerina*.

Pseudoschwagerina probably was derived from *Triticites*. Some primitive forms of *Pseudoschwagerina* resemble closely highly developed forms of *Triticites*.

Pseudoschwagerina is first known in North America above the base of the Wolfcampian series, and it is last known near the top of the Wolfcampian. The genus is widespread in North America and occurs in Texas, Oklahoma, Kansas, Nebraska, New Mexico, Utah, Montana, Nevada, and California. Possibly congeneric forms are also known from Greenland. The genus is widespread outside North

America and occurs in South America, Europe, Asia Minor, southern and eastern Asia, islands of the Pacific and Indian Oceans, and islands of the Arctic Ocean. So far as can be determined, *Pseudoschwagerina* is confined to rocks of Wolfcampian age throughout the world. However, some reports (CHEN, 1934b, p. 93) indicate that *Pseudoschwagerina* may occur higher in the Permian section of the Orient (TORIYAMA, 1947, Japanese Jour. Geol. Geog., vol. 20, p. 63-82, pls. 16, 17). Some such reports possibly give the genus greater latitude than is indicated here.

SUBGENUS ZELLIA KAHLER & KAHLER, 1937

Plate 11, figures 1-5

SUBGENOTYPE. — *Pseudoschwagerina* (*Zellia*) *heritschi* var. *heritschi* KAHLER & KAHLER, 1937, *Palaeontographica*, Band 87, Abt. A, p. 22-25, pl. 2, figs. 1-3 (Holotype illustrated as fig. 2, pl. 2).

Pseudoschwagerina (*Zellia*) KAHLER & KAHLER, 1937, *Palaeontographica*, Band 87, Abt. A, p. 20, 21.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 147.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey, Bull.* 67, p. 84.

Schwagerina [part] of authors prior to 1936. [*Not* MÖLLER, 1877.]

Pseudoschwagerina [part] DUNBAR & SKINNER, 1936, *Jour. Paleontology*, vol. 10, p. 89.—CIRY, 1943, *Annales Paléontologie*, tome 30, p. 15, 16.

The shell of the subgenus *Zellia* KAHLER & KAHLER is large and is spherical to subspherical in shape. The ends are rounded. The proloculus is relatively large. The first one to three volutions are tightly coiled, but the outer volutions are inflated and are loosely coiled. The chambers are of about the same height throughout the length of the shell. The septa are thick and closely spaced in the inner volutions, but are widely spaced in the outer volutions. The septa are unfluted to slightly fluted in their basal margins in the outer volutions, and they are coated on both sides by thick secondary deposits. Septal pores are coarse and are unusually abundant. The spirotheca is relatively thick throughout the shell. It is composed of a tectum and a thick coarsely alveolar keriotheca.

The subgenus *Zellia* resembles the typical subgenus *Pseudoschwagerina* closely, and they may not be subgenerically distinct. They are distinguished mainly by the thicker spirotheca, deposits on the septa, more inflated early volutions, and more abundant septal pores of *Zellia*.

As pointed out by KAHLER & KAHLER (1937), the genus *Pseudoschwagerina* contains several kinds of forms. The genotype, *P. uddeni* (BEUDE & KNIKER), is near one extreme, having rather tightly coiled early volutions, relatively highly fluted septa, inflated fusiform shape with pointed poles, and thin spirotheca in all volutions except the outermost. The subgenotype of *Zellia* is near the other extreme of the genus.

Zellia is rather widespread geographically in Europe and Asia. Forms have been described from

rocks probably of Wolfcampian age in Cammon, French Indo-China, the Troghofel limestone of the Carnic Alps of Europe, and the Permian of Turkey.

GENUS *PSEUDOFUSULINA* DUNBAR &
SKINNER, 1931

Plate 12, figures 1-7; Plate 13, figures 1, 2, 5

GENOTYPE.—*Pseudofusulina hucoensis* DUNBAR & SKINNER, 1931, *Am. Jour. Sci.*, 5th ser., vol. 22, p. 257, 258, pl. 1, figs. 3-6a (Holotype here designated as specimen illustrated by DUNBAR & SKINNER as fig. 5, pl. 1).

Pseudofusulina DUNBAR & SKINNER, 1931, *Am. Jour. Sci.*, 5th ser., vol. 22, p. 252-257.

Pseudofusulina [part] GALLOWAY, 1933, *Manual Foraminifera*, p. 404, 405.—DUNBAR, 1933, *Cushman Lab. Foraminifera Research, Special Pub. no. 4*, p. 136.—DOUTKEVITCH & KHABAKOV, 1934, *Acad. Sci. U. S. S. R.*, Tadjik Complex Exped. 1932, *Geol. Pamir*, vol. 8, p. 72.—GUBLER, 1935, *Soc. Géol. France, Mém.*, new ser., tome 11, fasc. 4, no. 26, p. 65, 66.—RAUSER-CERNOUSSOVA, 1935, *Soc. naturalistes Moscou, Bull., Sec. Geol.*, vol. 13, p. 142.—RAUSER-CERNOUSSOVA & BELJAEV, 1936, *Acad. Sci. U. S. S. R.*, *Trans. Polar Comm.*, vol. 28, p. 195, 224.—RAUSER-CERNOUSSOVA, 1936, *Acad. Sci. U. S. S. R.*, *Bull., Classe Sci. Math. et Nat.*, p. 573-584.—RAUSER-CERNOUSSOVA, 1938, *Acad. Sci. U. S. S. R.*, *Work Geol. Inst.*, tome 7, p. 132.—BELJAEV & RAUSER-CERNOUSSOVA, 1938, *Acad. Sci. U. S. S. R.*, *Work Geol. Inst.*, tome 7, p. 169.

Fusulina [part] of authors prior to 1931. [Not FISCHER DE WALDHEIM, 1829.]

Schellwienia [part] of authors.

Leeina GALLOWAY, 1933, *Manual Foraminifera*, p. 406. [GENOTYPE.—*Fusulina vulgaris* var. *fusiformis* SCHELLWIEN, 1909, *Palaeontographica*, Band 56, p. 165-168, pl. 15, figs. 1-4 (Holotype here illustrated as fig. 3 on Pl. 12).]

Schwagerina [part] DUNBAR & SKINNER, 1936, *Jour. Paleontology*, vol. 10, p. 85, 86.—NEEDHAM, 1937, *New Mexico School Mines, Bull.* 14, p. 46.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 623-627.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 145, 146.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey, Bull.* 67, p. 82.—THOMPSON, WHEELER & HAZZARD, 1946, *Geol. Soc. America, Mem.* 17, p. 17, 18. [Not MÖLLER, 1877.]

The shell of the genus *Pseudofusulina* DUNBAR & SKINNER is large and elongate fusiform, having a straight axis of coiling and sharply pointed poles. Mature shells of five to eight volutions are as large as 15 mm long and 6 mm wide. The average sizes of most forms more closely correspond to a length of 10 mm and a width of 3.5 mm. The form ratio is about 2.0 to 4.5, the average for most forms being about 3.0. The proloculus is large, and the shell is loosely coiled throughout. The septa are fluted throughout the length of the shell. In primitive forms, including the genotype, the septa are more intensely fluted in their basal margins than in their upper parts, and they are more strongly fluted in the polar regions than in the center of the shell. In highly developed forms, the septa are intensely fluted throughout the height of the chambers, forming closed chamberlets almost to the tops of the chambers. The spirotheca is thick throughout the shell and is composed of a tectum and a coarsely alveolar keriotheca. Phrenothecae occur in all known American forms and in most, and

possibly all, forms from Europe and Asia. The tunnel path is straight. Chomata are distinct in some early forms, including the genotype, but are indistinct in late forms. Axial fillings are thin in the genotype and closely similar forms and are confined to the extreme polar regions. Axial fillings seemingly are absent in some Leonardian forms.

The genotype of *Pseudofusulina* was considered by DUNBAR & SKINNER (1936) congeneric with *Schwagerina princeps* (EHRENBERG). Accordingly, they placed *Pseudofusulina* in synonymy with *Schwagerina*, which has priority. In the broad sense in which *Pseudofusulina* was originally defined by DUNBAR & SKINNER, they would still be considered synonymous. It seems evident, however, that the latitude originally allowed for *Pseudofusulina* was too broad, and the genus as thus defined was polyphyletic. It is, therefore, proposed to recognize as valid both *Schwagerina* and *Pseudofusulina*. *Pseudofusulina* resembles *Schwagerina* somewhat closely, although the entire group of forms here referred to *Pseudofusulina* have several features in common that are not present in forms of *Schwagerina*. These features of *Pseudofusulina*, listed in the approximate order of importance are as follows: Large proloculus, loosely coiled nature of the shell, and thick spirotheca throughout the shell. The one possible exception to this is *P. frigidis* DEPRAT, which has thin spirotheca but resembles *Pseudofusulina* in other respects. In most forms of *Schwagerina*, including the genotype, the first volutions are tightly coiled, the outer volutions are inflated, and the spirotheca increases in thickness regularly outward from the first volution. Although the nature of the phrenothecae in *Pseudofusulina* is not clearly understood, these structural features are found in almost all forms of the genus and are not found in typical forms of *Schwagerina*. The following list includes some of the forms from America, Europe, and Asia which I am referring to *Pseudofusulina* and which contain well-developed phrenothecae.

Species Referred to Pseudofusulina

AMERICA

- Pseudofusulina hucoensis* DUNBAR & SKINNER, 1931
Schwagerina hessensis DUNBAR & SKINNER, 1937
S. nelsoni DUNBAR & SKINNER, 1937
S. hawkinsi DUNBAR & SKINNER, 1937
S. chiapasensis THOMPSON & MILLER, 1944
Parafusulina? calx THOMPSON & WHEELER, 1946
P. turgida THOMPSON & WHEELER, 1946

EUROPE AND ASIA

- Fusulina mölleri* SCHELLWIEN, 1908. [Not *Fusulina moelleri* ROMANOUSKI, 1890.]
F. vulgaris SCHELLWIEN, 1909
F. krafti SCHELLWIEN-DYHRENFURTH, 1909
F. multiseptata SCHELLWIEN (DEPRAT, 1912)
F. ambigua DEPRAT, 1913
F. complicata SCHELLWIEN (DEPRAT, 1912)
F. globosa DEPRAT, 1912. [Not *F. vulgaris* var. *globosa* SCHELLWIEN-DYHRENFURTH, 1909.]
F. cf. F. granum-avenae ROEMER (COLANI, 1924)
(?) *F. japonica* GÜMBLE (COLANI, 1924)

- F. solida* COLANI, 1924
F. chamchitensis COLANI, 1924
F. dongvanensis COLANI, 1924
 (?) *F. fragilis* COLANI, 1924
Schellwienia crassiseptata (DEPRAT) OZAWA, 1925
S. granum-avenae (ROEMER) OZAWA, 1927
 (?) *Pseudofusulina borealis* RAUSER-CERNOUSSOVA & BEL-JAEV, 1936

The proloculus is large and the shell is relatively loosely coiled in some highly developed forms of doubtful generic affinity having heavy axial fillings, such as *Schwagerina? diversiformis* DUNBAR & SKINNER, 1937, *S.? crassitectoria* DUNBAR & SKINNER, 1937, *S.? pavilionensis* THOMPSON & WHEELER, 1942, and *S.? figueroai* THOMPSON & MILLER, 1944.

GALLOWAY (1933) proposed the genus *Leeina* and designated *Fusulina vulgaris* var. *fusiformis* SCHELLWIEN (1909) the genotype (SCHELLWIEN'S specimen of his fig. 2, pl. 15, was designated as a "Typischer Axialschnitt" and is here designated as the holotype of *Fusulina fusiformis* SCHELLWIEN. It is illustrated below as fig. 3 on Pl. 12.) GALLOWAY distinguished *Leeina* from *Pseudofusulina* by the presence of axial fillings in the former and their absence in the latter. Otherwise the two genera were described as very closely similar. So far as can be determined, the axial fillings of the type species of both genera are almost identical, being discontinuous and poorly developed in the extreme polar regions of both. The differences in magnitude of chomata, expansion of the shells, spirothecal thicknesses, septal flutings, sizes of proloculi, and abundance of phrenothecae are of only specific values. Therefore, *Leeina* is placed in synonymy with *Pseudofusulina*, which has priority.

Pseudofusulina is widespread geographically in America, occurring in Chiapas, Texas, New Mexico, and California. It occurs in many regions of Europe and Asia, including Russia, Turkestan, French Indo-China, China, and Japan. *Pseudofusulina* is known in America from slightly above the base of the Wolfcampian to near the top of the Leonardian. Although the stratigraphic position of some Eurasian forms is poorly known, all seemingly are restricted in Europe and Asia to rocks of Wolfcampian and Leonardian ages.

GENUS NAGATOELLA THOMPSON, 1936

Plate 8, figure 11

GENOTYPE.—*Schellwienia ellipsoidal* var. *orientis* OZAWA [part], 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 22, 23, pl. 8, fig. 3. [Not pl. 6, fig. 1a, pl. 8, fig. 5.] = *Nagatoella orientis* THOMPSON, 1936, Geol. Soc. Japan, Jour., vol. 43, p. 198-200, pl. 12, figs. 1, 2 (Holotype).

Nagatoella THOMPSON, 1936, Geol. Soc. Japan, Jour., vol. 43, p. 196-198.

Schellwienia [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 21. [Not STAFF & WEDEKIND, 1910.]

Schwagerina [part] DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 623-627.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 145, 146.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 82. [Not MÖLLER, 1877.]

The shell of the genus *Nagatoella* THOMPSON is large and ellipsoidal, having broadly rounded poles. Mature shells of thirteen volutions are 6 to 7 mm long and 3.5 to 4.5 mm wide. The shell is ellipsoidal throughout growth of the individual, and the poles are broadly rounded throughout the shell. The spirotheca is composed of a tectum and a coarsely alveolar keriotheca. The spirotheca is thin in the first three to four volutions, but it is thick in the outer volutions. The septa are fluted throughout the length of the shell. The fluting is widely spaced and is confined to the lower margins of the septa. The chomata are narrow and low in the inner four to five volutions and are discontinuous in the outer volutions. Dense calcite almost fills the chambers to the edges of the tunnel in the inner five to six volutions, and fillings cover the inside of chambers from the tunnel to the poles in outer volutions.

Nagatoella is distinguished from *Schwagerina* by its ellipsoidal shape, low septal fluting, distribution of axial fillings, and the development of the spirotheca with growth of the shell. It differs from *Pseudofusulina* in the shape and expansion of the shell, low and uniform septal fluting, and distribution of axial fillings.

Only two forms have been referred to *Nagatoella*. Both are from the Middle Permian of Japan. The status of *Nagatoella* is somewhat open to question. DUNBAR & SKINNER and DUNBAR & HENBEST place it in synonymy with *Schwagerina*. Although it now seems almost certain that *Nagatoella* is not synonymous with *Schwagerina* as defined above, just what biological limits should be placed on *Nagatoella* is not clear. It is not certain how important the shape of the shell of fusulinids should be considered. Several species generally placed in *Schwagerina*, including *S. gruperensis* THOMPSON & MILLER and *S. pavilionensis* THOMPSON & WHEELER, have some features, such as development of the spirotheca, axial fillings, and expansion of the shell, similar to those of *Nagatoella*. These two species are not closely similar to the genotype of *Schwagerina*, except in regard to septal fluting and general outline of the shell. It seems probable that *Dunbarinella*, *Pseudofusulina*, *Rugosofusulina*, *Schwagerina*, and *Nagatoella* should be employed to include many forms formerly referred to *Schwagerina*. As with many other groups of fossil forms outside the family Fusulinidae, many intermediate forms are known among these genera.

Nagatoella is known only from the Middle Permian of Japan.

GENUS PALAEOFUSULINA DEPRAT, 1912

Plate 9, figures 3, 4

GENOTYPE.—*Palaeofusulina prisca* DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 37, 38, pl. 10, figs. 8-17 (Holotype here designated as specimen illustrated by DEPRAT as fig. 8, pl. 10). (= *Fusulina pseudo-prisca* COLANI, 1924, Indochine Service Géol., Mém., vol. 11,

fasc. 1, p. 79-83, 133.) [*Not Fusulina prisca* (EHRENBERG) MÖLLER, 1878.]

Palaeofusulina DEPRAT, 1912, Acad. Sci. Paris, Comptes rendus, tome 154, p. 1548, 1549.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 36, 37.—LICHAREW, 1926, Comm. Geol. Leningrad, Bull., vol. 45, p. 59-66.—GALLOWAY, 1933, Manual Foraminifera, p. 403, 404.—DUNBAR, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 136, 137.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 569.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 150, 151.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 84, 85.

Fusulina [part] COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 79, 133.—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 134. [*Not FISCHER DE WALDHEIM*, 1829.]

Schwagerina [part] THOMPSON, WHEELER & HAZZARD, 1946, Geol. Soc. America, Mem. 17, p. 18, 19. [*Not MÖLLER*, 1877.]

The genus *Palaeofusulina* DEPRAT is the least understood of the many genera here referred to this subfamily. The shell is small and inflated fusiform, having a straight axis of coiling and pointed poles. Mature shells of four to five volutions are 2.8 to 3.5 mm long and 2.0 to 2.9 mm wide. The proloculus is relatively large, and the shell is loosely coiled. The septa are highly and narrowly fluted throughout the length of the shell and in all volutions. Closed chamberlets extend at least three-fourths the height of the chambers. The spirotheca is thin, and seems to be composed of a single layer. Most specimens seemingly are replaced by secondary mineralization. Some specimens seem to have a tectum and a thin structureless lower layer. The tunnel is singular. Chomata are unknown.

The genus *Palaeofusulina* was proposed by DEPRAT in 1912. The first species was described in 1913 as *Palaeofusulina prisca* DEPRAT. Therefore, that species is the genotype. In 1924, COLANI considered *Palaeofusulina* a synonym of *Fusulina*, and the name *P. prisca* DEPRAT automatically became a homonym of *Fusulina prisca* (EHRENBERG) MÖLLER (1878). COLANI proposed the name *Fusulina pseudo-prisca* COLANI for the form described by DEPRAT as the genotype of *Palaeofusulina*. The specimen illustrated by DEPRAT in 1913 as figure 8 on his plate 10 is here designated the holotype of *Palaeofusulina prisca* DEPRAT. Therefore, it is the holotype of *F. pseudo-prisca* COLANI. *Palaeofusulina prisca* DEPRAT may be congeneric with the genotype of *Fusulina*.

DEPRAT stated that the original specimens of the genotype of *Palaeofusulina* were silicified. His illustrations seemingly are a combination of photographs, retouched photographs, and drawings. The spirotheca of the illustrations that do not seem to be retouched is composed of a single thin dense layer. In other illustrations, including that of the holotype, obvious retouching of a photograph has produced rather abnormal structural features. For instance, a thick keriotheca having coarse alveoli is shown across the shell of most volutions, but the keriotheca abruptly ends laterally and is continuous

with a spirotheca composed of only a single dense layer. Other illustrations of paratypes show a spirotheca composed of only a single layer throughout the length of the shell. COLANI's specimens from the same general locality as the holotype seem silicified. All her photographic illustrations show a thin spirotheca. Keriotheca possessing an alveolar structure is not observed in any of them.

The type specimens of *Palaeofusulina nana* LICHAREW (1926) from the Caucasus seem largely replaced by secondary mineralization. The spirotheca is thin and is composed of a tectum and thin structureless lower layer.

In the thin spirotheca and highly and narrowly fluted septa, *Palaeofusulina* resembles *Gallowainella* somewhat closely. However, *Gallowainella* contains heavy axial fillings and has a highly elongate shell.

The degree of septal fluting and the expansion and general shape of the shell of *Palaeofusulina prisca* resemble somewhat closely *Pseudofusulina turgida* (THOMPSON & WHEELER) from the McClellan limestone of California. The major differences are that the spirotheca of *P. turgida* are thick and have a coarse alveolar keriotheca, its shell is much larger, and it has phrenothecae.

Palaeofusulina resembles *Pseudofusulina* in expansion of the shell and large proloculus. However, some forms of *Pseudofusulina*, including the genotype, have poorly developed axial fillings and thick spirotheca with alveolar keriotheca, and most, if not all, have phrenothecae.

Only two species of *Palaeofusulina* are known. The genotype is from the Permian of French Indochina, and *P. nana* LICHAREW is from the "anthracolithique de Caucase septentrional."

GENUS PARAFUSULINA DUNBAR & SKINNER, 1931

Plate 13, figures 3, 9; Plate 14, figures 1-7

GENOTYPE.—*Parafusulina wordensis* DUNBAR & SKINNER, 1931, Am. Jour. Sci., 5th ser., vol. 22, p. 261-263, pl. 2, figs. 1-4.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 690, 691, pl. 42, fig. 11; pl. 72, figs. 1-8 (Holotype here designated as specimen illustrated by DUNBAR & SKINNER, 1937, as fig. 5, pl. 72).

Parafusulina DUNBAR & SKINNER, 1931, Am. Jour. Sci., 5th ser., vol. 22, p. 258-261.—GALLOWAY, 1933, Manual Foraminifera, p. 406.—DUNBAR, 1933, India Geol. Survey, Records, vol. 66, p. 405-413.—DUNBAR, 1933, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 137.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 80, 81.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 66, 67.—NEEDHAM, 1937, New Mexico School Mines, Bull. 14, p. 56.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 672.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 39.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 148.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 83.—HANZAWA, 1942, Japanese Jour. Geology and Geography, vol. 18, p. 127.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 501, 502.—THOMPSON, WHEELER & HAZZARD, 1946, Geol. Soc. America, Mem. 17, p. 19, 20.

Fusulina [part] of authors prior to 1931. [Not FISCHER DE WALDHEIM, 1829.]

The genus *Parafusulina* DUNBAR & SKINNER contains some of the largest and most highly elongate of the fusulinids. The shell is large and highly elongate subcylindrical to elongate fusiform, having broadly rounded to bluntly pointed poles and flat or irregular to sloping lateral sides. The axis of coiling is straight to irregular. The proloculus is large, and the shell expands slowly and uniformly. The septa are highly and narrowly fluted throughout the length of the shell. Resorption or excavation of the downturned forward edges of the salients of the septal fluting gave rise to transverse tunnel-like paths, termed cuniculi. The cuniculi are bordered by spiral traces of the septa at the base of the volution. In primitive forms, the cuniculi are low in the outer volutions but are absent in the earlier volutions. The tunnel is singular but is irregular in highly evolved forms. Axial fillings occur in practically all typical forms. The spirotheca is relatively thin, being composed of a tectum and a thin keriotheca. The tectum is missing in some parts of the shells seemingly due to resorption along some cuniculi and the tunnel.

Parafusulina was originally distinguished from several other closely similar genera by its intensely fluted septa and the presence of cuniculi. Cuniculi have since been observed in Permian fusulinids obviously not generically related to *Parafusulina wordensis*.

The type specimens of *Parafusulina wordensis* are highly silicified. Therefore, their internal structures are poorly preserved. Most closely similar forms of *Parafusulina* have irregular but definite axial fillings. Because the axis of coiling is so irregular in many of the larger forms, many axial sections of them do not encounter the axis over great distances, and axial sections seldom show axial fillings throughout the length of the shell.

Representatives of *Parafusulina* can be distinguished from those of *Schwagerina*, *Pseudofusulina*, *Rugosofusulina*, and *Nagatoella* by their more intensely fluted septa, distinct cuniculi, large subcylindrical shell, and thin spirotheca. *Parafusulina* is closely similar to *Polydiexodina* in regard to all the above features. However, *Polydiexodina* has multiple tunnels but *Parafusulina* has only a single tunnel.

All available evidence indicates that *Parafusulina* was derived from a subcylindrical stock of *Schwagerina*, and *Parafusulina* in turn gave rise to *Polydiexodina*.

Parafusulina is widespread geographically in America and is known from Texas, New Mexico, northern and southern Mexico, Guatemala, California, Oregon, and possibly Montana. The most primitive American form of *Parafusulina* is from basal McCloud limestone, presumably of upper Wolfcampian age. The highest stratigraphic occur-

rence in America is in the Word group of middle Guadalupian age. The stratigraphic range in Europe and Asia is not so well known. Forms have been referred to *Parafusulina* from Middle Permian rocks of many areas; including Japan, the Swine and Chihshia limestones of South China, the Lower Productus limestone of India, the Artinskian limestone of the western Ural Mountains of Europe, and the Troghofel limestone of the Carnic Alps. It is possible that *Parafusulina* is even more widely distributed geographically and stratigraphically in Europe and Asia than now known. Many early forms were not so described or illustrated that *Parafusulina* can be definitely recognized.

GENUS POLYDIEXODINA DUNBAR & SKINNER, 1931

Plate 15, figures 1-8

GENOTYPE.—*Polydiexodina capitansensis* DUNBAR & SKINNER, 1931, *Am. Jour. Sci.*, 5th ser., vol. 22, p. 264-267, pl. 3, figs. 7-11.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 693-695, pl. 80, figs. 1-9 (?10, 11) (Holotype here designated as specimen illustrated by DUNBAR & SKINNER, 1937, as fig. 9, pl. 80).

Polydiexodina DUNBAR & SKINNER, 1931, *Am. Jour. Sci.*, 5th ser., vol. 22, p. 263, 264.—GALLOWAY, 1933, *Manual Foraminifera*, p. 406, 407.—DUNBAR, 1933, *Cushman Lab. Foramin. Research, Special Pub. no. 4*, p. 137, 138.—KAHLER, 1933, *Palaeontographica*, Band 79, Abt. A, p. 168.—DUNBAR, SKINNER, & KING, 1936, *Texas Univ. Bull.* 3501, p. 176.—NEEDHAM, 1937, *New Mexico School Mines, Bull.* 14, p. 58.—DUNBAR & SKINNER, 1937, *Texas Univ. Bull.* 3701, p. 393.—LICHAREW *et al.*, 1939, *Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R.*, vol. 6, Permian, p. 40.—DUNBAR, 1940, (*In* CUSHMAN) *Foraminifera*, p. 149.—DUNBAR & HENBEST, 1942, *Illinois Geol. Survey, Bull.* 67, p. 83.—THOMPSON, 1946, *Jour. Paleontology*, vol. 20, p. 149, 150.

Fusulina [part] some authors prior to 1931. [Not FISCHER DE WALDHEIM, 1829.]

?*Parafusulina* [part] GUBLER, 1935, *Soc. Géol. France, Mém., new ser.*, tome 11, fasc. 4, no. 26, p. 66, 67.

The genus *Polydiexodina* DUNBAR & SKINNER is the most highly evolved of the schwagerinids. It has a large highly elongate subcylindrical to irregular shell. The axis of coiling is straight, broadly curving, or irregular. The poles are sharply to bluntly pointed. Mature specimens attain a length as great as 36 mm, or perhaps even larger for specimens of a sexual generation. The form ratio of mature specimens is as large as 9.0. The proloculus of most forms is large and irregular. The innermost volutions are essentially symmetrical and have a straight axis of coiling. Most all mature specimens are highly elongate and have an irregular axis of coiling. The septa are highly and closely fluted throughout the length of the shell. Cuniculi are distinct throughout the length of the shell. The tunnel is multiple. Primitive forms contain several tunnels, one of which is central in position. Advanced forms have as many as 24 tunnels in the outer volutions, but some do not have a central tunnel. Axial fillings occur throughout shell of most forms, except-

ing the outer part of the last volution. The fillings are heavy in some and light in others.

Polydioxodina resembles *Parafusulina* closely in most respects. However, multiple tunnels occur in *Polydioxodina*, but only a single tunnel is present in *Parafusulina*. Also, most forms of *Polydioxodina* are more highly elongate and more slender than most forms of *Parafusulina*.

DUNBAR, SKINNER, & KING (1936) and DUNBAR & SKINNER (1937) described and illustrated rather rare giant specimens from the Permian of Texas and Mexico associated with normal appearing specimens of several species of *Parafusulina* and *Polydioxodina*. The giant specimens possess a minute proloculus, highly asymmetrical early volutions, and no tunnel. The associated and more abundant specimens of *Parafusulina* have a large proloculus, a well-developed tunnel, and a relatively smaller shell. The giant specimens were believed to represent the microspheric generation and the more abundant smaller specimens to represent the megalospheric generation. A similar set of large and small specimens has been observed in some species of *Polydioxodina*. The giant specimens associated with *Polydioxodina* do not possess tunnels. For the present, at least, no further discussion of this unique association seems necessary or advisable.

Polydioxodina is known in America only from the upper Guadalupian of Texas, New Mexico, and Coahuila, Mexico. *Polydioxodina* seems to be widespread in Europe and Asia and is known from the Bamian limestone of Afghanistan, the Darwas series of Darwas, and Permian limestones of Burma. Possibly congeneric forms have been reported from Greece and Asia Minor. The exact stratigraphic age of several of the occurrences in the Eastern Hemisphere is poorly known. In Afghanistan, *Polydioxodina* is associated with a typical fusulinid Tethys Sea fauna of the Zone of *Verbeekina-Neoschwagerina*. This association strongly suggests a close age relationship between the upper Guadalupian of America and the Tethyan Zone of *Verbeekina-Neoschwagerina*.

SUBFAMILY VERBEEKININAE STAFF & WEDEKIND, 1910

The subfamily Verbeekininae includes the genera *Eoverbeekina*, *Verbeekina*, *Misellina*, *Brevaxina*, and *Pseudodoliolina*. With the exception of one form of *Eoverbeekina* described from Central America, all members are confined to the Eastern Hemisphere and are restricted to rocks of Middle and Upper Permian age of the Tethys Sea area. Although the verbeekinids are recognized to be among the more advanced members of the fusulinids, few of them have been found to be good index fossils. This perhaps is due largely to the lack of detailed studies of verbeekinid faunas over sufficiently widespread areas.

The mature shell of *Eoverbeekina*, *Verbeekina*,

and *Brevaxina* is spherical to subspherical in shape, that of *Misellina* is ellipsoidal, and that of *Pseudodoliolina* is elongate cylindrical with hemispherical polar regions. The range of size of mature specimens is rather large. The maximum diameter is slightly less than 1 mm for some forms of *Misellina* and is more than 11 mm for some forms of *Verbeekina*. The axis of coiling is straight. The spirotheca of most members is composed of a tectum and a lower thicker layer, having fine alveoli-like lines. The upper and lower surfaces of the spirotheca of the inner volutions are covered by dense discontinuous layers that are probably continuous with the parachomata. The spirotheca of one genus, *Pseudodoliolina*, is composed of only a single thin dense layer throughout most of the shell. The septa are closely spaced and are unfluted. They contain the tectum and a short downward extension of the lower layer of the spirotheca. Both sides of the septa are covered by dense deposits that may be continuous with the parachomata. In primitive members, the tunnel is singular in the inner volutions, becomes double in the next few volutions, and develops into numerous small elliptical openings (foramina) at base of the septa in the outer volutions. In more advanced genera, foramina are abundant throughout most of the shell. The foramina are bordered by symmetrical parachomata. The antetheca is thin and it is perforated by septal pores. In primitive forms, the parachomata are distinct only adjacent to the septa and are discontinuous in the center of the chambers. In highly developed forms, the parachomata are continuous across the chambers of parts of the shell, leaving small lateral elliptical openings near the tops of the chambers. The proloculi of most genera are minute, but the proloculus of *Pseudodoliolina* is relatively large.

The evolutionary trend for most of the larger groups within this subfamily can be determined with some degree of certainty. *Eoverbeekina* seemingly developed from the ozawainellids and gave rise to *Verbeekina*. The introduction of closely spaced foramina and parachomata was the major change between these genera. Also, most forms of *Verbeekina* are larger than those of *Eoverbeekina*. Another branch of the subfamily includes *Misellina* and *Pseudodoliolina*. The ancestral form of this branch is not known. It may have evolved from some of the ozawainellids and probably from the same group that gave rise independently to *Eoverbeekina*. Parachomata are massive in *Misellina* and are even more massive in *Pseudodoliolina*. Also, the shell of *Pseudodoliolina* is highly elongate, and its spirotheca is composed of only a single layer throughout most parts of the shell.

Members of the subfamily are known from the Tethys Sea area on the northern, southern, and eastern bordering region of the Mediterranean Sea and Black Sea, southern Asia, islands of the Indian and Pacific Oceans, and extreme eastern Asia. So

far as can be determined, the subfamily is confined to rocks of Leonardian to uppermost Permian age. In the Tethys Sea area of the Eastern Hemisphere, members of the subfamily are best developed in the Middle Permian fusulinid Zone of *Verbeekina-Neoschwagerina*, but members are also common in the highest of the Permian fusulinid faunal zone, the Zone of *Yabeina*. However, no members of the subfamily are found associated in the Zone of *Yabeina* fusulinid faunas of northwestern North America. In Central America, *Eoverbeekina* is associated with primitive fusulinids of the Zone of *Parafusulina*.

GENUS *Eoverbeekina* LEE, 1933

Plate 16, figures 1-6

GENOTYPE.—*Eoverbeekina intermedia* LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 18, 19, pl. 1, figs. 4, 4a, pl. 2, figs. 1-3 (Holotype here designated as the specimen illustrated by LEE as fig. 4, pl. 1).

Eoverbeekina LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 18.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 103.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 135.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 573.—SCHENCK & THOMPSON, 1940, Jour. Paleontology, vol. 14, p. 586.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 151.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 86.—THOMPSON & MILLER, 1944, Jour. Paleontology, vol. 18, p. 492.

The genus *Eoverbeekina* LEE has a small spherical to subspherical shell. The periphery is broadly rounded and axial regions are slightly depressed in all volutions (umbilicate). The axis of coiling is straight. The ratio is of unit value or slightly less than unit value. Mature specimens of nine to fifteen volutions are 2.7 to 4.0 mm wide. The proloculus is minute, and the shell expands slowly. The first three volutions are discoidal, having a short axis of coiling. The spirotheca is composed of a tectum, a middle thicker layer having fine alveolite-like structures, and a lower thin layer of dense material. This lower layer may be continuous with the parachomata. The septa are closely spaced, and they extend anteriorly at a small angle from normal to spirotheca. The septa are unfluted. The tunnel is low and narrow in the inner four volutions. It divides into two tunnels in the fifth volution. Beyond the sixth volution, numerous foramina occur throughout the length of the septa. The principal tunnel is not distinguishable in the outer volutions of mature specimens. Narrow chomata border the single tunnel in the inner volutions, and rudimentary parachomata border the foramina in the outer volutions.

Eoverbeekina most closely resembles *Verbeekina*, to which it probably is ancestral. The major differences are the singular tunnel in the inner volutions, the more nearly discoidal inner volutions, and the indistinct parachomata of *Eoverbeekina*.

As pointed out by LEE (1933), *Eoverbeekina* resembles closely *Staffella moellerana*, the genotype of

Staffella, in shape, general size, expansion of the shell, and outline shape of different parts of the shell. LICHAREW *et al.* (1939) illustrated specimens from the Djulfa beds of Armenia, the same locality as the type specimens of *S. moellerana*, and all their general features correspond closely to those of the genotype of *Eoverbeekina*. The only major difference is the seeming absence of foramina and parachomata in *Staffella*. It is of interest that LICHAREW *et al.* reported *Staffella* in association with *Nankinella* in the Djulfa beds of Armenia, and LEE found *Eoverbeekina* and *Nankinella* in the Chihhsia limestone of the Nanking area of China. It should also be pointed out that ozawainellids are associated with *Eoverbeekina* in Central America, western China, and central and southern China.

The position of *Eoverbeekina* in the classification of the fusulinids is somewhat problematical. *Eoverbeekina* seems closely related to the ozawainellids in many respects, especially in its similarity to *Staffella*, as pointed out above, and in the almost universal replacement of *Eoverbeekina* by secondary mineralization.

Three species of *Eoverbeekina* have been described. One of these, the genotype, is from the Chihhsia limestone of the Nanking area, another is from the Yanghsin limestone of western China, and the third is from the Paseo Hondo formation of Chiapas, Mexico. The genotype came from rocks of upper Leonardian or lower Guadalupian Permian age; *F. cheni* from the Yanghsin limestone is associated with fusulinids of the Zone of *Verbeekina-Neoschwagerina* and seemingly is of Guadalupian age; and *E. americana* from the Paseo Hondo formation is of lower Leonardian age.

GENUS *Verbeekina* STAFF, 1909

Plate 16, figures 7-13; Plate 17, figures 1, 2

GENOTYPE.—*Fusulina verbeeki* GEINITZ, 1876, Palaeontographica, Band 22, p. 399, 400.—*Verbeekina verbeeki* STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 476, text fig. 6, pl. 7, figs. 5, 7.—*Doliolina verbeeki* TAN, 1933, Dienst. Mijnb. Nederl.-Indië, Wetensch. Med., no. 25, p. 57-65, pl. 1, figs. 1-6.—*Verbeekina verbeeki* THOMPSON, 1936, Jour. Paleontology, vol. 10, p. 197-200, pl. 24, figs. 1-8.

Verbeekina STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 476.—STAFF, 1910, Zoologica, Heft 58, Band 22, Lief. 6, p. 40.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 25.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 15, 48.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 141, 153.—OZAWA, 1928, Cushman Lab. Foraminifera, Special Pub. no. 1, p. 135.—GALLOWAY, 1933, Manual Foraminifera, p. 407, 408.—DUNBAR, 1933, Cushman Lab. Foraminifera, Special Pub. no. 4, p. 138.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 101.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 67, 68.—THOMPSON, 1936, Jour. Paleontology, vol. 10, p. 196, 197.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 573, 574.—SCHENCK & THOMPSON, 1940, Jour. Paleontology, vol. 14, p. 586, 587.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 151, 152.—DUNBAR & HEN-

BEST, 1942, Illinois Geol. Survey, Bull. 67, p. 86.—CIRY, 1942, Annales Paléontologie, tome 29, p. 68.

Fusulina [part] GEINITZ, 1876. [Not FISCHER DE WALDHEIM, 1829.]

Schwagerina [part] of authors prior to 1909.—DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 36.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 44.—DEPRAT, 1914, Indochine Service Géol., Mém., vol. 3, fasc. 1, p. 19.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 106, 147. [Not MÖLLER, 1877.]

Mollerina [part] SCHELLWIEN, 1898, Palaeontographica, Band 44, p. 238. [Not ULRICH, 1886.]

Doliolina [part] SCHELLWIEN, 1902, Phys.-Ökon. Gesell. Königsberg, Schr., Jahrg. 43, p. 67.—DUNBAR & HENBEST, 1930, Am. Jour. Sci., 5th ser., vol. 20, p. 363.—TAN, 1933, Dienst. Mijnb. Nederl.-Indië, Wetensch. Med., no. 25, p. 57-65. [Not BORGERT, 1894.]

The genus *Verbeekina* STAFF is one of the most nearly consistent of the Permian fusulinids. The shell is large and is spherical to subspherical. The axis of coiling is straight. The axial areas are slightly umbilicate. Mature shells of twelve to twenty-one volutions have a maximum diameter of 14 mm. The first to third volutions are discoidal, having a short axis of coiling. The outer volutions are spherical and have a form ratio of about 1.0. The proloculus is minute. The inner three to four volutions are tightly coiled and the following two to three volutions expand rapidly. The outer volutions are all of about the same height. The height of the chambers is about the same throughout the length of the shell. The spirotheca is thin and is composed of a tectum and lower thicker and less dense layer, showing fine alveoli. The upper and lower surfaces of the spirotheca are covered in the inner volutions by thin layers of dense material similar in structure to the parachomata. The septa are unfluted, closely spaced, and extend anteriorly at small angle from normal to spirotheca. The lower less dense layer of the spirotheca extends a short distance down the posterior side of the septa. The septa are coated by dense layers of material similar to the parachomata. The foramina are small, numerous, and elliptical in cross section. There are more than 60 foramina in the outer volutions of advanced forms. Parachomata are absent or are poorly developed in the inner volutions. They extend only partly across the chambers in intermediate volutions, but they extend completely across the chambers in the outer volutions of most forms.

Verbeekina resembles *Eoverbeekina*. However, in *Verbeekina* foramina occur throughout the shell, the parachomata are more distinct, the size is larger, and the tunnel is absent. *Verbeekina* can be distinguished from *Misellina* by the smaller size, larger parachomata, thicker spirotheca, and general shape of the shell of *Misellina*.

GUBLER (1935) described as *Doliolina douvillei* a form from French Indo-China that has larger parachomata and a more elongate shell than most forms of *Verbeekina*. However, the expansion of

the shell, attitude of the septa, and size of the shell of this form resemble the genotype of *Verbeekina* more closely than the genotype of *Misellina* or of *Pseudodoliolina*.

Verbeekina is widespread in the Tethys Sea area of southern Europe, southern Asia, and islands of the Pacific and Indian Oceans, including the Sosio beds of Sicily, the Permian of Aegean Islands of Greece, the Permian of Turkey, possibly the Permian of Pamir, the Bamian limestone of Afghanistan, the Yanghsin limestone of western China, the Chihhsia limestone of southern China, the middle Permian of French Indo-China, the Boekit Besi beds of Sumatra, the middle Permian of Japan, and the Permian of Java. At many of these localities *Verbeekina* is associated with typical forms of *Neoschwagerina* and of other Tethys Sea genera. At least in Afghanistan, *Verbeekina* is associated with *Polydioxodina*, the index genus of the upper Guadalupian series of America. It therefore seems likely that part of the fusulinid Zone of *Verbeekina-Neoschwagerina* of the Eastern Hemisphere corresponds in age to the upper Guadalupian of America. *Verbeekina* has not been found in rocks older than this fusulinid zone. The upper limits of the genus are not definitely known. All available information indicates that it does not extend to the top of the Upper Permian Zone of *Yabeina*.

GENUS *MISELLINA* SCHENCK & THOMPSON, 1940

Plate 17, figures 5-7

GENOTYPE.—*Doliolina ovalis* DEPRAT, 1915, Indochine Service Géol., Mém., vol. 4, fasc. 1, p. 15, 16, pl. 3, figs. 1-4 (Holotype here designated as the specimen illustrated by DEPRAT as fig. 1, pl. 3).

Misellina SCHENCK & THOMPSON, 1940, Jour. Paleontology, vol. 14, p. 587.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 86.

Mollerina [part] SCHELLWIEN, 1898, Palaeontographica, Band 44, p. 238. [Not ULRICH, 1886.]

Doliolina [part] SCHELLWIEN, 1902, Phys.-Ökon. Gesell. Königsberg, Schr., Jahrg. 43, p. 67.—YABE, 1903, Geol. Soc. Tokyo, Jour., vol. 10, no. 113, p. 5.—YABE, 1906, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 21, art. 5, p. 3.—STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 506.—STAFF & WEDEKIND, 1910, Upsala Univ., Geol. Inst., Bull., vol. 10, p. 114.—DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 14, 42.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 49.—DEPRAT, 1915, Indochine Service Géol., Mém., vol. 4, fasc. 1, p. 13.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 25.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 15.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 141.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 74 (1927).—OZAWA, 1928, Cushman Lab. Foram. Research, Special Pub. no. 1, p. 135, 136.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 68-71.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 42. [Not BORGERT, 1894.]

Doliolina YABE & HANZAWA, 1932, Imp. Acad., Proc., vol. 8, no. 2, p. 42.—GALLOWAY, 1933, Manual Foraminifera, p. 408.—DUNBAR, 1933, Cushman Lab. Foram. Research, Spe-

cial Pub. no. 4, p. 138, 139.—DOUTKEVITCH & KHABAKOV, 1934, Acad. Sci. U. S. S. R., Tadjik Complex Exped. 1932, Geol. Pamir, vol. 8, p. 79.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 574. [Not BORGERT, 1894.]

The shell of the genus *Misellina* SCHENCK & THOMPSON is small and ellipsoidal. The axis of coiling is straight. The form ratio of most mature shells is less than 1.6 and is as small as 1.06 for some forms. Mature shells of most forms contain less than eight volutions, and they measure 0.93 to 2.56 mm in maximum diameter, averaging 1.54 for eight species. The proloculus is minute. The shell expands uniformly. The inner two to three volutions are deeply umbilicate. The axis becomes the greatest diameter beyond the third volution. The spirotheca is composed of a tectum and a lower thick alveolar layer. The lower surface of the spirotheca is covered by a thin dense layer that may be continuous with the parachomata. Foramina are developed throughout the shell, numbering less than 20 in the outer volutions of mature shells. The parachomata are broad and high and are continuous across the chambers; they are low in the inner two to three volutions. Septa are numerous and unfluted, and are about normal to the spirotheca.

Schwagerina lepida SCHWAGER (1883), the genotype of *Doliolina* SCHELLWIEN (1902), does not agree closely with the above description. The shell of that form is larger at maturity and contains more volutions, has a relatively much thinner spirotheca although of similar structure, and has more abundant foramina. Also, the parachomata of *S. lepida* are narrower and much higher than in typical *Misellina*. In general shape and size, *S. lepida* resembles the genotype of *Pseudodoliolina* closely, but their spirothecal structures are different. For the present, I am referring *S. lepida* to *Misellina*, although I realize that it may not be congeneric with *Misellina ovalis* (DEPRAT).

Forms here referred to *Misellina* have been referred to numerous generic groups. The history of this misunderstanding was recently reviewed by SCHENCK & THOMPSON (1940) and need not be repeated here.

Misellina resembles *Cancellina* HAYDEN closely in size, shape, foramina development, parachomata development, and spirothecal structure. The important difference between these genera is the presence of transverse septula in *Cancellina*. *Misellina* differs from *Pseudodoliolina* in size, shape, spirothecal structure, foramina and parachomata development, and early development of the shell.

Brevaxina was formerly considered a subgenus of *Misellina*. I now prefer to consider them distinct genera. *Brevaxina* has a subspherical shell with a short axis of coiling, deeply umbilicate axial region, and parachomata that are more narrow and high than in *Misellina*. Thus they differ mainly in shape. This difference is so prominent, however, that it seems of generic importance.

At least eight species of *Misellina* have been described. All are from the Tethys Sea area of the Eastern Hemisphere. So far as can be determined, most of them are of Middle Permian age. The genus has been reported from Pamir, French Indo-China, China, Japan, and Sumatra. The most primitive form is from the lower Chihhsia limestone of China. The genus may occur in the Upper Permian.⁶

GENUS *BREVAXINA* SCHENCK & THOMPSON, 1940

Plate 17, figures 8-10

GENOTYPE.—*Doliolina compressa* DEPRAT, 1915, Indochine Service Géol., Mém., vol. 4, fasc. 1, p. 15, 16, pl. 3, figs. 10-14 (Holotype here designated as the specimen illustrated by DEPRAT as fig. 10, pl. 3).

Brevaxina SCHENCK & THOMPSON, 1940, Jour. Paleontology, vol. 14, p. 587.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 86.

Doliolina [part] of authors 1915 to 1940. [Not BORGERT, 1894.]

The genus *Brevaxina* SCHENCK & THOMPSON is represented by only one species. The shell is small, subspherical, and laterally compressed. The axis of coiling is the smallest diameter. The form ratio is 0.58. It is deeply umbilicate throughout the shell. Mature shells of six volutions are about 2.0 mm long and 3.3 mm wide. The spirotheca is composed of a tectum and a thick lower layer having fine alveoli. Foramina occur throughout most of the shell. There are at least 21 foramina in the outer volutions. The first one to two volutions have very faint parachomata. The parachomata of the middle and outer volutions are more than half as high as the chambers.

Brevaxina was originally described as a subgenus of *Misellina*. It differs from the latter principally in that the shell is subspherical in shape and the polar regions are deeply umbilicate. Also, the parachomata of *Brevaxina* are not as wide but are higher than those of *Misellina*.

The genotype and only known species of *Brevaxina* is from the Permian of Cammon, French Indo-China.

GENUS *PSEUDODOLIOLINA* YABE & HANZAWA, 1932

Plate 17, figures 3, 4, 11, 12

GENOTYPE.—*Pseudodoliolina ozawai* YABE & HANZAWA, 1932, Imp. Acad., Proc., vol. 8, no. 2, p. 41 = *Doliolina lepida* DEPRAT, 1914, Indochine Service Géol., Mém., vol. 3, fasc. 1, p. 22, pl. 3, figs. 12-14. [Holotype.—DEPRAT's fig. 12, pl. 3 (THOMPSON & FOSTER, 1937).]

Pseudodoliolina YABE & HANZAWA, 1932, Imp. Acad., Proc., vol. 8, no. 2, p. 41.—GALLOWAY, 1933, Manual Foraminifera, p. 410.—DUNBAR, 1933, Cushman Lab. Foraminifera Research, Special Pub. no. 4, p. 139.—CHEN, 1934, China Geol. Survey, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 100.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 138-140.—DUNBAR & SKINNER, 1937, Texas Univ.

6. See Addendum, p. 67.

Bull. 3701, p. 575.—DUNBAR, 1940, (*In CUSHMAN*) Foraminifera, p. 152.—SCHENCK & THOMPSON, 1940, Jour. Paleontology, vol. 14, p. 587, 588.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 87.

Doliolina [part] of authors prior to 1932.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 68-71. [*Not* BORGERT, 1894.]

The genus *Pseudodoliolina* YABE & HANZAWA represents an advanced aberrant group of the verbeekinids. It has a medium size elongate ellipsoidal shell containing a straight axis of coiling and bluntly to broadly rounded poles. Mature shells of fourteen to twenty volutions are 5 to 8 mm long and 2.5 to 4 mm wide, having a form ratio of 1.6 to 2.6. The proloculus is large and the shell expands uniformly. The first one or two volutions of most forms are slightly fusiform. Beyond the second volution, the poles are broadly rounded or dome-shaped. The center of the shell of the genotype is cylindrical, but in some forms it is slightly inflated, having low lateral slopes. Septa are numerous and are about normal to the spirotheca. They are composed of a single dense layer in most parts of the shell. A suggestion of a lower very thin layer of less dense material with fine lines normal to its surface is discernible in the outer volutions of the genotype. Foramina are numerous; at least fifty occur in the outer volutions. Parachomata are narrow and distinct throughout the shell. They extend to the tops of the chambers immediately adjacent to the septa.

Pseudodoliolina may be distinguished from typical *Misellina* by its thinner spirotheca, larger and more highly elongate shell, narrower and higher parachomata, larger proloculus, and more expanded early volutions. *Misellina lepida* and several other large elongate species of *Misellina* resemble *Pseudodoliolina* closely. They have the same general shape and size. However, the occurrence of a well-defined keriotheca in *M. lepida* suggests that it is referable to *Misellina* rather than to *Pseudodoliolina*.

Pseudodoliolina is widely distributed in Tethyan Permian rocks of southern and southeastern Asia, Japan, and the East Indies. The following forms of *Pseudodoliolina* have been described from these areas: *Pseudodoliolina pseudolepida* (DEPRAT) (1912), French Indo-China and eastern China; *P. major* (DEPRAT) (1914), French Indo-China; *P. lettensis* (SCHUBERT) (1915), Island of Letti; *P. ozawai* YABE & HANZAWA (1930), Japan; and *P. dunbari* (GUBLER) (1935), French Indo-China. *Pseudodoliolina* seemingly occurs in the fusulinid Zone of *Verbeekina-Neoschwagerina* and in the Zone of *Yabeina*.

GENUS CHUSENELLA Hsu, 1942

Text figures 5 A, B

GENOTYPE.—*Chusenella ishanensis* Hsu, 1942, Geol. Soc. China, Bull., vol. 22, p. 175, 176, text figs. 1, 2 (Holotype here designated as the specimen illustrated by Hsu as text figure 1 and re-illustrated below as text figure 5 A).

Chusenella Hsu, 1942, Geol. Soc. China, Bull., vol. 22, p. 175-176.—*Chusenella* LEE, 1942, Geol. Soc. China, Bull., vol. 22, p. 171-173 (*nomen nudum*).

The name *Chusenella* was published by LEE (1942) for a new genus which he thoroughly diagnosed, but he neither designated a genotype nor listed any species as belonging to the genus. In an article published at the same time on immediately following pages, Hsu (1942) described *Chusenella ishanensis*, n. sp., designating it as the type species of *Chusenella*. The International Rules of Zoological Nomenclature, Article 25 (as particularly revised in 1927), explicitly requires designation of a genotype in order to establish a genus. LEE did not do this and thus he can not be considered as having established *Chusenella*. Seemingly, Hsu must be recognized as author of this genus under stipulations of the Rules inasmuch as he first described a species referred to *Chusenella* and designated it as the type species. The fact that Hsu cited LEE as author of the name *Chusenella* has no effect at all in establishing authorship under the Rules.

The unusual genus *Chusenella* came to my attention after this report was in press and too late to incorporate illustrations on the plates. The original illustrations of the genotype species were camera lucida drawings, and they are reproduced here as text figures 5 A and B. LEE's diagnosis of *Chusenella*, part of his remarks, and Hsu's description of the genotype species, *C. ishanensis* Hsu, are as follows:

GENERIC DIAGNOSIS: Test fusiform, size medium; whorls moderately numerous, rather compact in the earlier, but becoming markedly more evolute in the adult stage; antetheca (septa of authors) almost straight or gently flexuous; chomata obsolescent in the inner whorls, disappearing in the outer ones; parachomata crowded, dichotomous in the lower part, and sigmoidally fluted to the extent that, at regular intervals, the fluted portion becomes alternatively contiguous with the neighbouring ones forming a labyrinth of chamberlets; basal part of the parachomata sometimes perforated affording passages in the axial direction; tectum and tectorium well defined; keriotheca comparatively thick and almost indetectably fine; buccal aperture relatively narrow and low, rarely median in the adult stage; proloculum small and spherical.

REMARKS: The most important characteristic of the present genus is the partially split and fluted parachomata. The unsplit and unfluted part generally stands perpendicularly on the floor of the chamber; the upper part is quite solid, almost opaque and club-shaped in section, but the lower part is more transparent being enclosed by a dark lamella on both sides. The transparent part corresponds to a layer of diaphanotheca, and the dark lamella the tectorium. In preparing serial para-axial sections it is observed that a given parachomata appears at first as a simple, outstanding ridge, or semipartition. But by grinding it down, the lower part gradually becomes triangular in shape, and at the same time the interior of the triangle becomes far more transparent indicating the initial appearance of a vacant space. Further grinding shows the presence of an arched chamberlet. The side-walls of the neighboring chamberlets often become fused together in their basal part.

Between a pair of unsplit parachomata a connecting lamella is sometimes present. These lamellae appear to form "bridges." Their true interpretation is however still a matter of doubt. (LEE, 1942, p. 171, 172.)

DIAGNOSIS [of *Chusenella ishanensis*]: Test fusiform, slightly rounded at the ends; about 11.2 mm long, 3.7 mm wide, giving an axial ratio of about 1:3; whorls 9 to 10, the first three or four volutions closely coiled thence gradually evolute; spiral wall increases in thickness as the test grows, being 0.016 mm in the first whorl and 0.064 mm in the final volution; three layers enter into the composition of the spiral wall; the outer tectorium clearer and thicker than the inner which latter can hardly be recognized in the axial section, keriotheca rather thick, and exhibits faint alveolar structure; antethecae numbering 7, 10, 12, 16, 17, 18, 18, 15,

The genus is here included with question in the subfamily Verbeekinae.

Occurrence.—The genotype species of *Chusenella*, and the only known representative, is abundant in the Chungkuh limestone of the upper Hoshan series, probably uppermost Permian in age: Chungkuhtsun, Ishan, Kuangsi, China. It is associated with *Verbeekina*, *Yabeina* (*Colania*?), and *Pseudodoliolina*.

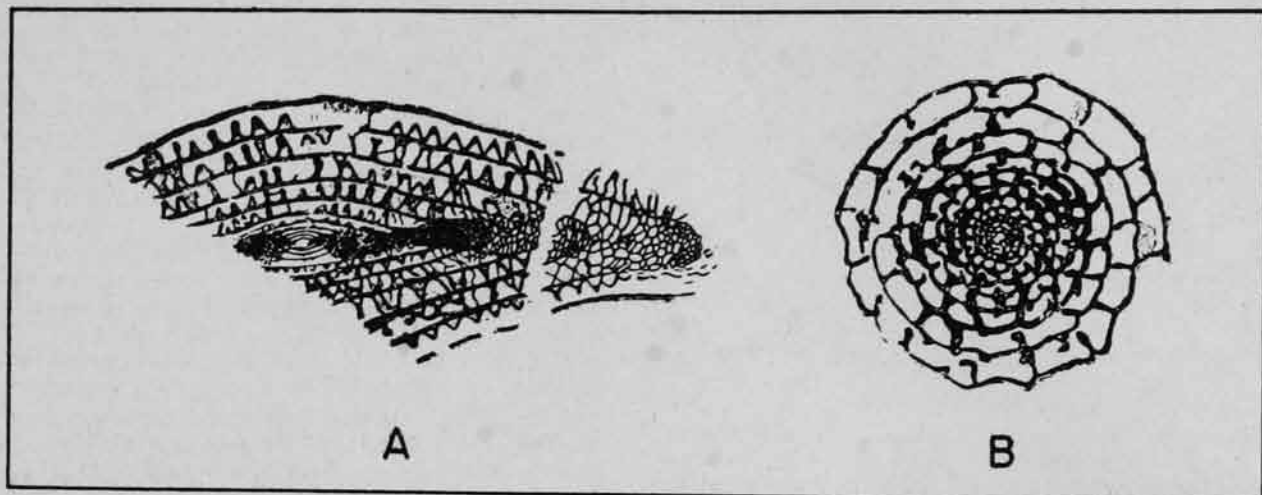


FIGURE 5.—*Chusenella ishanensis* Hsu. Camera lucida sketches of an axial section of the holotype (A) and of a sagittal section of a paratype (B), both $\times 10$. Chungkuh limestone, upper Hoshan series, Kuangsi, China. (After Hsu, 1942.)

14, 17 from the first whorl onward; rudimentary chomata only developed in the first few whorls; parachomata strongly developed from the third volution onward forming a reticulate meshwork by strong folding and fusion of the split parts; buccal aperture crescentic, small in the young stage but rather high in the outer volutions, reaching some $\frac{1}{2}$ to $\frac{5}{8}$ of the height of the chamber; intricate folds occur at the poles; axial filling generally present in the inner whorls, proloculum minute and nearly spherical, 0.014 mm in external diameter. (Hsu, 1942, p. 175.)

The diagnosis of *Chusenella* indicates that the genotype species has fluted and dichotomous parachomata. No other fusulinid has a similar structural feature. The genotype possesses a single tunnel, chomata in the first three or four volutions, and axial fillings confined to the immediate axial area. The general shape, low and indistinct chomata, and axial fillings of the genotype resemble these features of some Upper Permian fusulinids of the Tethys here questionably referred to *Schwagerina*. Parachomata have not been recognized in the schwagerinids, however. LEE compares this genus to *Pseudodoliolina* with which it is associated, but he points out that the phylogenetic position of *Chusenella* in the fusulinid family must await further studies.

SUBFAMILY NEOSCHWAGERININAE DUNBAR & CONDRA, 1928

The subfamily Neoschwagerininae DUNBAR & CONDRA (1928) includes some of the most highly complex of the fusulinids. Members of the subfamily are confined to the middle and upper parts of the Permian.

Mature specimens of the subfamily have a range in maximum diameter from about 3 mm to more than 22 mm. The maximum diameter of all forms is along the axis of coiling. Most shells are inflated subglobular or ellipsoidal in shape. Species of the genus *Sumatrina* are elongate subcylindrical to fusiform in shape. The spirotheca of primitive genera is composed of a tectum and lower thick layer having distinct alveoli. More advanced genera have thinner spirotheca. In the most evolved genera, such as *Sumatrina* and *Lepidolina*, the spirotheca is composed of only a single thin dense layer. Foramina and parachomata are present in all genera. Short blunt transverse septula occur in the outer volutions of the primitive genus *Cancellina*. More

advanced genera contain axial septula between the septa. At least three secondary transverse septula occur between the primary transverse septula in the outer volutions of highly developed members of the subfamily, and, in these forms, at least eight axial septula occur between adjacent septa.

The subfamily Neoschwagerininae is distinguished from the subfamily Verbeekinae by the presence of septula in the former—transverse septula in primitive members and transverse and axial septula in advanced members.

Six genera of Neoschwagerininae are recognized: *Cancellina*, *Neoschwagerina*, *Afghanella*, *Sumatrana*, *Yabeina*, and *Lepidolina*.

Neoschwagerininae are confined to the Tethys Sea area of northern Africa, southern Europe, southeastern, southern, and eastern Asia, the East Indies, Japan, and northwestern North America. The most primitive members occur in Middle Permian rocks and younger members occur in the highest fusulinid-bearing rocks.

GENUS CANCELLINA HAYDEN, 1909

Plate 18, figures 6-11

GENOTYPE.—*Neoschwagerina primigena* HAYDEN, 1909, India Geol. Survey, Records, vol. 38, p. 249, pl. 22, figs. 1-7 (Holotype here designated as the specimen illustrated by HAYDEN as fig. 1, pl. 22).

Cancellina HAYDEN, 1909, India Geol. Survey, Records, vol. 38, pt. 3, p. 224.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 26.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 16.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 74 (1927).—OZAWA, 1928, Cushman Lab. Foramin. Research, Special Pub. no. 1, p. 138.—GALLOWAY, 1933, Manual Foraminifera, p. 410.—DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 139.—DOURKEVITCH & KHABAKOV, 1934, Acad. Sci., U.S.S.R., Tadzhik Complex Exped. 1932, Geol. Pamir, vol. 8, p. 86.—HUZIMOTO, 1936, Tokyo Bunrika Daigaku, Sci. Repts., sec. C, no. 2, p. 111.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 575.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 43.—DUNBAR, 1940, (*In* CUSHMAN) Foraminifera, p. 153.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 87. [*Not* OZAWA, 1927; CHEN, 1934.]

Neoschwagerina [part] OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 153.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 71-74.

The shell of the genus *Cancellina* HAYDEN is small and inflated fusiform, having a straight axis of coiling, pointed poles, and an inflated central region. Mature shells of ten to twelve volutions are about 3.2 mm long and 2.7 mm wide. The proloculus is small, and the shell expands uniformly in the first five to six volutions. It expands very slowly in the outer volutions. The chambers are of about the same height throughout the length of the shell. The spirotheca is composed of a tectum and a lower thick layer containing closely spaced alveoli. Foramina and intervening parachomata are present throughout the shell. In occasional specimens, the proloculus is minute, and the first two or three

volutions are tightly coiled and asymmetrical. Parachomata are indistinct in these tightly coiled volutions. Septa are closely spaced and are slightly arcuate. The lower layer of the spirotheca extends about one-third the distance down both sides of the septa. The parachomata are narrow and high and are in contact with the transverse septula adjacent to the septa. The transverse septula occur from at least the fourth volution to maturity. They are short and broad and are formed by the downward extension of part of the lower layer of the spirotheca. The alveoli of spirotheca extend completely to the base of septula, expanding fan-shaped. The transverse septula occur immediately above the parachomata and they join immediately adjacent to the septa. Small elliptical lateral openings are present above the parachomata and near the center of the chambers.

Cancellina resembles *Neoschwagerina* closely. The major differences between these genera are that the shells of most *Neoschwagerina* are larger at maturity, the transverse septula are narrower and longer, and axial septula occur between the septa in the outer volutions.

Several small species of neoschwagerinids having elongate fusiform shells and exceedingly thin spirotheca have been described from French Indo-China and Japan. These include *Doliolina schellwieni* DEPRAT (1913), *D. neoschwagerinoides* DEPRAT (1913), and *Cancellina nipponica* OZAWA (1927). These forms are more or less intermediate in development between *Cancellina* and *Neoschwagerina*. Some paleontologists have referred them to *Doliolina* (= *Misellina*), some to *Neoschwagerina*, and others to *Cancellina*. Axial septula appear in *D. schellwieni* in the third to fourth volution. Therefore, it is not included in *Cancellina*. The generic affinities of the other two forms are in doubt. Their thin spirotheca indicates that they are not referable to *Cancellina*. However, they are more closely similar to *Cancellina primigena* than to any other genotype and are here referred to *Cancellina* with question.

With the possible exception of the above forms, only two species of *Cancellina* have been described—the genotype and *Cancellina simplex* (OZAWA) (1927). The genotype was originally described from Afghanistan. It has also been described from Pamir and Russian Turkestan and is known from Iran. *C. simplex* is from Japan. Closely similar, if not conspecific, specimens are known from Pamir.

In Afghanistan, *Cancellina* occurs in the Bamian limestone from which typical faunas of the Tethys Sea fusulinid Zone of *Verbeekina-Neoschwagerina* have been described and also from which the genus *Polydiexodina* has been described. Just how closely *Cancellina* is associated with these other fusulinids in the Bamian limestone is not known. *Cancellina* occurs in Pamir closely associated with fusulinids of the Zone of *Verbeekina-Neoschwagerina*.

GENUS *NEOSCHWAGERINA* YABE, 1903

Plate 20, figures 1-4

GENOTYPE.—*Schwagerina craticulifera* SCHWAGER, 1883, (In VON RICHTHOFEN) China, Band 4, p. 140-143, pl. 18, figs. 15-25 (Holotype here designated as the specimen illustrated by SCHWAGER as fig. 17, pl. 18).

Neoschwagerina YABE, 1903, Geol. Soc. Tokyo, Jour., vol. 10, no. 113, p. 5.—YABE, 1906, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 21, art. 5, p. 3.—DOUVILLÉ, 1906, Soc. Géol. France, Bull., sér. 4, tome 6, p. 584.—STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 506.—DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 15.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 9.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 25.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 16.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 141, 142.—DUNBAR & CONDRA, 1923, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 75 (1927).—OZAWA, 1928, Cushman Lab. Forum. Research, Special Pub. no. 1, p. 136.—GALLOWAY, 1933, Manual Foraminifera, p. 410, 411.—DUNBAR, 1933, Cushman Lab. Forum. Research, Special Pub. no. 4, p. 140.—SILVESTRI, 1933, Istit. Geol. R. Univ. Padova, Mem., vol. 10, p. 16.—DOUTKEVITCH & KHABAKOV, 1934, Acad. Sci. U. S. S. R., Tadjik Complex Exped. 1932, Geol. Pamir, vol. 8, p. 94.—SILVESTRI, 1935, Pont. Acad. Sci. Ent. Novi Lyncaei, Mem., ex ser. 3, vol. 2, p. 98.—HUZIMOTO, 1936, Tokyo Bunrika Daigaku, Sci. Repts., sec. C, no. 2, vol. 1, p. 112.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 142.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 576.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U. S. S. R., vol. 6, Permian, p. 44.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 153, 154.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 87, 88.—THOMPSON, 1946, Jour. Paleontology, vol. 20, p. 155.

Neoschwagerina [part] LANGE, 1925, Geol.-mijnb. genootsch. Nederland en Koloniën Verh., Geol. ser., Deel 7, p. 265.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 71.

Schwagerina [part] some authors prior to 1903.

The genus *Neoschwagerina* YABE bears the oldest generic name of the subfamily. The shell is small and elongate fusiform, having a straight axis of coiling, steep convex lateral slopes, and bluntly pointed to narrowly rounded poles. Mature specimens of eleven to twenty volutions are 4.0 to 9.5 mm long and 2.2 to 6.0 mm wide. The form ratio is 1.3 to 1.6. The proloculus is minute and the shell expands slowly in the first ten volutions. The outer five to six volutions are of about the same height. The chambers change in height only slightly throughout the length of the shell. The inner two or three volutions have form ratios of less than unit value. The spirotheca is composed of a tectum and a thick keriotheca containing closely spaced alveoli. The septa are closely spaced and are composed of a tectum and anterior and posterior downward extensions of the keriotheca of the spirotheca. The keriotheca extends about two-thirds the distance down the septa. Throughout the shell there are foramina, narrow and high parachomata, and transverse septula immediately above the parachomata. The transverse septula are formed by the downward deflection of the lower surface of the keriotheca of spirotheca. They reach the tops of

parachomata almost across the chambers, leaving a small lateral opening at the top of the parachomata in the center of the chamber. There is a short secondary transverse septula between the primary transverse septula in the outer two or three volutions of advanced species, but in more primitive forms secondary transverse septula are absent. Axial septula occur between the septa in the outer volutions of primitive forms and in all volutions of more evolved forms. As many as three septula occur between adjacent septa of the outer volutions of some of the most highly advanced species. Alveoli extend to the base of all primary and secondary septula.

Neoschwagerina is distinguished from *Cancellina* by its more abundant axial septula and larger and more highly elongate shell. Also, secondary transverse septula occur in the outer volutions of late *Neoschwagerina*. *Neoschwagerina* differs from more advanced genera, such as *Yabeina* and *Lepidolina*, in its thicker spirotheca, thicker and broader septula, fewer secondary septula, and smaller shell.

The primitive genus *Cancellina* seems to have been the ancestral form of the neoschwagerinids. *Cancellina* evolved to *Neoschwagerina*, *Neoschwagerina* to *Yabeina*, and *Yabeina* to *Lepidolina*. The evolutionary changes were gradual and many gradational forms between adjacent generic groups have been observed. The general trends in evolution were the introduction of additional transverse and axial septula, a reduction in the thickness of the spirotheca and the width of the septula, and a general increase in size of mature individuals.

Neoschwagerina is widespread geographically in the Permian of the Eastern Hemisphere. It has been recognized in the Sosio beds of Sicily, Permian rocks of Russian Turkestan, Afghanistan, Asia Minor, eastern China, southern China, French Indo-China, Sumatra, and Japan. At most of these places, it is associated with typical fusulinids of the Zone of *Verbeekina-Neoschwagerina*. In Afghanistan it is also associated with the genus *Polydiexodina*. The Sosio beds of Sicily are considered lower Guadalupian in age. The Bamian limestone of Afghanistan which contains *Neoschwagerina* seemingly is upper Guadalupian in age. In Japan, French Indo-China, and Sumatra, *Neoschwagerina* seems to occur even higher stratigraphically than in Sicily and Afghanistan.

GENUS *AFGHANELLA* THOMPSON, 1946

Plate 18, figures 1-5

GENOTYPE.—*Afghanella schencki* THOMPSON, 1946, Jour. Paleontology, vol. 20, p. 153-155, pl. 25, figs. 1-12 (Holotype illustrated by fig. 2, pl. 25).

Afghanella THOMPSON, 1946, Jour. Paleontology, vol. 20, p. 152, 153.

Yabeina [part] OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 60. [Not DEPRAT, 1914.]

Neoschwagerina [part] HAYDEN, 1909, India Geol. Survey, Records, vol. 38, pt. 3, p. 250.—GUBLER, 1935, Soc. Géol.

France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 123. [Not YABE, 1903.]

Sumatrina [part] CIRY, 1942, Annales Paléontologie, tome 29, pl. 3, figs. 8, 9. [Not VOLZ, 1904.]

The shell of the genus *Afghanella* THOMPSON is small and inflated fusiform to ellipsoidal, having a straight axis of coiling, broadly convex lateral slopes, and rounded to bluntly pointed poles. Mature specimens of ten to thirteen volutions are 3 to 4 mm long and 1.8 to 2.0 mm wide. All volutions are symmetrical. The proloculus is small, and the chambers increase in size uniformly. The spirotheca is thin and is composed of a tectum and a lower thin layer that is irregular in thickness and possesses fine alveoli. In most parts of the shell the lower layer is very thin and structureless. The septa extend forward at a small angle. Dense layers of calcite probably continuous with the parachomata cover both sides of the septa. The primary transverse septula join the tops of the parachomata almost completely across the chambers. The uppermost part of the primary transverse septula hang from the spirotheca by an exceedingly thin layer. Secondary transverse septula occur from the fourth or fifth volution to maturity. The innermost transverse septula are short downward extensions of the spirotheca. In most outer volutions, they are pendant-shaped and uniform in length and there are two above each foramen. In the last volution of mature shells, the secondary transverse septula are irregular in length and are not pendant-shaped. Axial septula first occur near the end of the third volution. One axial septula is present between adjacent septa in the fourth to the seventh volutions, increasing to four in outer volutions of mature specimens. Axial septula are pendant-shaped, are of uniform length, and have exceedingly thin upper surfaces where joined to the spirotheca in the fifth and later volutions. Foramina are developed throughout the shell.

The outer secondary septula and the exceedingly thin upper margins of primary and secondary septula of *Afghanella* resemble those of *Sumatrina*. However, multiple axial septula and multiple secondary transverse septula occur between the primary septa and between the primary transverse septula throughout the shell of *Sumatrina*. Also, the secondary transverse septula are of about the same length throughout the shell of *Sumatrina*. Furthermore, the shell of *Sumatrina* is subcylindrical in shape but that of *Afghanella* is inflated.

The shape of the shell of *Afghanella* is closely similar to that of *Neoschwagerina*. However, the spirothecal structure and septula development of these genera are markedly different. *Afghanella* differs from *Yabeina* and *Lepidolina* especially in that the septula of *Afghanella* are pendant-shaped and they are very thin in their upper margins. Also, axial and secondary transverse septula are absent in early volutions of *Afghanella*.

The position of *Afghanella* in the evolutionary de-

velopment of the neoschwagerinids is not understood. The structure of the young shell of *Afghanella* suggests that it developed from *Neoschwagerina*. The gerontic stages of the shell of *Afghanella* with pendant-like secondary transverse and axial septula suggest that *Sumatrina* developed from an early branch of the former.

Afghanella is widespread in the Permian Tethyan rocks of Asia and Europe, having been described or illustrated from Japan, French Indo-China, Afghanistan, Turkey, and Greece.

Four or possibly five species of *Afghanella* are known: the genotype from Afghanistan, *Neoschwagerina sumatrinaeformis* GUBLER from French Indo-China, *Sumatrina pesuliensis* OZAWA & TOBLER from Greece, "*Yabeina schellwieni*" OZAWA from Japan [Not *Doliolina schellwieni* DEPRAT], and "*Sumatrina sumatrinaeformis*" CIRY (= ?*A. schencki*) from Turkey. All these forms are associated with a typical fusulinid fauna of the Zone of *Verbeekina-Neoschwagerina*. In Afghanistan, the genus is associated with *Polydiexodina*. So far as known, *Afghanella* is restricted to the Middle Permian.

GENUS SUMATRINA VOLZ, 1904

Plate 19, figures 1-8

GENOTYPE.—*Sumatrina annae* VOLZ, 1904, Geol. u. palaeont. Abh., neue Folge, Band 6 (Ganz. Band 10), Heft 2, p. 98-100, text figs. 27-31 (Holotype here designated as the specimen illustrated by VOLZ as text fig. 28).

Sumatrina VOLZ, 1904, Geol. u. palaeont. Abh., neue Folge, Band 6 (Ganz. Band 10), Heft 2, p. 98.—DOUVILLÉ, 1906, Soc. Géol. France, Bull., sér. 4, tome 6, p. 584, 585.—STAFF, 1909, Neues Jahrb. Min., Geol. und Pal., Beilage-Band 27, p. 506.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 116, 150.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 26.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 16.—DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 75 (1927).—OZAWA, 1928, Cushman Lab. Foramin. Research, Special Pub. no. 1, p. 138, 139.—GALLOWAY, 1933, Manual Foraminifera, p. 411.—SILVESTRI, 1933, Istit. Geol. R. Univ. Padova, Mem., vol. 10, p. 38.—DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 140.—DOUTKEVITCH & KHABAKOV, 1934, Acad. Sci. U.S.S.R., Tadjik Complex Exped. 1932, Geol. Pamir, vol. 8, p. 99.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 74.—THOMPSON & FOSTER, 1937, Jour. Paleontology, vol. 11, p. 143.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 577, 578.—LICHAREW *et al.*, 1939, Cent. Geol. Prosp. Inst., Atlas Leading Forms Fossil Fauna U.S.S.R., vol. 6, Permian, p. 46.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 155, 156.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 89.

Sumatrina [part] DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 15.—DEPRAT, 1913, Indochine Service Géol., Mém., vol. 2, fasc. 1, p. 9.—DEPRAT, 1914, Indochine Service Géol., Mém., vol. 3, fasc. 1, p. 34.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 142.

The genus *Sumatrina* VOLZ has a small elongate subcylindrical to fusiform shell that possesses a straight to slightly irregular axis of coiling and irregular lateral slopes. Most shells are slightly inflated in their central regions; some are subcylin-

dricial in shape. Mature shells of eight to ten volutions are 5 to 10 mm long and 1.5 to 3.0 mm wide. The form ratio is 3.0 to 4.3. The proloculus is relatively large, and the shell expands uniformly. The chambers increase in height from the center of the shell toward the poles. Foramina are numerous and are subcircular in cross section. As many as 70 foramina occur in the outer volutions of some forms. The spirotheca is exceedingly thin and is composed of a single compact layer. The upper surface of the spirotheca is distinctly dimpled, and the borders of the dimples are bounded by the depressions above septula. The septa are widely spaced and extend forward slightly. The primary transverse septula reach the base of the chambers immediately adjacent to the septa. The septa have exceedingly thin upper surfaces and thick lower surfaces. Lateral elliptical openings occur in the primary septula near the base of the chambers. The transverse secondary septula are of uniform length throughout the shell. Two transverse secondary septula occur between adjacent primary septula in the first volution, and at least four occur in the outer volution. Their upper surfaces are exceedingly thin, but their lower margins are thickened and have a dumbbell- or pendant-shaped cross section. Two axial septula occur between adjacent septa in the first volution; as many as seven occur between adjacent septa in the outermost volution. Both the axial and the secondary transverse septula are short, they are of uniform length, their lower surfaces have a pendantlike cross section, and they have exceedingly thin upper margins. The spirotheca bends downward sharply at the point of junction with the septula. The parachomata are narrow and are not massive. Axial fillings are developed in all forms. They are light and discontinuous in some but are relatively heavy in others.

Sumatrina can be distinguished from *Afghanella* by the more elongate shell, more numerous septula, the presence of septula in the innermost volutions, and thinner spirotheca. The genotype of *Lepidolina* was referred originally to *Sumatrina*. *Lepidolina* and *Sumatrina* have exceedingly thin spirotheca and thin compact primary and secondary septula. They can be distinguished, however, by the elongate shell, uniform septula, and smaller size of *Sumatrina*. *Sumatrina* is distinguished from *Neoschwagerina* and *Yabeina* by its more highly elongate and smaller shell, less numerous volutions, exceedingly thin spirotheca, and uniform septula.

Sumatrina has been described or identified from many parts of the Eastern Hemisphere, including Sicily, Asia Minor, Pamir, Szechuan, French Indo-China, Sumatra, and Japan.

The stratigraphic distribution of *Sumatrina* is not established. In Japan, the genus has been reported as ranging from the Zone of *Verbeekina-Neoschwagerina* to the top of the fusulinid-bearing part of the Permian. However, several of the Japanese forms

reported or described as *Sumatrina* are referable to *Afghanella* or to some genus other than *Sumatrina*. *Sumatrina* formerly included forms now referred to *Afghanella*, and the generic affinities of all forms can not be determined from older faunal lists. At many localities, *Sumatrina* is associated with a typical fusulinid fauna of the Zone of *Verbeekina-Neoschwagerina*. It may also range into the Zone of *Yabeina*.

GENUS YABEINA DEPRAT, 1914

Plate 21, figures 1-5

GENOTYPE.—*Yabeina mouyei* DEPRAT, 1914, Indochine Service Géol., Mém., vol. 3, fasc. 1, p. 30-34, text figs. 6, 7a, pl. 6, figs. 4-10, pl. 7, figs. 1, 2 (HOLOTYPE.—Pl. 6, fig. 4).

Yabeina DEPRAT, 1914, Indochine Service Géol., Mém., vol. 3, fasc. 1, p. 30.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 4, p. 26.—OZAWA, 1925, Tokyo Imp. Univ., Coll. Sci., Jour., vol. 45, art. 6, p. 16, 60.—DUNBAR & CONDRA, 1923, Nebraska Geol. Survey, Bull. 2, 2d ser., p. 74 (1927).—GALLOWAY, 1933, Manual Foraminifera, p. 411.—SILVESTRI, 1933, Istit. Geol. R. Univ. Padova, Mem., vol. 10, p. 16.—DUNBAR, 1933, Cushman Lab. Foramin. Research, Special Pub. no. 4, p. 140.—LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 9-13.—HUZIMOTO, 1936, Tokyo Bunrika Daigaku, Sci. Repts., sec. C, no. 2, vol. 1, p. 119.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 577.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 154, 155.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 88.—THOMPSON & WHEELER, 1942, Jour. Paleontology, vol. 16, p. 703-705.

Neoschwagerina [part] of authors prior to 1914.—COLANI, 1924, Indochine Service Géol., Mém., vol. 11, fasc. 1, p. 118, 152.—OZAWA, 1927, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3, p. 142, 153.—OZAWA, 1928, Cushman Lab. Foramin. Research, Special Pub. no. 1, p. 136, 137.—DOUVILLÉ, 1934, Service Carte Géol. Tunisie, Mém., new ser., no. 1, p. 77-79.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 71-74. [Not YABE, 1903.]

The genus *Yabeina* DEPRAT characterizes the highest of the fusulinid faunal zones. Its shell is large and inflated fusiform, having a straight to slightly irregular axis of coiling, uniform convex lateral slopes, and strongly to bluntly pointed poles. Mature shells of some forms contain as many as twenty-two volutions. The shells of some forms are 16 mm long and 8 mm wide. Some are as small as 5 mm long and 2.5 mm wide. The average size is about 10 mm long and 7 mm wide. The form ratio of mature shells is 1.2 to 2.6. The proloculus of some forms is minute, but that of others is large. The shell expands uniformly. Foramina are numerous. There are 50 to 60 foramina in the outer volutions of most forms and as many as 135 in the outer volutions of some larger forms. Parachomata occur throughout the shell, are narrow and high, and are in contact with the lower surface of primary transverse septula across chambers, except in the central part of the chamber. Septa are numerous, thin, and slightly irregular. They extend forward at a small angle. The lowermost margin of the septa extends forward at a sharp angle. Primary transverse septula are present throughout the shell. They

join the tops of parachomata across the chambers, except for a small elliptical lateral opening near the center of the chambers. Secondary transverse septula are short and are irregular in length. They first develop in the inner sixth to eighth volution. A maximum of two or three secondary transverse septula occur between primary transverse septula in the outer volutions. Axial septula are abundant in the outer volutions; as many as nine occur between adjacent septa of the outer volutions in some forms. The axial septula are irregular in shape and length. The spirotheca is composed of a tectum and a lower thick finely alveolar layer. In the outer volutions of highly developed forms, the spirotheca is thin and is composed of a single layer. The alveoli of the spirotheca extend more than half the distance toward the base of the septula. The lower margins of all septula are dense and seemingly are heavily coated with secondary deposits.

Yabeina can be distinguished from *Neoschwagerina* by its larger shell, more numerous volutions, a larger number of transverse and axial septula in the outer volutions, the thinner spirotheca, and the thinner septula. In *Neoschwagerina*, the alveoli of the spirotheca extend further toward the base of the septula, and the lower margins of the septula are thicker than in *Yabeina*. *Lepidolina* is distinguished from *Yabeina* by its thinner spirotheca and thinner septula. In *Yabeina*, a distinct keriotheca occurs throughout the shell of most forms and in all except the outer volutions of others. Throughout the shell of *Lepidolina*, the spirotheca is composed of only a thin dense layer, and the septula have similar structures. In most other respects, the two genera are closely similar.

The evolutionary position of *Yabeina* seems to be intermediate between *Neoschwagerina* and *Lepidolina*. LEE (1933) proposed the name *Colania* for some forms here included in *Yabeina*. The spirotheca and septula in the outer volutions of these forms is composed of only a thin dense layer. LEE indicated that the genotype of *Colania*, *C. kwang-siana* LEE (1933), is intermediate in development between the genotype of *Neoschwagerina* and the genotype of *Yabeina*. The trend in evolution of the neoschwagerinids seems to be in the direction of a decrease in the thickness of the spirotheca, progressing from *Cancellina* having a relatively thick spirotheca to *Lepidolina* which has spirotheca composed of only a thin dense layer. It does not seem likely that *Colania* developed from *Neoschwagerina*, obtaining a spirotheca composed of only a single layer in the outer volution and in turn giving rise to *Yabeina* with a spirotheca that has a distinct keriotheca throughout the shell.

Yabeina is widespread in the Upper Permian of Europe, Africa, Asia, and northwestern North America; including Tunis, Crimea, French Indo-China, Japan, possibly extreme southeastern Siberia, southern British Columbia, northern Washington, and central Oregon. At some of these localities,

Yabeina is stratigraphically above typical fusulinid faunas of the Zone of *Verbeekina-Neoschwagerina*. *Yabeina* seemingly is among the last of the fusulinids.

GENUS *LEPIDOLINA* LEE, 1933

Plate 20, figures 5, 6; Plate 22, figures 1-6

GENOTYPE.—*Neoschwagerina (Sumatrana) multiseptata* DEPRAT, 1912, Indochine Service Géol., Mém., vol. 1, fasc. 3, p. 53-55, pl. 3, figs. 2-8 (Holotype here designated as the specimen illustrated by DEPRAT as fig. 3, pl. 3).

Lepidolina LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 21.—DUNBAR & SKINNER, 1937, Texas Univ. Bull. 3701, p. 578.—DUNBAR, 1940, (In CUSHMAN) Foraminifera, p. 155.—DUNBAR & HENBEST, 1942, Illinois Geol. Survey, Bull. 67, p. 88.

Neoschwagerina [part] of authors prior to 1933.—GUBLER, 1935, Soc. Géol. France, Mém., new ser., tome 11, fasc. 4, no. 26, p. 71-74. [Not YABE, 1903.]

Yabeina [part] HUZIMORO, 1936, Tokyo Bunrika Daigaku, Sci. Repts., sec. C, no. 2, vol. 1, p. 119.—THOMPSON & WHEELER, 1942, Jour. Paleontology, vol. 16, p. 703. [Not DEPRAT, 1914.]

?*Colania* LEE, 1933, Nat. Research Inst. Geology, Mem., no. 14, p. 20. (GENOTYPE.—*Colania kwang-siana* LEE, 1933. Holotype here illustrated as fig. 6, Pl. 22.)

The genus *Lepidolina* LEE is considered the most highly evolved of the fusulinids. Its shell is large and highly inflated fusiform, having a straight axis of coiling, convex lateral slopes, and bluntly pointed to narrowly rounded poles. Mature shells of twenty-one to twenty-two volutions are 13 to 14 mm long and 7 mm wide. The form ratio is 1.3 to 1.5. The proloculus is unusually large, and is irregular in shape in some forms. The shell is tightly coiled, and the volutions increase in height uniformly. Chambers increase in height poleward from the center of the shell. The spirotheca is thin and is composed of a single thin layer of dense opaque material. The septa are thin and are identical in structure to the spirotheca; they are slightly irregular and extend forward at a slight angle. The lowermost surface of the septa bends forward at a sharp angle, and it is in contact with the preceding volution at a low angle. All the septula are thin and irregular in shape. The secondary transverse septula first appear in the inner one to three volutions, as many as two occurring between adjacent primary transverse septula in the outer volutions. Axial septula are present throughout the shell; one to three occur between adjacent septa in the inner volutions and as many as seven occur between adjacent septa in the outer volutions. Both the transverse secondary and axial septula are irregular in length. The septula are very thin near their junction with the spirotheca and they increase in thickness slightly toward their base. This thickening may be due to dense deposits extending from the parachomata. Foramina are abundant, small, and elliptical in cross section. At least 95 occur in a septum of the outer volutions of some forms. The parachomata are very narrow; they extend up to the base of the primary transverse septula, except

for a small elliptical lateral opening near the center of the chamber.

The validity of *Lepidolina* has been questioned by several. DUNBAR & SKINNER (1937), DUNBAR (1940), and DUNBAR & HENBEST (1942) recognized *Lepidolina* with reservations. It is here recognized that *Lepidolina* may be a synonym of *Yabeina*, or at most that it may be only a subgenus of *Yabeina*.

The septula of the neoschwagerinids, beginning with *Cancellina*, are formed by downward projecting ridges from the base of the spirotheca. In *Cancellina*, *Neoschwagerina*, and primitive *Yabeina*, the septula contain well-defined extensions of the alveoli of the keriotheca. In *Yabeina*, however, the lower surfaces of the septula are thin, are dense, and seemingly are coated by dense secondary deposits laid down during deposition of the parachomata. In *Lepidolina*, alveoli are absent in both the spirotheca and the septula. It has been suggested that the thin septula of *Lepidolina* and *Sumatrina* were formed by bunching of alveoli of the keriotheca. However, if this were the correct interpretation, it would seem that the septula should be thickest at their upper surfaces. The septula of both these genera become exceedingly thin at their upper margins.

The pendantlike shape of some septula of *Lepidolina multiseptata* seemingly influenced DEPRAT in referring it to *Sumatrina*. However, the septula of *Lepidolina* are irregular in length and are less numerous in the inner volutions than those of *Sumatrina*, and the size and shape of the shell of *Lepidolina* are markedly different from those of *Sumatrina*.

Lepidolina differs from *Yabeina* mainly in that the former has a thinner spirotheca and thinner septula.

A large variety of forms have been referred to *Lepidolina multiseptata* from French Indo-China and Japan by DEPRAT (1912a, 1914), COLANI (1924), and GUBLER (1935). Without a detailed study of the specimens illustrated by the above workers, it is not advisable to attempt specific corrections. All are not conspecific and probably not congeneric. LEE clearly demonstrated that the genotype of *Lepidolina* is *Neoschwagerina (Sumatrina) multi-*

septata DEPRAT (1912). However, LEE gave a footnote reference to DEPRAT's 1914 publication. Although *L. multiseptata* was originally based on specimens from Cambodge, French Indo-China, the illustrations referred to by LEE in his footnote include specimens from Akasaka, Japan.

Colania is here considered a synonym of *Lepidolina* with question. It is realized that when *Colania kwangsiensis* and closely similar forms are studied further, it may be necessary to resurrect *Colania*.

Lepidolina seemingly is associated with *Yabeina* in the Permian of the Tethys Sea area of Asia. It is one of the most advanced of the fusulinids, and it occurs among the stratigraphically highest members of the family.

ADDENDUM

Several fusulinid publications were received after proof of this paper was completed. A. S. ERK (Eclogae geol. Helvetiae, 1941, vol. 34, p. 243-253, pls. 12-14) established the genus *Reichelina* ERK with *R. criboseptata* ERK, 1941, (Holotype illustrated by ERK as fig. 17, pl. 14) as genotype. The genotype from Diskaya, Turkey, is associated with *Codonofusiella*, *Neoschwagerina*, *Cancellina*, and *Misellina*. *Reichelina* has a sharply angular periphery in the outer volutions, a rounded periphery in the inner volutions, a spirotheca composed of tectum and diaphanotheca, an axial length of about 0.5 mm and a width of about 1.2 mm, and an evolute ultimate volution of mature specimens. *Reichelina* is referable to Ozawanellinae, and its irregularly uncoiled gerontic stage indicates that it is an aberrant member of that subfamily. ERK interprets the horizon of *Reichelina* as older than the Zone of *Polydioxodina*, although he did not find it immediately below *Polydioxodina*-bearing rocks. He also points out that *Polydioxodina* is found in Turkey.

REICHEL (In VISSER's Karakorum, 1940, Band 3, p. 89-118, pls. 17-24) described a large fauna of fusulinids from Caracorum, including forms of *Staf-fella*, *Schubertella*, *Neofusulinella?*, *Yangchienia*, *Gallowaiinella?* [*Palaeofusulina*], *Triticites?*, *Dunbarinella*, *Schwagerina s. l.*, *Pseudofusulina*, *Parafusulina*, *Cancellina?*, and *Misellina*.

PART III

EARLY PENNSYLVANIAN FUSULINIDS OF NEW MEXICO AND
WESTERN TEXAS

INTRODUCTION

Studies of Pennsylvanian stratigraphy and faunas of New Mexico were started by C. E. NEEDHAM in 1931 for the New Mexico Bureau of Mines and Mineral Resources. In 1937, NEEDHAM published as Bulletin 14 of the New Mexico School of Mines a report on some of the fusulinids of the New Mexico Pennsylvanian. In a later paper, NEEDHAM (1940) summarized the stratigraphy of the Pennsylvanian of New Mexico. At the beginning of NEEDHAM's administration as President of the New Mexico School of Mines and as Director of the New Mexico Bureau of Mines and Mineral Resources he assigned me the project to continue the study of the Pennsylvanian of New Mexico. A summary of the classification of Pennsylvanian rocks in New Mexico was published as Bulletin 17 of the New Mexico School of Mines (THOMPSON, 1942b). The correlations of the different stratigraphic units within New Mexico discussed in that report were based partly on the abundant and widespread fusulinid faunas. The stratigraphic classification published in 1942 was to be followed by reports on the entire fusulinid fauna of New Mexico, and this is the first of these fusulinid studies.

Most of the descriptions of the different rock units contained in the 1942 report were taken from exposures in central and southern New Mexico, and all the stratigraphic type sections are located in that part of the state. Some lithologic units can be traced throughout most of the southern two-thirds of New Mexico. Other units change lithology markedly as the ancient land areas are approached, and they can be correlated most easily by their faunal content. Up to the present time, fusulinids have been found to be the most reliable index fossils for correlating the Pennsylvanian within New Mexico and for correlating the New Mexico rocks with those of similar age in other areas. In areas outside New Mexico, fusulinids are also recognized to be among the most reliable of the Pennsylvanian index fossils. Fusulinids are found in more than 80 distinct zones in the Pennsylvanian of New Mexico. It is the purpose of this report to describe the fusulinids from rocks of Early Pennsylvanian age in New Mexico and the immediately adjacent area of extreme western Texas.

This is the third report to describe fusulinids from New Mexico. The first was that published by NEEDHAM in 1937. The second was by THOMPSON in 1942. NEEDHAM described numerous fusulinids from

Pennsylvanian and Permian rocks of New Mexico, but THOMPSON described only two species from New Mexico. All of NEEDHAM's forms came from rocks of upper Middle Pennsylvanian age or younger, whereas the two forms described by THOMPSON were from lower Upper Pennsylvanian rocks.

ACKNOWLEDGMENTS

I wish to acknowledge the help given to me by many in the preparation of this report. The field work was financed largely by the New Mexico Bureau of Mines and Mineral Resources, and the present Director has consented that this report be published in this series. C. E. NEEDHAM gave valuable assistance in carrying on the field work and supplied much information based on his studies of the New Mexico Pennsylvanian. E. N. K. WAERING, R. E. KING, and others spent several days with me in the field. WAERING was especially helpful in furnishing comparative fusulinid collections and KING was especially helpful on several field conferences in New Mexico and the Hueco Mountains of western Texas. Information published by others concerning fusulinids and stratigraphy of New Mexico, Texas, and other areas has been used freely. The final completion of this report was made possible by financial and technical aid given by the Kansas Geological Survey, the Graduate Research Committee of the University of Kansas, and the Research Committee of the University of Wisconsin. Stenographic help for the final stages of the work was furnished by the Department of Geology of the University of Wisconsin and the State Geological Survey of Kansas.

STRATIGRAPHIC SUMMARY

THOMPSON (1942b) proposed the term Derry series for the lower part of the Pennsylvanian of southcentral New Mexico and defined Derryan rocks as of post-Morrowan and pre-Desmoinesian age. As thus defined, the Derryan contains rocks of pre-Desmoinesian age as the Desmoinesian is generally limited in its type section in Iowa. The Derryan rocks are equivalent in age in part to several other proposed stratigraphic units; including the Bendian (DUMBLE, 1890), Lampasan (CHENEY, 1940), and Atokan (SPIVEY & ROBERTS, 1945). The Derryan may be almost the exact equivalent of the Atokan. As defined by CHENEY and others in 1946, the Lampasan includes rocks equivalent in age to almost half the type section of the Desmoinesian.

The major classification used for the Pennsylvanian recognizes lower, middle, and upper series, named Lower Pennsylvanian, Middle Pennsylvanian, and Upper Pennsylvanian. The Lower Pennsylvanian series as here used includes all Pennsylvanian rocks formerly included in the Morrowan or older units. The Middle Pennsylvanian series includes the rocks of New Mexico formerly referred to the Derryan and to the Desmoinesian. The Upper Pennsylvanian series consists of all rocks formerly referred to the Missourian and the Virgilian series.

The fusulinids in New Mexico show a gradual evolutionary change in the Middle Pennsylvanian from the earliest *Profusulinella*, through the complete development of *Profusulinella* and *Fusulinella*, and to some of the most highly developed American forms of *Fusulina*. As pointed out by THOMPSON in 1942, there is no marked unconformity recognized throughout this stratigraphic interval in New Mexico. Also, the fusulinid fauna indicates that there is no great paleontologic break in this part of the section in New Mexico.

The Pennsylvanian of the Ardmore Basin in Oklahoma contains rocks of Lower, Middle, and Upper Pennsylvanian ages. The Pennsylvanian Basin had its beginning in early Lower Pennsylvanian time. The stratigraphic relationship here between the Lower and Middle Pennsylvanian is not known. They may be unconformable. The fusulinid faunas do not show a prominent faunal break between the series. In the Ardmore Basin and in several other major basins of sedimentation, a prominent faunal break occurs between the Middle and Upper Pennsylvanian.

The Middle Pennsylvanian of the Rocky Mountain area and of the midcontinent region progressively overlaps beyond the areas of early Middle Pennsylvanian sedimentation. Far from the areas of early Middle Pennsylvanian sedimentation, late Middle Pennsylvanian rocks overlie erosional remnants of rocks of Lower Pennsylvanian older age.

The unconformity separating the Middle and Upper Pennsylvanian is widespread. In the Rocky Mountain region, this unconformity is marked by a prominent uplift of the ancestral Rocky Mountains, and Upper Pennsylvanian rocks contain abundant arkosic clastic near the land areas. Basal Upper Pennsylvanian rocks containing closely similar or identical faunas are very widespread in the

midcontinent region and in the southern part of the Rocky Mountain region, which indicates that the advance of the Upper Pennsylvanian seas was much more rapid than that of the early Middle Pennsylvanian seas.

The fusulinids described in this report are from rocks of probable Lower Pennsylvanian age and from rocks of lower Middle Pennsylvanian age of extreme western Texas and southcentral New Mexico. They include fusulinids from the upper part of the Zone of *Millerella*, the entire Zone of *Profusulinella*, and the entire Zone of *Fusulinella*.

Pennsylvanian rocks of the fusulinid zones of *Profusulinella* and *Fusulinella* were first reported from New Mexico by NEEDHAM in 1940 (footnote, p. 176). Since that time, Pennsylvanian rocks of lower Middle Pennsylvanian age have been recognized in many of the mountain ranges of southcentral New Mexico and in the subsurface as far northwest in New Mexico as the Rattlesnake field of San Juan Basin (THOMPSON, 1942b). So far as can be determined, rocks of lower Middle Pennsylvanian age are restricted in central and southern New Mexico to the area west of the Pederal Land Mass, in northcentral New Mexico to the region just east of the Nacimiento Uplift, and in northwestern New Mexico to the area between the Nacimiento Uplift and the Zuni Uplift. The western limits of lower Middle Pennsylvanian rocks of southern New Mexico are not known. Rocks of this age are found as far west as Silver City but are absent in the Salt River Valley of eastern Arizona. The interpreted paleogeography of the Middle Pennsylvanian Zone of *Fusulinella* in New Mexico is shown on the accompanying map (Fig. 6). Several hundred feet of massive to massively bedded limestones are present in the Hueco Mountains of extreme western Texas at the base of the Pennsylvanian. They contain a prolific fusulinid fauna composed of *Millerella*. These limestones were referred to the lower part of the Lower Division of the Magdalena limestone by KING, KING, & KNIGHT (1945). Although individual forms of *Millerella* are not good index fossils, the absence of more highly developed fusulinids strongly suggests that these lower limestones are of Lower Pennsylvanian age. Furthermore, the basal overlying Middle Pennsylvanian rocks contain one of the most primitive *Profusulinella* faunas known in America, sup-

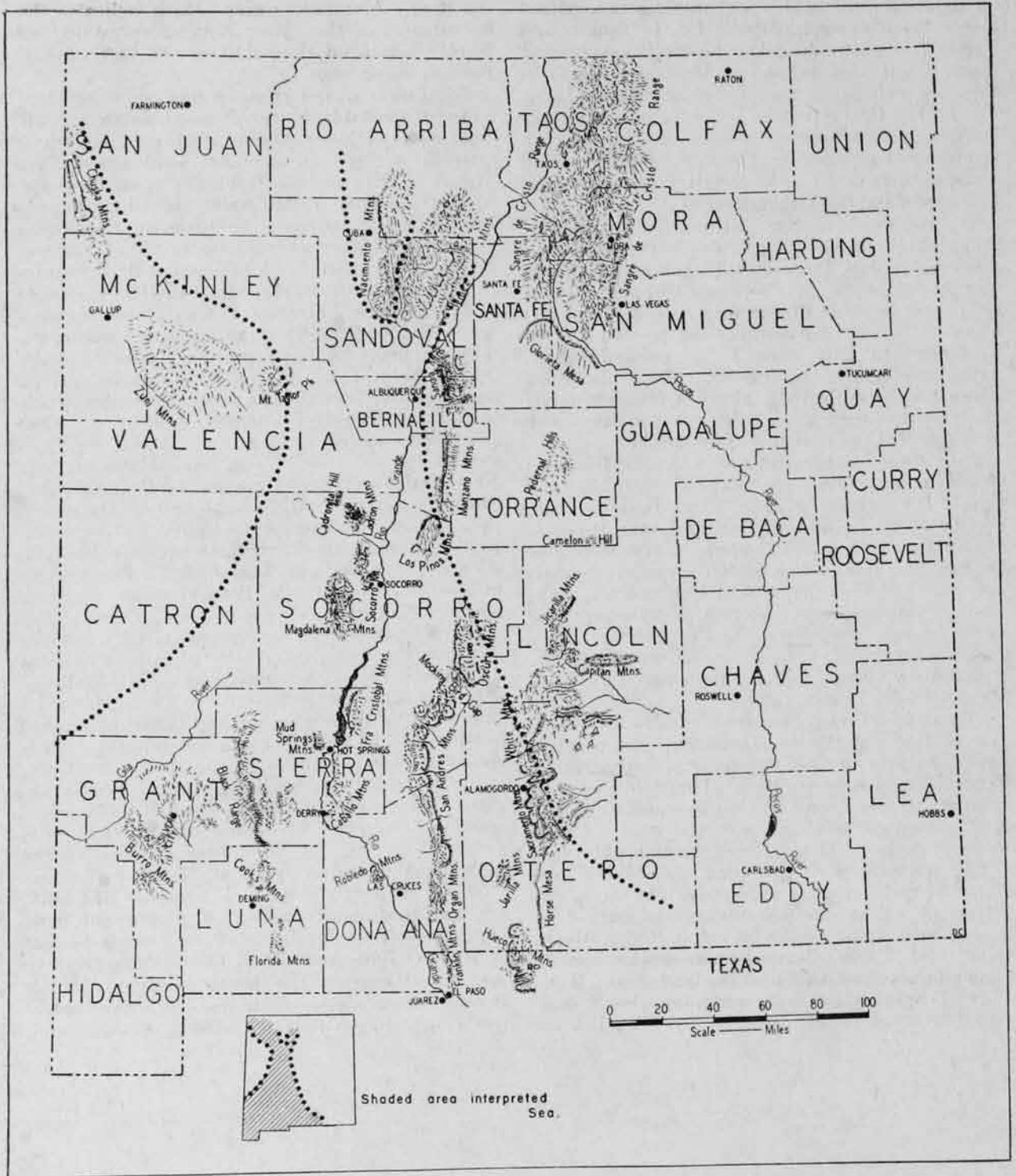


FIGURE 6.—Interpreted paleogeography of the Middle Pennsylvanian Zone of *Fusulinella* in New Mexico.

Section 52, Powwow Canyon, Texas

On west face of cliff at the west end of Powwow Canyon and approximately one-third mile south of U. S. Highway 62. Base of section begins at base of cliff. July 17, 1942.

LOWER PENNSYLVANIAN(?)

Thickness, (feet)	Bed
240.0	(8) <i>Limestone</i> , light gray, dense and massive; in beds 10 feet to 15 feet thick; very fossiliferous; basal 27 feet well exposed; next 17 feet mainly covered; next 86 feet forms cliffs; next 35 feet thin and irregularly bedded, interbedded with abundant thin beds of light-gray chert; upper 75 feet massively bedded, forms top of cliff.
50.0	(7) <i>Limestone</i> , bluish-gray to light gray, alternating beds; highly algal in places; abundance of light-gray chert beds and nodules throughout; great abundance of silicified horn corals showing on face.
16.0	(6) <i>Limestone</i> , gray, highly fossiliferous; thin-bedded with abundant light-gray chert in lower 10 feet; next 6 feet highly crinoidal, very light gray, looks like sand.
31.0	(5) <i>Limestone</i> , light gray, seems finely brecciated; massive beds up to 15 feet thick; long horn corals very abundant in lower 15 feet; cliff forming.
26.0	(4) <i>Limestone</i> , bluish-gray, algal (?), spotted surface; very massively bedded, in beds up to 8 feet thick; upper 2 feet highly oölitic.
20.0	(3) <i>Limestone</i> , gray to purplish, granular; contains abundant red to purplish masses of chert; massively bedded; oölitic; upper 7 feet poorly exposed.
25.0	(2) <i>Sandstone</i> , fine-grained, dark brown to reddish-brown, cross-bedded; probably does not occupy all this interval.

MISSISSIPPIAN (CHESTERIAN)

4.0-5.0	(1) <i>Limestone</i> , brown to yellow, slabby, highly fossiliferous; abundant bryozoans, trilobites, blastoids, brachiopods, etc.; poorly exposed at this place.
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Lower Middle Pennsylvanian rocks are exposed in many of the mountains of southcentral New Mexico. In the area north and south of the Mud Springs Mountains, the Lower Pennsylvanian is unconformable on Devonian shale. In many areas of extreme southern New Mexico, they lie unconformably on Mississippian limestone. In northcentral New Mexico and in areas near the Pennsylvanian land areas, they rest on the pre-Cambrian.

The lithology of the lower Middle Pennsylvanian rocks in New Mexico is highly variable. In the area of the Mud Springs Mountains, they are composed largely of limestone, interbedded in the lower part with gray shale and argillaceous sandstone and siltstone. Thin beds of granule to coarse sandstone conglomerates of reworked white quartzite occur in the upper part. Most of the limestones are medium to dark gray.

Southward toward the extreme western part of Texas and in the Hueco Mountains of Texas, the lower Middle Pennsylvanian is composed largely of massive to massively bedded gray limestone, interbedded with thin softer zones of algal and nodular limestone. In the Franklin Mountains of extreme

western Texas and southern New Mexico, the rocks are composed largely of massively bedded limestone, interbedded with softer nodular zones. In the Silver City region, the rocks of this age are composed of alternating dark-gray massive limestone and dark-gray nodular to argillaceous limestone.

In the Sacramento Mountains, the lower Middle Pennsylvanian contains abundant conglomeratic limestones, sandstones, and dark-gray shales, interbedded with dark-gray limestones. Only the upper part of the lower Middle Pennsylvanian seems to be present in the region of the Magdalena Mountains. It is composed of dark-gray to gray limestones interbedded with thick sandy shales, thick sandstones, and granule conglomerates composed of reworked light-colored quartzite. Northward from the Magdalena Mountains, rocks of this age are more highly clastic. They include thick shales, conglomeratic sandstones, and a few highly argillaceous and sandy limestones in the region of Cadronito Hill and Ladron Mountain. Only the upper part of this unit is present in the eastern part of the Nacimiento Mountains, and it is composed of thin limestones, interbedded with thick shales and sandstones.

The lower Middle Pennsylvanian rocks in the region of the Oscura Mountains are composed largely of conglomeratic sandstone, sandy limestone, and gray shale. Also, only the upper part of the Zone of *Fusulinella* is present in this region. The Oscura Mountains are near the overlapping eastern edge of the upper part of the Zone of *Fusulinella*.

All available evidence indicates that the lower part of the Middle Pennsylvanian progressively overlaps northward up the general region of the Rio Grande valley. The thick conglomerates of this age in the region of Magdalena Mountains and Ladron Mountain indicate that their source was from quartzites similar in lithology to the pre-Cambrian quartzites in Los Pinos Mountain and Manzanos Mountains to the east of the Rio Grande (STARK & DAPPLES, 1946).

The seaway was bordered on the east by a land barrier near the present location of the Pedernal Mountains. This ancient land area is referred to as the Pedernal Land Mass (THOMPSON, 1942b). Evidence that a land area was present east of the Oscura Mountains and east of the western edge of the Sacramento Mountains during lower Middle Pennsylvanian time is found in the coarsely clastic nature of the rocks in these areas.

Lower Middle Pennsylvanian rocks have not been found in New Mexico east of the Pedernal Land Mass. The uppermost Middle Pennsylvanian and Upper Pennsylvanian rocks east of the Pedernals are markedly different lithologically from rocks of similar ages west of the Pedernals, thus supporting the hypothesis that the Pedernal Land Mass formed a north-south barrier in central New Mexico through most, if not all, of Pennsylvanian time. Evidence has been presented in the last few years to indicate

that the late Pennsylvanian seaways of eastern New Mexico were connected with the seaways of the Rio Grande region around the north end of the Pedernal Land Mass.

Fusulinids are exceedingly abundant throughout the Green Canyon and Mud Springs groups at many localities in New Mexico, including the type sections of all formations of these groups. Fusulinids of the same ages are also abundant in Powwow Canyon in the Hueco Mountains. The lower part of the Middle Pennsylvanian is well exposed in Powwow Canyon, but the middle part of the series is eliminated by several faults. Part of the Mud Springs group is missing on the south wall of the canyon. How-

ever, fusulinids indicate that at least a part of the Mud Springs group occurs here below rocks of the lower part of the Zone of *Fusulina*. These *Fusulina*-bearing rocks are equivalent in age to the type section of the Whiskey Canyon formation of New Mexico and to the Cherokee shale of the midcontinent region.

All fusulinids described below are either from the Mud Springs Mountains and Derry area or from Powwow Canyon. The accompanying diagrammatic illustrations of the lower Middle Pennsylvanian rocks in the Mud Springs Mountains and at Derry (Fig. 8) and in Powwow Canyon (Fig. 7) show the stratigraphic distribution of the fusulinids.

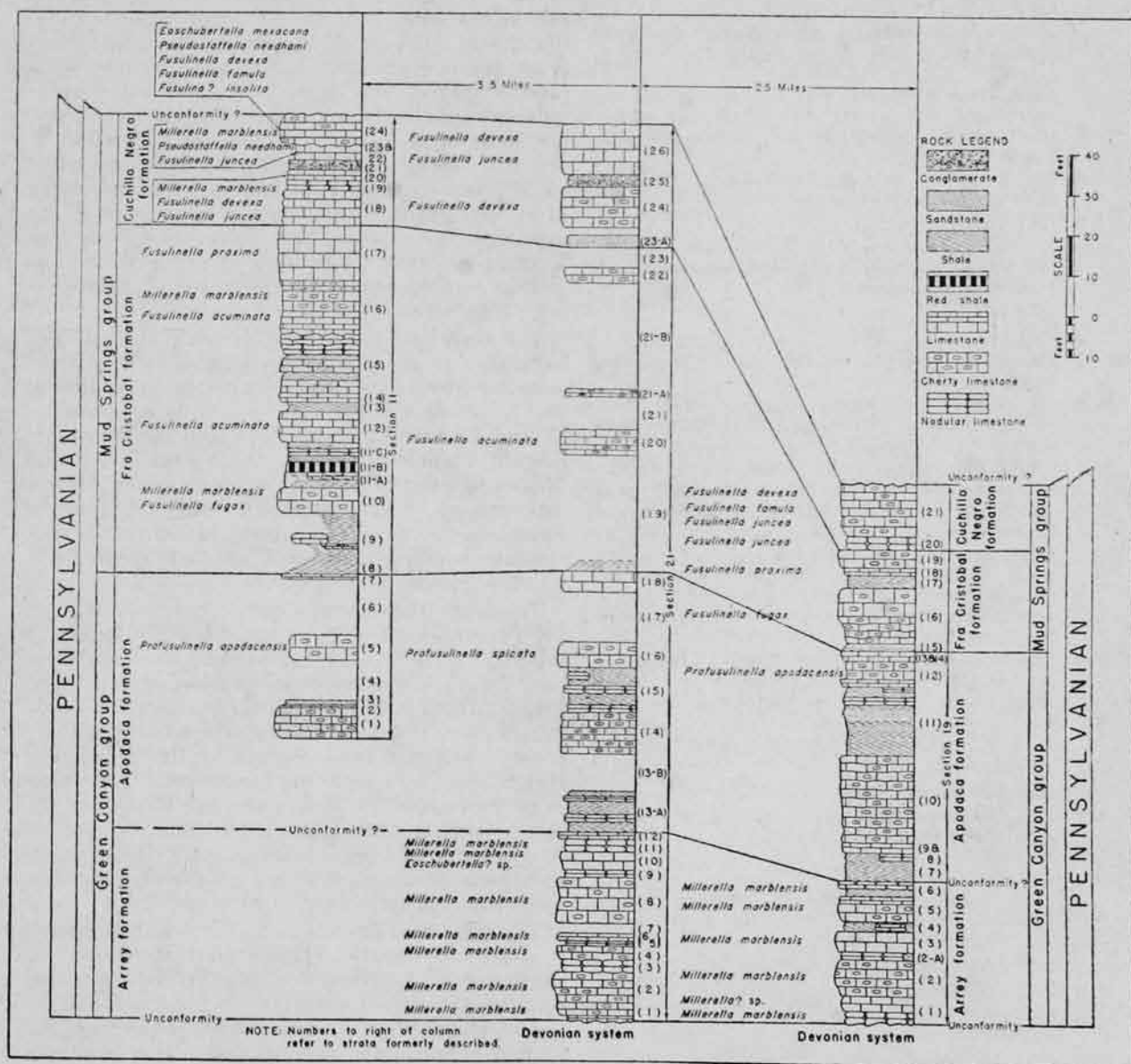


FIGURE 8.—Diagrams of sections of lower Middle Pennsylvanian rocks in southern New Mexico, showing fusulinid faunas.

Detailed descriptions of the individual rock units of Figure 7 were given by THOMPSON in 1942. The units of the Powwow Canyon section are briefly described below.

Section 17, Powwow Canyon, Texas

Measured on east side of small valley 1¼ miles south of U. S. Highway 80 in Powwow Canyon, Hueco Mountains, Texas, beginning just east of the El Paso-Hudspeth County line and extending northeastward toward highway.

Thickness, (feet)	LOWER MIDDLE PENNSYLVANIAN Bed
2.0	(44) <i>Limestone</i> , cherty, gray, coarse-grained; glistening; fossiliferous; carries fusulinids.
15.1	(43) <i>Covered</i> .
1.0	(42) <i>Limestone</i> , gray to light gray, brownish on fresh surfaces; weathers yellowish-gray; fusulinids rather common.
27.0	(41) <i>Covered</i> . NOTE.—Beds 41-44 were measured on the cliff below beacon light on the easternmost wall of the small canyon that drains into a sharp bend of Powwow Canyon.
3.0	(40) <i>Limestone</i> , light gray, extremely fossiliferous; chert in thin wavy bands on faces.
1.0	(39) <i>Covered</i> .
31.2	(38) <i>Slope</i> , probably largely <i>limestone</i> ; several beds exposed; limestone light gray and massive; at least two limestone cycles.
5.0	(37) <i>Limestone</i> , gray.
18.4	(36) <i>Covered</i> .
26.2	(35) <i>Slope</i> , lower 15 feet one bed of <i>limestone</i> , light gray, algal.
59.0	(34) <i>Partly covered</i> in lower and upper part; middle part shows massively bedded fine-grained limestone.
20.4	(33) <i>Limestone</i> , very coarse-grained to crystalline, weathers on surface like sand; yellowish-gray color.
40.1	(32) <i>Slope</i> , mainly covered; several thin ledges of <i>limestone</i> showing on slope.
6.5	(31) <i>Limestone</i> , thin-bedded in lower 3 feet; massively bedded in upper 3.5 feet, coarse-grained, massive; lower part weathers out in thin sheets, very highly crinoidal; abundant silicified fossils weather out on surface of upper part.
18.0	(30) <i>Covered</i> , several small ledges of limestone show on slope.
4.5	(29) <i>Limestone</i> , irregularly bedded in lower 1.5 feet; much chert in large nodules up to 0.8 foot thick in lower 1.5 feet; upper part thinner bedded.
3.5	(28) <i>Covered</i> .
4.0	(27) <i>Limestone</i> , as below; one massive bed.
6.5	(26) <i>Limestone</i> , light gray, massive, two nearly equal beds; highly algal in upper part; partly covered.
74.5	(25) <i>Limestone</i> , alternating massive to thick-bedded, light gray; lower 35 feet very cherty; fusulinids abundant 60 feet above base; highly algal in upper 6 to 7 feet.
22.5	(24) <i>Limestone</i> , massive, light gray.
21.0	(23) <i>Limestone</i> , light gray, massive in lower part; upper 5 feet highly algal, irregularly bedded, gray to medium gray.
3.0	(22) <i>Covered</i> .
3.5	(21) <i>Limestone</i> , hard, dense, coarse-grained; crinoidal; brownish-gray; oölitic.

Thickness, (feet)	Bed
8.0	(20) <i>Marl</i> , soft, friable, highly calcareous; thin layers and small nodules of limestone; light yellow to white; possibly a highly weathered shale.

The type section of the Arrey formation is composed largely of limestones. The Arrey may represent a considerable length of time, although the type section is relatively thin. Several disconformities seem to occur at the type section. At least seven sequences of limestone are recognized in the type section, and each sequence may correspond to a sedimentary cyclothem of the Pennsylvanian in the northern midcontinent region. One of the disconformities is indicated by borings in the top of one of the limestone sequences. There is a marked lithologic change between the Arrey limestone and the clastic phase of the overlying Apodaca formation. It seems probable that an unconformity separates the Arrey and Apodaca formations. Fusulinids are exceedingly abundant throughout the Arrey, but most of them are referable to *Millerella*. A primitive form referred below to *Eoschubertella?* sp. is present in the Arrey type section and in the Mud Springs Mountains, but specimens of it are rare. Farther south in New Mexico and in western Texas, rocks tentatively referred to the Arrey formation contain abundant specimens of *Profusulinella copiosa*, n. sp.

The lower part of the type section of the Apodaca formation is composed largely of shale, siltstone, and silty limestones. It does not contain fusulinids. The upper part of the type section is composed of alternating limestone and shale, and the limestones contain abundant faunas of *Profusulinella* and *Millerella*. Rocks in extreme southern New Mexico and western Texas correlated with the Apodaca formation are composed largely of limestones that contain abundant faunas of *Profusulinella*, *Staffella*, *Nankinella*, and *Millerella*.

The term Hot Springs formation was proposed by THOMPSON (1942) for the lower formation of the Mud Springs group. This term was previously used for a Quaternary deposit in Yellowstone Park (WEED, 1896) and for a Pennsylvanian formation in Arkansas (PURDUE, 1910). The name Fra Cristobal formation is here proposed for the rocks called Hot Springs formation by THOMPSON. This name is derived from the Fra Cristobal Range on the east side of the Rio Grande, but the type locality is the same as that of THOMPSON'S Hot Springs formation; that is, in Whiskey Canyon on the northwest side of Mud Springs Mountains.

The type section of the Fra Cristobal formation is composed largely of limestone, interbedded in the lower part with gray shales. The formation contains at least six sequences of limestone. *Fusulinella*, *Pseudostaffella*, and *Millerella* are abundant in four zones of the type section. The formation is widespread in southern New Mexico and seemingly extends northward at least as far as the

Magdalena Mountains. Fusulinids have not been found in the basal part of the Pennsylvanian at Magdalena Mountains or in any part of the lowermost Pennsylvanian at Ladron Mountain or Cadronito Hill. It is possible that the lowermost clastic rock in the Magdalenas and in the Ladron area may be equivalent in age to the Fra Cristobal formation.

The upper formation of the Mud Springs group, the Cuchillo Negro formation, is largely limestone, interbedded with several thin granule conglomerates and sandstones composed largely of reworked quartzites. Fusulinids referable to *Fusulina?*, *Fusulinella*, *Pseudostaffella*, *Eoschubertella*, and *Millerella* are abundant in the type section of the formation. Fusulinid-bearing limestones of the Cuchillo Negro formation are exposed in the Silver City region, Santa Rita district, Oscura Mountains, Magdalena Mountains, Nacimiento Mountains, San Andres Mountains, Franklin Mountains, Hueco Mountains, and near Derry.

FAUNAL SUMMARY

Two species of *Millerella*, *M. inflecta* and *M. circuli*, are illustrated from the lower part of the Pennsylvanian in Powwow Canyon. Although several *Millerella*, in addition to these two forms, are exceedingly abundant in these lower Pennsylvanian rocks (Fig. 7), forms of more advanced fusulinids have not been observed. These lower rocks are tentatively referred to the Lower Pennsylvanian.

The type section of the Arrey formation contains abundant *Millerella* that are all tentatively referred to *Millerella marblensis*, rare specimens of *Nankinella*, and scattered specimens illustrated below as *Eoschubertella?* sp. The last form may be referable to *Profusulinella*. I do not have any well-centered or well-oriented sections of this form. It needs further study. This questionable form is minute in size, is inflated fusiform, and possesses unfluted septa. The Arrey formation may be of Lower Pennsylvanian age.

Twenty-two species of fusulinids are described and illustrated below from the lower part of the Middle Pennsylvanian of New Mexico and extreme western Texas. They are referred to the genera *Millerella*, *Staffella*, *Nankinella*, *Pseudostaffella*, *Eoschubertella*, *Profusulinella*, *Fusulinella*, and *Fusulina?*. The genus *Profusulinella* is represented by practically all major stages of evolutionary development from its most primitive stages to its transitional stages with *Fusulinella*. *Fusulinella* is represented by several stages of evolution from *Profusulinella* to its most advanced forms. One primitive species of *Fusulina?* is described from the upper part of the Mud Springs group.

The genus *Millerella* is abundant throughout the Middle Pennsylvanian. It is most abundant and

prolific in the more massively bedded Arrey formation. *Millerella* is also more abundant throughout the Zone of *Profusulinella* than in the overlying Zone of *Fusulinella*. Although a large variety of forms are recognizable, for the present, at least, I defer specific separation of most of them. Some are referred to three previously described species.

Forms here referred to *Nankinella* and *Staffella* are exceedingly abundant in thin zones of the Green Canyon group. They assume rock-building importance in the Hueco Mountains. All their shells are completely replaced by secondary mineralization, but associated *Millerella* and other fusulinids generally are not replaced. Two species of *Staffella* and several unidentified species of *Nankinella* are described and illustrated. Although *Nankinella* and *Staffella* are abundant in some parts of the Zone of *Profusulinella*, they are sparse in the overlying rocks.

The genus *Nankinella* was originally described from the Permian of China. The forms here referred to it from the Green Canyon group may not in reality be congeneric with the genotype, but they seem more closely similar to *N. discoidea* (LEE) than to any other genotype. The forms of *Nankinella* described below are closely similar to forms in the upper part of the Marble Falls limestone on the east side of the Llano Uplift, Texas. They are associated with *Profusulinella* at both places, but the evolutionary trend of *Nankinella* is not well enough understood to permit correlation.

The genotype of *Staffella* is from the Permian of Armenia. The forms here referred to *Staffella* may not be referable to that genus. They are closely similar to forms from the upper part of the Marble Falls limestone of the Llano Uplift. *Staffella* as here defined has a very long stratigraphic range, and its evolution is not well enough understood to permit detailed correlation within the Pennsylvanian. However, the close similarity among the forms from the Green Canyon group and those known from the upper part of the Marble Falls limestone (THOMPSON, 1947) suggests that the lower Green Canyon group is to be correlated with the upper part of the Marble Falls limestone.

Several forms of *Eoschubertella* occur in the lower Middle Pennsylvanian of New Mexico, but specimens are sparse. The New Mexico forms occur in dense limestone, and it is difficult to obtain well-oriented sections of their minute shells. Hence, many of them can not be reliably defined. Only one species, *E. mexicana*, n. sp., is here described.

Only one species of *Pseudostaffella*, *P. needhami* THOMPSON (1942), is described from New Mexico. *Pseudostaffella* is most common in the Mud Springs group. The genus occurs throughout most of the Middle Pennsylvanian of America. Individual species have not been found to be of much stratigraphic

value for detailed correlations. Some European and Asiatic species are considerably larger than the American forms. A definite evolutionary trend has not been observed within the genus. So far as known, the stratigraphic range of *Pseudostaffella* in the Eastern Hemisphere is closely similar to that in America.

The *Profusulinella* and *Fusulinella* give the most reliable information for the correlation of the lower Middle Pennsylvanian rocks within this region and for the correlation of the New Mexico rocks with those of similar age in other areas. *Profusulinella* is abundant in the Green Canyon group, and seven new species are described below. *Fusulinella* is abundant throughout the Mud Springs group, and six new species and one previously known form are described below. *Profusulinella* and *Fusulinella* do not overlap stratigraphically. *Millerella* is associated with both genera but it is more abundant and varied with *Profusulinella*. Also, forms of *Nankinella* and *Staffella* are abundant in certain beds of the Green Canyon group associated with *Profusulinella*, especially in the Hueco Mountains. *Pseudostaffella* occurs sparsely in the Green Canyon group associated with *Profusulinella* and more abundantly in the Mud Springs group associated with *Fusulinella*.

Profusulinella copiosa, n. sp., from the basal part of the Green Canyon group, is among the most primitive forms of the genus. The most closely similar American form is from the upper half of the Marble Falls limestone in the eastern part of the Llano Uplift, Texas. *Profusulinella apodacensis* from the upper part of the Green Canyon group is one of the most advanced forms of the genus in America. It is closely similar to forms from the lower part of the Big Saline limestone near Mason, Texas.

The most primitive form of *Fusulinella* from New Mexico, *F. fugax*, occurs in the basal part of the Mud Springs group. Closely similar forms are known from the basal part of the Reclamation group of Wyoming, the lower part of the Atoka formation of Oklahoma, the basal part of the type section of the Big Saline limestone of Texas, and the upper Bostwick limestone of the Ardmore Basin, Oklahoma. The forms of *Fusulinella* from the upper part of the Mud Springs group are closely similar to *Fusulinella* in the Lester limestone of the Ardmore Basin, Oklahoma, the upper part of the Big Saline limestone of Texas, and the lower Minnelusa formation of South Dakota.

Fusulina? insolita, n. sp., from the Cuchillo Negro formation is more or less transitional in development between *Fusulinella* and *Fusulina*.

SYSTEMATIC PALEONTOLOGY

FAMILY FUSULINIDAE MÖLLER, 1878

SUBFAMILY OZAWAINELLINAE THOMPSON & FOSTER, 1937

GENUS MILLERELLA THOMPSON, 1942

Millerella marblensis THOMPSON

Plate 23, figures 1-12, 16-31; Plate 24, figures 1-9

Millerella marblensis THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 405-407, pl. 1, figs. 3-14.—1944, Kansas Geol. Survey, Bull. 52, p. 420-423, pl. 1, figs. 1-9, pl. 2, figs. 1-15, 24.—(?) 1945, Kansas Geol. Survey, Bull. 60, p. 43.

A large variety of specimens has been referred to this species. The holotype came from the type section of the Marble Falls limestone of the Llano Uplift, Texas. Paratypes are from the Marble Falls limestone and from the Green Canyon and Mud Springs groups of New Mexico. THOMPSON referred to this species specimens from the type sections of the Morrowan of Arkansas and the Kearny formation of Kansas, and he indicated that specimens which have affinities with the types occur in the Belden formation in Colorado and Utah. The specimens here illustrated came from the lower part of the Pennsylvanian in Powwow Canyon and from several zones in the Arrey formation of central New Mexico. A variety of specimens is here included in this species. Although it is not likely that all the specimens here illustrated are conspecific, most of them are shown mainly to demonstrate the variation of this general type of *Millerella* present in the lower part of the Pennsylvanian of New Mexico and western Texas.

Occurrence.—*Millerella marblensis*, as here defined in a very broad sense, has a long stratigraphic range. It is a primitive fusulinid and could be expected to have a long stratigraphic range. It is probable, however, that further studies will demonstrate that several species are included under this name. Specimens referred to this species occur in the Marble Falls limestone of Texas, the Morrowan of Arkansas, the Kearny formation of Kansas, the Belden formation of Colorado and Utah, the Lower Pennsylvanian of the Hueco Mountains, and throughout the Green Canyon and Mud Springs groups of southcentral New Mexico and Hueco Mountains, Texas.

Millerella inflecta THOMPSON

Plate 24, figures 10-15

Millerella inflecta THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 44-46, pl. 1, figs. 1-7, pl. 5, figs. 2, 3, text figure 11.

The specimens here illustrated from the lower part of the Pennsylvanian in Powwow Canyon, Hueco Mountains, agree closely with the types of *Millerella inflecta* from the Belden formation of Colorado and eastern Utah.

The Texas specimens of five volutions are about 0.38 mm wide and 0.17 mm long, form ratio 0.50. The heights of the first to the fifth volution of two

specimens are 16, 25, 35, 56, and 65 microns, respectively. The form ratios of the first to the fifth volution of one specimen are 0.53, 0.42, 0.54, 0.50, and 0.50, respectively. Thus, the form ratios of corresponding volutions of these specimens are only slightly less than those of the types. The proloculus is small, and its outside diameter measures 34 to 41 microns.

Remarks.—The Texas specimens agree closely with the types from Colorado. However, I do not have a sufficient number of well-oriented specimens to be sure that they are conspecific.

Occurrence.—The specimens here illustrated are from the Lower Pennsylvanian, Powwow Canyon, Hueco Mountains, Texas. The types are from the Belden formation of Colorado and eastern Utah.

Millerella circuli THOMPSON

Plate 24, figures 16-18

Millerella circuli THOMPSON, 1945, Kansas Geol. Survey, Bull. 60, p. 46, 47, pl. 1, figs. 15-18.

The specimens here illustrated from the lower part of the Pennsylvanian of western Texas agree closely in all measurable details with the holotype and paratypes from the Belden formation of Colorado. One of the larger specimens of five volutions measures 0.61 mm in width and 0.25 mm in axial length. The heights of the second to the fifth volution of one specimen are 44, 61, 85, and 102 microns, respectively. The tunnel is distinct and the chomata are highly asymmetrical. The tunnel angles of the fourth and fifth volutions are about 23 and 28 degrees, respectively. Thus, the tunnel angle of the Texas specimens is slightly larger than that of the holotype and paratypes.

Occurrence.—*Millerella circuli* is abundant in Bed 6 of Section 52, Powwow Canyon, Hueco Mountains, Texas. It is also abundant and widespread in the Belden formation of northwestern Colorado and eastern Utah.

GENUS NANKINELLA LEE, 1934

Nankinella sp.

Plate 25, figures 13-16

A number of specimens have been sectioned from Beds 33 and 34, Section 17, Powwow Canyon, Hueco Mountains, Texas, that seem to be referable to *Nankinella*. All of them are entirely replaced by secondary mineralization. However, most associated specimens of *Profusulinella* and *Millerella* are not replaced by secondary mineralization.

The specimens are not well preserved, but, for the sake of completeness, I am illustrating two of the better preserved specimens. One of the larger specimens of six and one-half volutions, presumably a mature specimen, measures 0.65 mm in axial length and 1.52 mm in width. The form ratio is about 0.43. The shell is planispiral throughout growth, and it is umbilicate from the second volution to maturity. The periphery of the inner two volutions is rounded,

but that of the outer volutions is angular. The proloculus has an outside diameter of about 70 microns. The heights of the first to the sixth volution are about 30, 56, 76, 135, 212, and 210 microns, respectively. The chomata are low and are slightly asymmetrical. The structure of the septa and spirotheca was not determined.

Remarks.—These specimens resemble *Nankinella plummeri* THOMPSON from the Marble Falls limestone of Texas in several respects, and part of them possibly are conspecific with that form. So little can be determined concerning the specimens under consideration that I hesitate to refer any of them to *N. plummeri* until more information is obtained.

GENUS STAFFELLA OZAWA, 1925

Staffella depressa, new species

Plate 25, figures 1-6

Staffella depressa, n. sp., has a minute subellipsoidal umbilicate shell, possessing a straight axis of coiling and a narrowly rounded periphery at maturity. The periphery of the first and second volutions is rounded, that of the third and fourth volutions is broadly angular, and that of the outer two volutions is narrowly rounded. Mature specimens of five and one-half to six volutions are 0.61 to 0.68 mm long and 1.25 to 1.39 mm wide, giving a form ratio of 0.50. The form ratio of the first to the fifth volution of the holotype is 0.57, 0.54, 0.54, 0.58, and 0.55, respectively. Thus, the general outline of the shell remains about the same throughout growth of the individual.

The proloculus is minute. Its outside diameter is about 41 microns in the holotype. It is as large as 76 microns in some paratypes. The heights of the first to the sixth volution of the holotype and of the illustrated axial section of a paratype are about 32, 51, 92, 139, 178, and 177 microns, respectively. The heights of the chambers in the outer volutions of other paratypes are closely similar to the above figures. The chambers are highest over the tunnel in outer volutions. They decrease in height poleward. In the inner three volutions, the heights of the chambers decrease rapidly from the center of the shell toward the poles.

The spirotheca is thin. Secondary mineralization has largely destroyed details of the spirothecal structure. The spirotheca seems composed of a tectum and upper and lower tectoria. The combined thickness of all layers of the spirotheca in the fourth and the fifth volution of the figured axial section of a paratype is 13.6 and 27.0 microns, respectively.

Septa are numerous. They extend forward at an angle of about 10 degrees from normal to the spirotheca. The septal counts of the third to the sixth volution of two paratypes are 17, 18, 18, and 17, respectively. The septa are unfluted throughout the length of the shell.

The tunnel is low and wide. Its path is straight throughout the shell. The tunnel angles in the fifth and sixth volutions of the holotype and of the figured axial section of a paratype are about 18 and 19 degrees, respectively. The chomata are low. Their tunnel side is steep, and their poleward slope is low.

Remarks.—*Staffella depressa* resembles *S. powwowensis*, n. sp., more closely than any other American form. They can be distinguished, however, for *S. depressa* has a more narrowly rounded periphery, smaller form ratio for corresponding volutions, and more deeply umbilicate polar regions.

Staffella depressa resembles somewhat closely *Staffella expansa* THOMPSON from the Marble Falls limestone of Texas. The latter form has a more tightly coiled shell, more volutions at maturity, more highly discoidal early volutions, and broader umbilical areas. Also, the tunnel angles for corresponding volutions of *S. expansa* are smaller.

Occurrence.—*Staffella depressa* occurs 17 feet above the base of Bed 34, Section 17, Powwow Canyon. It is associated with *Profusulinella munda*, n. sp., and numerous forms of *Millerella*.

Staffella powwowensis, new species

Plate 25, figures 7-12

The shell of *Staffella powwowensis*, n. sp., is minute and subspherical, containing rounded periphery, slightly depressed axial regions (umbilicate), and straight axis of coiling. Mature specimens of six to eight and one-half volutions are 0.66 to 1.25 mm long and 0.95 to 1.69 mm wide. The form ratio is 0.70 to 0.80. The first volution is evolute. The second volution is involute, having a small form ratio. The length of the axis increases from the second volution to maturity. At maturity the axial

regions are only slightly umbilicate and the shell is about spherical. The form ratios of the first to the sixth volution of the holotype are 0.57, 0.54, 0.70, 0.74, 0.80, and 0.80, respectively. The periphery in the inner two to three volutions are narrowly rounded. From the third volution to maturity, the periphery is more broadly rounded. The axes of coiling of all volutions are parallel.

The proloculus is minute, having an outside diameter of 58 microns in the holotype. The shell expands slowly and somewhat uniformly for the first six volutions but it remains of about the same height in the seventh and eighth volutions. The heights of the chambers of the first to the sixth volution in the holotype are 27, 54, 78, 88, 132, and 153 microns, respectively. The heights of the chambers in the seventh and eighth volutions of a paratype are about 150 microns each. The heights of the chambers are about the same in the central third of the shell. It gradually decreases in height laterally and suddenly decreases in height at the poles.

The spirotheca is fairly thick. Secondary mineralization destroyed most detailed spirothecal structures. In thin section it seems to be a four-layered *Fusulinella*-type. This structure can not be demonstrated, however. The thickness of all layers of the spirotheca in the fourth to sixth volution of two specimens is 20, 23, and 27 microns, respectively. The spirotheca is of the same thickness from center of the shell to near the poles.

The septa are of the same structure as the spirotheca. They extend forward at angles of about 10 degrees from normal to spirotheca.

The tunnel is narrow and is relatively wide. Its path is straight. The tunnel angles of the fourth to the sixth volution are about 25, 26, and 32 degrees, respectively. The chomata are low and are

Measurements of *Staffella powwowensis* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions							
					1	2	3	4	5	6	7	8
1	1.25	1.69	0.74						.085	.101	.135	.152
2	0.46	0.86					.090	.110	.132			
3	0.90	1.21	0.74	.058	.027	.054	.078	.088	.132	.153		
4	0.66	0.95	0.70									

SPECIMEN	Form ratio of volutions						Thickness of spirotheca			Tunnel angle (degrees)		
	1	2	3	4	5	6	4	5	6	4	5	6
2							.021	.022			15	
3	0.57	0.54	0.70	0.74	0.80	0.80		.023	.027	25	26	32
4										25	26	

highly asymmetrical. They are about one-sixth as high as the chambers. Their tunnel side is steep, and their poleward slope is low.

Remarks.—*Staffella powwowensis* resembles *S. expansa* THOMPSON from the upper part of the Marble Falls limestone of Texas. They can be distinguished, however, by the larger form ratio of *S. powwowensis*, its less deeply umbilicate axial regions, its more broadly rounded periphery, its larger proloculus, and its wider tunnel angle.

Staffella powwowensis also resembles the form described by THOMPSON (1947) from the Marble Falls limestone of Texas as *Staffella* sp. They may be conspecific. However, the Texas specimens have much more massive chomata, more sharply angular periphery in the inner volutions, and more deeply umbilicate polar regions.

Occurrence.—*Staffella powwowensis* is abundant in Bed 33 and in the basal part of Bed 35, Section 17, Powwow Canyon, Texas. It is associated with abundant *Millerella*, *Nankinella* spp., and *Profusulinella* sp. A.

SUBFAMILY SCHUBERTELLINAE SKINNER,
1931

GENUS EOSCHUBERTELLA THOMPSON, 1937

Eoschubertella mexicana, new species

Plate 28, figures 1-8

Eoschubertella mexicana, n. sp., is one of the smallest of the schubertellids. The poles are pointed to broadly rounded. The first volution of the holotype and of many paratypes is coiled at an angle of about 90 degrees to the plane of coiling of the outer volutions. Mature specimens of three to four and one-half volutions are 0.32 to 0.47 mm long and 0.24 to 0.43 mm wide. The form ratio is about 1.35. The average form ratios of the first to the fourth

volution of two specimens are 1.12, 1.24, 1.35, and 1.37, respectively.

The proloculus is minute. Its outside diameter is 34 to 57 microns, averaging 43 microns for four specimens. The average heights of the first to the fourth volution of four specimens are 23, 35, 47, and 59 microns, respectively. The heights of the chambers are about the same throughout the length of the shell, excepting in the extreme polar regions of specimens having pointed poles.

The spirotheca is thin. It is composed of a tectum and upper and lower tectoria, and it is of about the same thickness throughout the length of the shell. The septa are thin and about normal to the spirotheca. The septal counts of the first to the fourth volution of two specimens are 8, 14, 15, and 19. The septa are unfluted throughout the length of the shell.

The tunnel is relatively wide, and its path is irregular. The tunnel angles of the third and fourth volutions are about 23 and 34 degrees, respectively. The chomata are low and symmetrical. Their tunnel side is steep, and their poleward slope is low. The first volution of some specimens, including the holotype, has a short axis of coiling. In some, the form ratio of the first volution is less than unit value.

Remarks.—*Eoschubertella mexicana* resembles somewhat closely *E. oliviformis* (THOMPSON) from about 500 feet below the top of the Atoka formation of Oklahoma. However, the former species is much smaller in size, is more tightly coiled, has a smaller proloculus, is more highly asymmetrical in its early stages, and has thinner spirotheca.

Occurrence.—Specimens here described and illustrated as *Eoschubertella mexicana* are from the Cuchillo Negro formation, Bed 24, Section 11, Mud Springs Mountains.

Measurements of *Eoschubertella mexicana* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions			
					1	2	3	4
1.	0.47	0.34	1.38	.034	.024	.031	.045	.050
2.		0.27		.047	.024	.041	.041	
3.	0.32	0.24	1.33	.034	.017	.030	.047	
4.		0.43		.057	.027	.037	.048	.068
5.	0.42	0.34	1.24					

SPECIMEN	Form ratio of volutions				Septal count				Tunnel angle (degrees)	
	1	2	3	4	1	2	3	4	3	4
1.	1.12	1.25	1.34	1.37					25	34
2.	1.12	1.23	1.36		8	14	15			
3.									20	
4.							15	19		

SUBFAMILY FUSULININAE RHUMBLER, 1895

GENUS PSEUDOSTAFFELLA THOMPSON, 1942

Pseudostaffella needhami THOMPSON

Plate 25, figures 17-25

Pseudostaffella needhami THOMPSON, 1942, Am. Jour. Sci., vol. 240, p. 411-413, pl. 1, figs. 15-20; pl. 3, figs. 10-14.

The type specimens of *Pseudostaffella needhami* THOMPSON (1942) were obtained from the upper 11 feet of the Cuchillo Negro formation in Whiskey Canyon at the north side of the Mud Springs Mountains. Numerous conspecific specimens have been found in the Mud Springs group of many areas in southern New Mexico and extreme western Texas. No additional information has been obtained concerning this form, and the original description and remarks are quoted here in full.

Shell minute, ellipsoidal, with broadly rounded periphery and depressed axial regions (umbilicate). Mature specimens of three and one-half to four and one-half volutions measure 0.36 to 0.55 mm in length and 0.37 to 0.59 mm in width. For eight specimens the average length is 0.45 mm and the average width is 0.51 mm. The form ratio of six typical specimens is 1:0.96 to 1:0.69, with an average form ratio of 1:0.89 for these same specimens. The periphery of all volutions are broadly rounded and the umbilical regions are slightly depressed in all volutions. The inner one to two volutions are coiled at a high angle to the axis of coiling of the outer two to three volutions. The angle between the axis of the juvenarium and the axis of the outer volutions varies between 24 and 90 degrees, with an average angle of 64 degrees for five typical specimens.

The proloculus is spherical in shape and its inside diameter measures 46 to 57 microns, with an average inside diameter of 52 microns for eight typical specimens. The heights of the first to the fourth volution of eight typical specimens measure 27 to 43, 39 to 61, 50 to 89, and 57 to 107 microns, respectively. The averages of the height of the first to the fourth volution of these same specimens are 34, 51, 68, and 83 microns, respectively. As is obvious from the above figures, the shell expands uniformly.

The spirotheca is thin and measures about 14 microns in thickness in the third and fourth volutions. It is composed of a tectum and upper and lower tectoria. In the outer volution of mature forms there is a suggestion of a lighter layer below the tectum that may correspond to the diaphanotheca of other fusulinids but it is thought to be only a slightly less dense portion of the lower tectorium. The septa are thin and they are unfluted. Near the poles the septa become curved. The septal count of seven typical specimens for the first to the fourth volution is 9, 10 to 13, 14 to 17, and 16. The averages of the septal count for these same specimens for the first to the fourth volution are 9, 12, 15, and 16.

The tunnel is low and its base is deeply rounded. The tunnel angle measures 20 to 28 degrees in the third volution and 23 to 33 degrees in the fourth volution. For six typical specimens the averages of the tunnel angle give 23 degrees in the third volution and 26 degrees in the fourth volution. The chomata are relatively very large and they reach one-half to two-thirds the height of the chambers and extend almost to the axial regions.

Discussion.—This species resembles *P. atokensis* (THOMPSON) more closely than any other previously described species. Some of the differences between specimens of these forms are that those of *P. needhami* are smaller at maturity, have a smaller form ratio and have a larger tunnel angle for corresponding volutions than representatives of *P. atokensis*. The major difference between representatives of these two species is that the juvenarium of almost all specimens of

P. needhami are markedly asymmetrical, whereas the juvenarium of *P. atokensis* is no more highly asymmetrical than any of the outer volutions. In addition to other factors, this latter feature would serve to differentiate specimens of *P. needhami* from those of all other described American representatives of the genus *Pseudostaffella*. (THOMPSON, 1942, p. 411-413.)

The generic name *Staffella* OZAWA has long been applied to this type of Lower Pennsylvanian fusulinids. Forms now referred to *Pseudostaffella* are widespread and common in rocks of Middle Pennsylvanian age throughout the world. They are associated with *Profusulinella* or *Fusulinella*, *Eoschubertella*, and *Millerella* in rocks of lower Middle Pennsylvanian age and with *Fusulina*, *Wedekindellina*, *Millerella*, *Eoschubertella*, and *Fusiella* in rocks of upper Middle Pennsylvanian age. At most places, the preservation of specimens of *Pseudostaffella* is the same as that of other typical fusulinids. The specimens described in this report and referred to *Staffella* are, without exception, largely replaced by secondary mineralization. However, the associated specimens of *Profusulinella*, *Eoschubertella*, and *Millerella* are not replaced. The specimens here referred to *Nankinella* LEE are also replaced by secondary mineralization. The same is true with specimens of *Staffella* and *Nankinella* in the Marble Falls limestone of Texas (THOMPSON, 1947). It seems important that the type specimens of the genotypes of both *Staffella* and *Nankinella* from the Permian of Asia are also replaced by secondary mineralization.

Occurrence.—The specimens of *Pseudostaffella needhami* illustrated on Plate 25 came from the upper 11 feet of the type section of the Cuchillo Negro formation, Mud Springs Mountains, New Mexico. Conspecific specimens are common throughout the Mud Springs group in the Mud Springs Mountains and more sparse in the Mud Springs group of extreme western Texas. Specimens somewhat closely similar are known from the upper part of the Marble Falls limestone in the McAnnelly's Bend area of Texas.

GENUS PROFUSULINELLA RAUSER-CERNOUSSOVA & BELJAEV, 1936

Profusulinella copiosa, new species

Plate 27, figures 1-3; Plate 28, figures 14-32

Profusulinella copiosa, n. sp., is perhaps the most primitive form of the genus. Its shell is minute and subellipsoidal, possessing a straight axis of coiling, highly convex lateral slopes, and bluntly pointed to narrowly rounded poles. Mature specimens of four volutions are 1.1 to 1.2 mm long and 0.8 to 0.9 mm wide. The form ratio is 1.4 to 1.5. The first volution is about spherical. The outer volution is elongate ellipsoidal to inflated fusiform. The average form ratios of the first to the fourth volution of five specimens are 1.0, 1.3, 1.4, and 1.4, respectively.

The proloculus is relatively large for the size of mature specimen. Its outside diameter is 100 to 160 microns, averaging 142 microns for 22 specimens. The shell expands about uniformly through-

out growth of shell. The average heights of the first to the fourth volution of six specimens are 44, 70, 110, and 144 microns, respectively. The heights of the chambers are about the same throughout the length of the shell.

The spirothecal structure is typical of the genus. The tectoria are relatively thick for the size of the shell. The average thicknesses of the spirotheca in the second to fourth volution of four specimens are 12, 18, and 22 microns, respectively. The spirotheca is of about the same thickness throughout the length of the shell. The spirotheca of the last part of the outer volution is composed of a single thin layer.

The septa are thin and are composed of a single layer, excepting in the region immediately over the tunnel where they are covered by extensions of deposits from chomata. The average septal counts of the first to the fourth volution in three specimens are 8, 12, 14, and 16, respectively. The septa are unfluted throughout the length of the shell. The lower margins of the septa in the polar regions of some specimens are broadly wavy, however. This undulation probably represents the beginning of the development of septal fluting. In the inner volutions, the septa are normal to the spirotheca, but, in the outer volutions, the septa extend forward at an angle of about 10 degrees from normal to the spirotheca.

The tunnel is about half as high as the chambers. They are relatively broad. The average tunnel angles of the second to the fourth volution in five specimens are 26, 30, and 37 degrees, respectively. The path of the tunnel is straight throughout all

volutions of some specimens. It is straight in the outer three volutions of all specimens. In some specimens, the tunnel is asymmetrical in the first volution. In none, however, has the first volution been found coiled normal to the outer volutions. The chomata are poorly developed throughout the shell. They are narrow and low. The tunnel side of the chomata immediately adjacent to septa is steep and the poleward side is lower.

Remarks.—The indistinct chomata, short ellipsoidal shape, small size, and unfluted septa of *Profusulinella copiosa* suggest a close relation to the genotype of *Eoschubertella*, *E. lata* (LEE & CHEN). However, it is considered even more closely related to the genotype of *Profusulinella*. *Profusulinella copiosa* resembles somewhat closely in size and general shape *P. fittsi* (THOMPSON) from the lower part of the Atoka formation of Oklahoma. These forms can be distinguished easily, however, for *P. copiosa* has a larger shell at maturity, smaller form ratio at maturity, smaller chomata, relatively larger proloculus, less numerous septa in corresponding volutions, and wider tunnel angles. *P. marblensis* THOMPSON from the upper part of the Marble Falls limestone on the east side of the Llano Uplift resembles *P. copiosa* more closely than any other American species. Some of the most important differences between these forms are the smaller shell, more distinct chomata, more sharply pointed poles, smaller proloculus and more tightly coiled shell of *P. marblensis*.

Occurrence.—Shells of *Profusulinella copiosa* compose almost half of a thick zone of the lower part of Bed 25, Sec-

Measurements of *Profusulinella copiosa* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions				Form ratio of volutions			
					1	2	3	4	1	2	3	4
1		0.80		.100	.034	.072	.104	.122	1.2	1.3	1.5	1.5
2	1.12	0.80	1.5	.150	.034	.060	.097	.117	1.2	1.4	1.5	1.5
3	1.10	0.72	1.5	.160	.040	.063	.120	.158	0.9	1.4	1.5	1.4
4	1.20	0.88	1.4	.140	.052	.070	.120	.156	1.0	1.3	1.2	1.2
5		0.96		.150	.059	.090	.120	.162				
6				.140								
7	0.92	0.74		.150	.045	.063	.099	.148	1.0	1.1	1.2	1.2

SPECIMEN	Thickness of spirotheca			Septal count				Tunnel angle (degrees)		
	2	3	4	1	2	3	4	2	3	4
1		.018	.023	8	11	13	16	16	27	34
2		.014	.018						20	33
3		.011	.023					23	36	37
4		.014	.018					33	33	45
5				9	13	14	16			
6				7	12	14	15			
7									32	36

tion 17, Powwow Canyon. Specimens that resemble the types in some respects (Pl. 28, figs. 9-13) occur sparsely in the Arrey formation near Derry and in the Mud Springs Mountains of New Mexico. They were formerly referred to *Profusulinella* by THOMPSON (1942b). Further studies seem to indicate they may be a primitive form of *Eoschubertella* rather than *Profusulinella*.

***Profusulinella munda*, new species**

Plate 27, figure 4; Plate 30, figures 1-7

The shell of *Profusulinella munda*, n. sp., is small and inflated fusiform. It has convex lateral slopes, a straight axis of coiling, and pointed poles. Mature specimens of six volutions measure 2.1 to 2.4 mm long and 1.2 to 1.5 mm wide. The form ratios are 1.7 to 1.8. The first volution is subspherical. The second is ellipsoidal. The third volution is inflated ellipsoidal. The shell increases in length uniformly from the second volution to maturity. The average form ratios of the first to the sixth volution of two typical specimens are 1.0, 1.2, 1.4, 1.6, 1.7, and 1.8, respectively.

The proloculus is small; its outside diameter is 80 to 100 microns, averaging 93 microns in four specimens. The shell expands gradually and almost uniformly. The average heights of the first to the sixth volution of five specimens are 40, 53, 80, 110, 150, and 187 microns, respectively.

The septa are thin and are about normal to the spirotheca. The average septa counts of the first to the sixth volution of three specimens are 8, 11, 13, 15, 17, and 22, respectively. Septal fluting is poorly developed in the extreme polar regions. The septa are almost straight across the central two-thirds of the shell.

The spirotheca are thin. The average thickness of all three layers of the spirotheca immediately above the tunnel in the third to the sixth volution

of four specimens are 14, 20, 25, and 33 microns, respectively. The thickness of the spirotheca varies considerably across the chambers in some volutions. Therefore, the above figures are only approximations. The spirotheca are slightly thinner poleward from the tunnel.

The tunnel is one-third to one-fourth as high as the chambers. Its path is almost straight throughout the shell. The tunnel is narrow in the first five volutions, but it expands rapidly in the sixth volution. The averages of tunnel angles in the third to the sixth volution of two specimens are 17, 21, 28, and 36 degrees, respectively. The chomata are asymmetrical. Their tunnel sides are vertical to overhanging, and their poleward slopes are low. In the center of the chambers, the chomata are about twice as wide as high. Adjacent to the septa, the chomata extend almost to poles.

Remarks.—*Profusulinella munda* resembles *P. regia* somewhat closely in general shell shape and internal features. Some of the major differences between these forms are that *P. munda* is smaller at maturity, has a smaller proloculus, more tightly coiled shell, and smaller tunnel angles. The close similarity between *P. munda* and *P. regia* strongly suggests that the former species is ancestral to *P. regia*. In fact, most of the differences pointed out above are not structural differences but are due to magnitude. These forms may in reality be varieties of the same species. Because they are restricted stratigraphically, I prefer to refer to them as distinct species.

Profusulinella munda also resembles *P. apodacensis* somewhat closely. The latter species, however, is more highly elongate with slightly concave lateral slopes in mature individuals, and has more

Measurements of *Profusulinella munda* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions					
					1	2	3	4	5	6
1.....		0.76		.100	.036	.059	.081	.113		
2.....		1.20				.060	.110	.130	.160	
3.....		1.38		.095	.045	.050	.068	.104	.135	.171
4.....	2.14	1.16	1.8	.080	.041	.045	.072	.086	.122	.171
5.....	2.44	1.46	1.7	.095	.040	.052	.070	.122	.173	.218

SPECIMEN	Form ratio of volutions						Thickness of spirotheca				Septal count						Tunnel angle (degrees)			
	1	2	3	4	5	6	3	4	5	6	1	2	3	4	5	6	3	4	5	6
1.....								.023	.023		10	12	11	15						
2.....												10	13	15	16					
3.....							.014	.016	.018	.027	7	12	14	15	18	22				
4.....	1.1	1.1	1.3	1.6	1.7	1.8		.013	.023	.027							11	17	25	35
5.....	1.0	1.3	1.6	1.7	1.7			.027	.036	.045							23	25	31	37

massive chomata, larger tunnel angles, and a more irregular tunnel path.

Occurrence.—This species is abundant 17 feet above the base of Bed 34, Section 17, Powwow Canyon, Texas.

***Profusulinella decora*, new species**

Plate 27, figures 5, 6, 12; Plate 29, figures 5-30

The shell of *Profusulinella decora*, n. sp., is small and inflated fusiform, and it has a straight axis of coiling, bluntly pointed poles, and convex lateral slopes. Mature specimens of five and one-half to six volutions are 2.1 to 2.4 mm long and 1.2 to 1.4 mm wide. The form ratio is 1.7 to 1.8. The first volution is discoidal and has a form ratio of about 0.6. The second volution is ellipsoidal to subspherical. Beyond the second volution the shell is broadly fusiform. The average form ratios of the second to the sixth volution are 1.2, 1.5, 1.8, 1.8, and 1.7, respectively.

The proloculus is minute. Its outside diameter is 73 to 95 microns, averaging 84 microns in six specimens. The first two volutions expand slowly, but the outer volutions expand more rapidly and uniformly. The average heights of the chambers in the first to the sixth volution of seven specimens are 34, 45, 73, 110, 158, and 200 microns, respectively. The above determinations were made of the chambers immediately above the tunnel. The heights of the chambers increase only slightly poleward from the tunnel.

The spirotheca is thin. The average combined thicknesses of all layers of the spirotheca immediately over the tunnel of the third to the sixth volution of five specimens are 10, 16, 20, and 24 microns, respectively.

The septa are thin and are relatively widely spaced. The septal counts of the first to the sixth volution are about 7, 9, 12, 13, 15, and 17, respectively. In most specimens examined, the septa are unfluted, though somewhat irregular, throughout the length of the shell. However, in one specimen the septa are fluted in their lower margins completely up to edges of the tunnel in the fifth and sixth volutions. The septa are almost normal to the spirotheca.

The tunnel is more than one-third as high as the chambers. Its path is straight in the outer four volutions and is irregular in the inner two volutions. The axis of coiling of the first volution in almost all specimens is at angles up to 90 degrees to axis of the outer volutions. The average tunnel angles of the third to the sixth volution in five specimens are 23, 31, 41, and 54 degrees, respectively. The chomata are low and are highly asymmetrical in the outer three volutions. They are not distinct in the inner volution. The tunnel side of the chomata is steep to vertical. The poleward slope is steep immediately adjacent to the tunnel, but it is low farther poleward.

Remarks.—A variety of specimens is associated

with the holotype and paratypes of *Profusulinella decora*. All of them may not be conspecific. One group of specimens (Pl. 29, figs. 18, 20) is more highly elongate and more tightly coiled than the holotype. However, for the present, these are referred with question to this form.

The general shape and rate of expansion of the shell of *Profusulinella decora* are closely similar to these features of *P. regia* from higher in the section. These forms may be easily distinguished, however, by the smaller shell of mature specimens of *P. decora*, its lower chambers for corresponding volutions, its smaller proloculus, its thinner spirotheca, and its wider tunnel angle for corresponding volutions. The holotype and many paratypes of *P. regia* have planispiral shells throughout all volutions, and their proloculi are relatively large. Only a few questionable specimens have highly asymmetrical first volutions with minute proloculi. On the other hand, the holotype and all paratypes of *P. decora* have highly asymmetrical first volutions with minute proloculi.

The smaller size of mature shells, the primitive nature of the embryonic part of the shell, and the thinner spirotheca of *P. decora* strongly indicate that it is ancestral to *P. regia*, a form that occurs higher in the stratigraphic section.

Occurrence.—*Profusulinella decora* is abundant 15 feet above the base of Bed 35 and less abundant at the base of Bed 35, Section 17, Powwow Canyon, Texas. Specimens that may be referable to this form are rare 35 feet above the base of Bed 35 of the same section, associated with abundant specimens of *P. regia*.

***Profusulinella regia*, new species**

Plate 1, figure 1; Plate 27, figures 7, 8, 13;
Plate 30, figures 8-19

Profusulinella regia, n. sp., is one of the largest forms of the genus. The shell is ellipsoidal to broadly fusiform, possessing a straight axis of coiling, convex lateral slopes, and narrowly rounded poles. Mature specimens of five and one-half to six and one-half volutions are 2.4 to 3.5 mm long and 1.4 to 1.9 mm wide. The form ratio is 1.9 to 1.5, averaging 1.7 for five specimens. The first volution is ellipsoidal to discoidal; the third to sixth volutions become inflated fusiform, but the outer volution is subelliptical in profile. The average form ratios of the first to the sixth volution in six specimens are 1.3, 1.5, 1.7, 1.7, 1.7, and 1.7, respectively.

The proloculus is small. Its outside diameter is 90 to 180 microns, averaging 125 microns for nine specimens. The shell is loosely coiled. The average heights of the first to the seventh volution of nine specimens are 49, 67, 102, 150, 179, 224, and 247 microns, respectively. These average heights of the volutions were measured in the center of the tunnel, but the heights of the chambers become only slightly greater poleward from the tunnel.

Measurements of *Profusulinella decora* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions						Form ratio of volutions				
					1	2	3	4	5	6	2	3	4	5	6
1.....	2.26	1.34	1.7	.095	.032	.041	.077	.104	.162	.225	1.1	1.3	1.6	1.7	1.7
2.....	2.10	1.24	1.7	.....	.....	.050	.070	.110	.144	.207	.....	1.4	1.6	1.8	1.7
3.....	.....	1.20	.....	.077	.032	.041	.059	.102	.150	.189	.....	.....	.....	.....	.....
4.....	2.40	1.36	1.8	.080	.036	.043	.079	.110	.168	.202	1.2	1.8	2.0	1.8	.....
5.....	.....	1.24	.....	.090	.040	.045	.068	.126	.180	.189	.....	.....	.....	.....	.....
6.....	.....	1.22	.....	.086	.033	.054	.072	.117	.149	.203	.....	.....	.....	.....	.....
7.....	2.34	1.28	1.8	.073	.032	.040	.065	.101	.150	.181	1.3	1.6	1.9	1.8	1.8

SPECIMEN	Thickness of spirotheca				Septal count						Tunnel angle (degrees)			
	3	4	5	6	1	2	3	4	5	6	3	4	5	6
1.....	.009	.014	.020	.027	6	.....	.....	.....	.....	.....	28	28	42	50
2.....	.....	.014	.018	.027	.....	.....	.....	.....	.....	.....	.....	33	37	55
3.....	.....	.....	.018	.023	7	.....	.....	.....	.....	.....	.....	.....	43	52
4.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	27	27	45	56
5.....	.....	.....	.....	.....	.....	9	13	13	16	18	.....	.....	.....	.....
6.....	.....	.018	.018	.018	.....	10	12	13	15	16	.....	.....	.....	.....
7.....	.012	.020	.024	.....	.....	.....	.....	.....	.....	.....	25	34	39	57

The spirotheca is thin. The average thicknesses of all layers of the spirotheca over the center of the tunnel in the second to the sixth volution of six specimens are 11, 15, 24, 27, and 26 microns, respectively. Poleward from the tunnel, the spirotheca gradually decreases in thickness. Although only three layers, a tectum, an upper tectorium, and a lower tectorium, are recognizable in the inner part of shell, the spirotheca of the outermost part of the last volution is composed of a single relatively dense layer. This layer is thinner toward the polar regions. In thickness and shape, this layer resembles a thin diaphanotheca, but in composition it is more dense than the diaphanotheca of forms of the genus *Fusulinella*.

The septa are thin but are relatively widely spaced. The average septal counts of the first to the sixth volution of five specimens are 8, 12, 14, 15, 17, and 20, respectively. The septa are plane across the central two-thirds of shell, but they are broadly fluted in their lower margins in the extreme polar regions. The septal count of the asymmetrical first volution is 6 to 10. In the polar regions the septa are composed of a tectum. In the center of the shell, they are covered with continuations of tectoria of the spirotheca or with deposits from the chomata.

The tunnel is narrow in the inner one to three volutions, but it is broad in the outer volutions. The average tunnel angles of the second to the sixth volution of five specimens are 26, 27, 32, 38, and 47 degrees, respectively. The chomata are relatively low in the center of the chambers, being less than one-third the height of the chambers in most parts of the shell. The chomata extend almost to the

pole in the inner two to three volutions, but they are narrow and nearly symmetrical in the outer volutions. The chomata extend almost to the top of the chambers immediately adjacent to the septa in the third to fifth volutions. Several specimens have minute proloculi, and the axis of coiling of their first volution is at approximately 90 degrees to the outer fusiform volution. In specimens having relatively large proloculi, the first and succeeding volutions correspond closely in most respects to the second and succeeding volutions of forms having minute proloculi and an asymmetrical first volution. Both of these types of specimens are referred to this form.

Remarks.—In general outline and development of the shell, *Profusulinella regia* resembles *P. decora*, and the former seems to be a direct descendant of the latter. *P. regia* differs from *P. decora* especially in that it has a larger shell at maturity, higher chambers for corresponding volutions, larger proloculus, thicker spirotheca, and narrower tunnel angles for corresponding volutions.

The development of the spirotheca of *Profusulinella regia* indicates that it is a highly developed form of the genus; the unusually large size of the shell also supports this conclusion. However, no American species of *Fusulinella* has been described that seems to be a descendant of this form. Most American species of *Fusulinella* seem to have been derived from a more highly fusiform stock of *Profusulinella*.

Occurrence.—Specimens of *Profusulinella regia* are abundant 35 feet above the base of Bed 35, Section 17, Powwow Canyon, Texas.

Measurements of *Profusulinella regia* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions							Form ratio of volutions					
					1	2	3	4	5	6	7	1	2	3	4	5	6
1	3.48	1.80	1.9	.180	.060	.070	.110	.180	.190	.235		1.3	1.5	1.9	1.9	1.8	1.9
2	2.88	1.88	1.5	.150	.041	.054	.081	.135	.153	.225	.247	1.4	1.7	1.5	1.7	1.8	
3	2.52	1.36	1.8	.090	.040	.050	.090	.160	.180	.165		1.3	1.5	1.7	1.9		
4	2.40	1.54	1.6	.103	.043	.063	.100	.130	.180	.247		1.4	1.5	1.5	1.6	1.5	
5				.120	.059	.090	.135	.158	.203	.243		1.2	1.5	1.7	1.9	1.6	1.7
6	2.90	1.58	1.8	.121	.059	.095	.135	.185	.158		1.5	1.7	1.8	1.6	1.9		
7		1.56		.131	.050	.059	.095	.149	.198	.225							
8		1.58		.117	.054	.059	.090	.122	.158	.225							
9		1.50		.113	.041	.059	.081	.131	.189	.225							

Specimen	Thickness of spirotheca					Septal count						Tunnel angle (degrees)					
	2	3	4	5	6	1	2	3	4	5	6	2	3	4	5	6	
1			.023	.023	.032							17	23	22	26		
2																	
3		.016	.023	.027	.020	6						23	26	30	35		
4			.031	.023	.027	10							26	30	39	47	
5	.011	.014	.023	.025	.027							38	28	33	45		
6												25	30	44	47		
7		.014	.018	.036		7	13	14	15	17	22						
8		.014	.023	.027	.023	7	12	15	15	17	17						
9						9	12	14	16	17	22						

***Profusulinella apodacensis*, new species**

Plate 27, figures 9, 10; Plate 31, figures 10-17

The shell of *Profusulinella apodacensis*, n. sp., is small and elongate fusiform. It has a straight axis of coiling, pointed poles, and uniform convex lateral slopes. Mature specimens of five to six and one-half volutions are 2.8 to 3.0 mm long and 1.2 to 1.6 mm wide. The form ratio is 1.9 to 2.4. In most specimens, the first volution is spherical, the second volution is ellipsoidal, and the outer volutions are fusiform. The form ratio of the first volution is less than unit value in some specimens. The form ratio of the first to the sixth volution of five specimens averages 1.2, 1.6, 1.9, 2.0, 2.1, and 2.1, respectively. The lateral slopes are convex throughout the central three-fourths of the shell. They are slightly concave and irregular in extreme polar regions of some mature specimens.

The proloculus is minute and its outside diameter averages 74 microns for eight specimens. The shell expands uniformly for the first five volutions and more slowly for the outer volutions. The average heights of the chambers above the tunnel in the first to the sixth volution of eight specimens are 36, 49, 78, 113, 143, and 183 microns, respectively. Poleward from tunnel, the chambers are slightly higher than the above figures.

The spirothecal structure is typical of the genus. The average thicknesses of all layers of the spiro-

theca in the first to the sixth volution of eight specimens are 9, 12, 19, 22, 24, and 18 microns, respectively. The tectoria are of about the same thickness throughout the length of the shell. Although a diaphanotheca is not recognized even in the last part of the outermost volution, the tectum is of measurable thickness in the outermost part of the shell.

The septa are about as thick as the spirotheca in most parts of the shell. The tectoria of the spirotheca continues uniformly onto septa. The average septal counts of the first to the sixth volution of three specimens are 8, 12, 13, 17, 20, and 21, respectively. The septa are broadly fluted in the extreme polar regions. They are broadly wavy in their lower margins in the end one-fourth of the shell, but they are almost plane in the center of the shell.

The tunnel is wide, and it is about one-third as high as the chambers in the outer part of the shell. The path of the tunnel is slightly irregular. In some specimens possessing a minute proloculus, the innermost discoidal volution is coiled at an angle of 90 degrees to the outer fusiform volution. This type of specimen is rare, however. The average tunnel angles of the second to the sixth volution of five specimens are 21, 28, 31, 41, and 49 degrees, respectively. The chomata are massive, and they extend more than half the distance from the tunnel to the poles in the inner three to four volutions. They are narrower in the outer volutions. The tunnel side of the chomata is steep, and the poleward slope is lower.

Remarks.—This is one of the most advanced species of *Profusulinella* in America. The structure of the shell indicates that this or a closely similar form was ancestral to the primitive species of *Fusulinella* in the lower part of the overlying Mud Springs group.

Profusulinella apodacensis resembles *P. spicata* closely. However, the former has a larger shell at maturity, a more highly elongate shell and therefore smaller form ratio for corresponding volutions, more nearly uniform lateral slopes, a wider tunnel for corresponding volutions, and a more loosely coiled shell. Although of questionable specific value, the spirotheca of *P. spicata* are thicker than those of *P. apodacensis*. Also, the chomata of *P. spicata* are relatively more massive and wider than those of *P. apodacensis*.

This form is closely similar to, and presumably is closely related in age to, *Fusulinella? primaeva* (SKINNER) from the base of the Big Saline limestone of central Texas. However, *F.? primaeva* has a typical *Fusulinella*-type spirothecal structure in its outer volutions, and, therefore, it is more advanced than *P. apodacensis*. The Apodaca formation, in which *P. apodacensis* occurs, seemingly is slightly older stratigraphically than the type section of the Big Saline of Texas.

Occurrence.—*Profusulinella apodacensis* is abundant in Bed 5, Section 11, and near the top of the type section of the Apodaca formation east of Derry, New Mexico. The above description is based entirely on specimens from the former locality.

Profusulinella spicata, new species

Plate 27, figure 11; Plate 31, figures 1-9

Profusulinella spicata, n. sp., is a highly advanced form of the genus. Its shell is small and fusiform, its axis of coiling is straight, and its poles are bluntly pointed. The lateral slopes are broadly convex, but they are slightly concave to irregular in polar regions. Mature specimens of five to six and one-half volutions are about 1.6 to 2.1 mm long and 0.9 to 1.0 mm wide. The form ratio is 1.8 to 2.1, averaging 1.9 for five specimens. The first volution is sperical to subdiscoidal. Beyond the first volution, the axis of coiling increases in length rapidly. The average form ratios of the first to the sixth volution of five specimens are 0.9, 1.3, 1.6, 1.8, 1.8, and 1.8, respectively.

The proloculus is minute. Its outside diameter measures 60 to 110 microns, averaging 85 microns for five specimens. The shell expands slowly and uniformly. The average heights of the chambers of the first to the sixth volution of eight specimens are 33, 41, 70, 95, 125, and 148 microns, respectively.

The spirothecal structure is typical of the genus. The average thicknesses of the spirotheca in the first to the sixth volution near the center of tunnel in six specimens are 10, 14, 20, 26, 30, and 32 microns, respectively. The thickness of the spirotheca is difficult to measure poleward from tunnel, but the tectoria seemingly become thinner in the polar regions.

Measurements of *Profusulinella apodacensis* Thompson, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. prol.	Height of volutions						Form ratio of volutions					
					1	2	3	4	5	6	1	2	3	4	5	6
1	2.80	1.32	2.2	.085	.033	.054	.087	.124	.158	.233	0.9	1.3	1.7	1.8	1.9	2.0
2	2.80	1.43	2.0	.083	.041	.063	.096	.117	.133	.190	1.7	2.0	2.0	2.0	2.0	2.0
3	2.88	1.22	2.4	.091	.047	.058	.090	.119	.166	.....	1.2	1.8	2.2	2.3	2.3	.....
4	2.97	1.56	1.9	.074	.033	.058	.086	.133	.145	.174	1.2	1.4	1.6	1.8	1.9	2.1
5	2.97	1.23	2.4	.058	.033	.040	.063	.110	.136	.187	0.8	1.3	1.8	2.2	2.4	.....
6	.....	1.32	.....	.068	.040	.048	.085	.126	.153	.....	.....	.....	.....	.....	.....	.....
7	.....	1.23	.....	.067	.027	.027	.051	.061	.102	.136	.....	.....	.....	.....	.....	.....
8	.....	1.56	.....	.068	.034	.048	.065	.112	.153	.176	.....	.....	.....	.....	.....	.....

SPECIMEN	Thickness of spirotheca						Septal count						Tunnel angle (degrees)					
	1	2	3	4	5	6	1	2	3	4	5	6	2	3	4	5	6	
1	.010	.019	.025	.025	.030	.017	.....	.....	.....	.....	.....	.....	16	26	28	40	.....
2	.010	.014	.024	.017	.017	.017	.....	.....	.....	.....	.....	.....	22	32	35	40	65
3	.010	.010	.017	.014	.017	.....	.....	.....	.....	.....	.....	.....	23	30	35	55	.....
4	.007	.010	.022	.031	.034	.020	.....	.....	.....	.....	.....	.....	23	22	25	25	30
5	.007	.010	.014	.024	.020	.020	.....	.....	.....	.....	.....	.....	.....	28	33	44	53
6	.010	.017	.030	.027	.020	.010	9	12	14	18	21	.....	.....	.....	.....	.....	.....
7	.....	.007	.010	.020	.023	.023	8	12	12	17	20	20	.....	.....	.....	.....	.....
8	.009	.010	.010	.017	.027	.020	8	11	13	17	19	23	.....	.....	.....	.....	.....

The septa are almost plane throughout the length of the shell, but they are broadly wavy in their lower margins in the polar regions. The septa are thick near the center of the shell, due largely to heavy chomata deposits lining the chambers. Poleward from the tunnel, the septa are thinner. The average septal counts of the first to the sixth volution of three specimens are 8, 13, 16, 18, 22, and 28, respectively.

The tunnel is narrow in the inner four to five volutions, and it becomes wider in the outer part of the shell. The average tunnel angles of the second to the sixth volution in five specimens are 19, 24, 26, 31, and 37 degrees, respectively. The chomata are massive and are more than half as high as the chambers in the inner volutions. They are lower in the outer volutions. The tunnel side of the chomata is about vertical, and the lateral side extends to poles in most volutions. Some questionable specimens of this species have narrower chomata. The path of the tunnel is slightly irregular. The axis of coiling of the first volution of many specimens is at a large angle to the axis of the outer volutions.

Remarks.—*Profusulinella spicata* resembles *P. apodacensis* somewhat closely. However, *P. spicata* has a smaller and relatively shorter shell, more irregular lateral slopes, smaller tunnel angle for corresponding volutions, a more tightly coiled shell, thicker spirotheca, and relatively higher and broader chomata.

Occurrence.—*Profusulinella spicata* is abundant in Bed 16, Section 21, Mud Springs Mountains, in the upper part of the Apodaca formation.

Profusulinella sp. A

Plate 29, figures 1-4

Samples from 37 feet above the base of Bed 34 and from the base of Bed 35, Section 17, Powwow Canyon, contain scattered specimens of a species of *Profusulinella* that differs considerably from the forms described above. I have not obtained a sufficient number of well-oriented sections of this form, however, to draw up a thorough description. For the sake of completeness, I illustrate several typical sections and give the following brief description.

The shell is small and fusiform. It has pointed poles, convex lateral slopes, and a straight axis of coiling. One specimen of six volutions is 2.3 mm long and 1.3 mm wide, giving a form ratio of 1.7. The relative length of the shell increases for the first four volutions, but it decreases in the outer volutions. The form ratios of the second to the sixth volution are about 1.6, 1.9, 2.0, 1.7, and 1.7, respectively. The form ratio of the first volution is slightly less than unit value.

The proloculus is minute. Its outside diameter is about 70 microns. The shell expands slowly and uniformly. The heights of the first to the sixth volution of a typical specimen are 56, 63, 90, 126, 148, and 216 microns, respectively. The combined thickness of all layers of the spirotheca is about 15 microns in the fourth volution and 23 microns in the sixth volution. The spirotheca is covered by chomata completely to the poles. The septal counts of the second to the fifth volution are about 11, 13,

Measurements of *Profusulinella spicata* Thompson, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. prol.	Height of volutions						Form ratio of volutions					
					1	2	3	4	5	6	1	2	3	4	5	6
1	2.00	1.00	2.0	.108	.033	.050	.083	.100	.140	.166	1.2	1.5	1.9	2.1	2.0	.....
2	1.40	0.80	1.8	.085	.034	.041	.065	.085	.119	.....	1.0	1.4	1.5	1.8	.....	.....
3	2.10	1.00	2.1	.061	.027	.041	.075	.105	.126	.146	0.6	1.2	1.5	1.7	1.8	1.8
4	1.60	0.88	1.8	.068	.028	.034	.051	.085	.136	.136	0.9	1.1	1.5	1.7	1.8	.....
5	1.86	1.00	1.9	.....	.....	.027	.041	.075	.102	.146	0.9	1.2	1.4	1.8	1.7	1.8
6	.....	1.00	.....	.102	.041	.054	.102	.119	.126	.....	.....	.....	.....	.....	.....	.....
7	.....	1.56	.....	.....	.028	.061	.089	.161	.181	.....	.....	.....	.....	.....	.....	.....
8	.....	1.40	.....	.....	.044	.064	.073	.121	.161	.198	.....	.....	.....	.....	.....	.....

SPECIMEN	Thickness of spirotheca						Septal count						Tunnel angle (degrees)					
	1	2	3	4	5	6	1	2	3	4	5	6	2	3	4	5	6	
1	.004	.010	.020	.030	.024	.....	.....	.....	.....	.....	.....	.....	19	24	28	35	44
2	.014	.017	.020	.034	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.014	.017	.027	.031	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.007	.017	.017	.024	.030	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.010	.017	.020	.034	.034	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.014	.014	.024	.020	.034	8	13	18	18	20	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	9	13	16	20	25	30	.....	.....	.....	.....	.....

14, and 17, respectively. The septa are broadly wavy in the extreme polar regions but they are straight in the center of the shell. The first volution is highly asymmetrical and its axis of coiling is at an angle of about 90 degrees to the axis of the outer volutions. The septal count of the first volution is 7 in two specimens.

The tunnel is narrow in the inner five volutions and is broad in the sixth volution. The tunnel angles of the second to the sixth volution of one specimen are about 20, 20, 23, 26, and 45 degrees, respectively. Chomata are well developed. Their tunnel side is vertical to overhanging, and the poleward slope is low. Chomata extend to the polar regions in the second to the sixth volution, and they connect with the dense filling of the axial regions.

Remarks.—*Profusulinella* sp. A differs from *P. decora*, with which it is associated in Bed 35, Section 17, especially in that its chomata are more massive and wider and its tunnel angle is wider. Also, the secondary deposits in the polar regions of this form are not present in *P. decora*.

Occurrence.—Scattered specimens of the form described as *Profusulinella* sp. A occur in the lower part of Bed 35, and 37 feet above the base of Bed 34, Section 17, Powwow Canyon, Texas.

GENUS FUSULINELLA MÖLLER, 1877

Fusulinella fugax, new species

Plate 32, figure 2; Plate 33, figures 1-8

Fusulinella fugax, n. sp., is one of the earliest species of the genus. Its shell is minute and inflated fusiform, possessing pointed poles, straight to slightly curving axis of coiling, and concave lateral

slopes. The inner two volutions are ellipsoidal. The next two volutions are uniformly inflated fusiform. Beyond the fourth volution the poles are extended, and the central part is more highly inflated. Mature specimens of six to seven volutions are 2.9 to 3.2 mm long and 1.3 to 1.5 mm wide. The form ratio is 2.1 to 2.4. The shell changes form ratio gradually. The average form ratios of the first to the seventh volution of three specimens are 1.1, 1.4, 1.7, 1.9, 2.1, 1.9, and 2.3, respectively.

The proloculus is small, and its outside diameter measures 77 to 101 microns, averaging 83 microns for six specimens. The average heights of the first to the seventh volution of six specimens are 32, 46, 73, 101, 126, 156, and 170 microns, respectively. Thus, the shell expands uniformly. The heights of the chambers change little laterally from the tunnel, but near the poles, they increase suddenly.

The septa are closely spaced. The average septal counts of the first to the sixth volution in three specimens are 8, 12, 17, 21, 24, and 24, respectively. They are broadly fluted in the extreme polar regions but are unfluted in the central half of the shell.

The spirotheca is relatively thick. It is composed of a tectum and a thick upper and lower tectoria throughout most parts of the shell. The diaphanotheca is first observed in the fifth to sixth volution. The diaphanotheca is thin even in the outer part of mature specimens. The wall of the proloculus measures about 10 microns. The average thicknesses of all layers of the spirotheca in the first to the seventh volution in six specimens are 11, 16, 20, 26, 31, 27, and 38 microns, respectively. The spirotheca thins only slightly poleward from the center of the shell.

The tunnel is narrow and its path is irregular.

Measurements of *Fusulinella fugax* Thompson, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. prol.	Height of volutions							Form ratio of volutions						
					1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	2.47	1.03	2.4	.081	.032	.044	.081	.109	.137	.149		1.3	1.5	2.0	2.0	2.4		
2	3.24	1.48	2.2	.081	.032	.053	.073	.101	.121	.145	.178	1.0	1.4	1.5	2.1	2.1	1.9	2.3
3	2.88	1.35	2.1	.077	.028	.044	.065	.093	.105	.141	.162	1.1	1.4	1.8	1.7	1.8	1.8	2.3
4		1.35		.077	.032	.044	.069	.097	.121	.158								
5		1.30		.101	.040	.044	.069	.097	.133	.178								
6		1.40		.081	.028	.048	.081	.109	.141	.162								

Specimen	Thickness of spirotheca							Septal count						Tunnel angle (degrees)					
	0	1	2	3	4	5	6	7	1	2	3	4	5	6	3	4	5	6	7
1	.010	.012	.016	.024	.036	.032	.020								22	23	21	27	
2	.012		.016	.020	.024	.036		.036							20	19	20	23	29
3		.008	.016	.020	.032	.036	.040	.040								14	15	19	25
4	.012		.014	.020	.016	.028	.016		8	13	17	20	26	25					
5		.012	.016	.012	.016	.024	.028		8	13	16	22	24	24					
6				.024	.032	.028	.032		8	11	18	20	22	23					

The average tunnel angles of the third to the seventh volution in three specimens are 21, 19, 19, 23, and 27 degrees, respectively. Chomata are massive and broad. Their tunnel side is about vertical, and their poleward slope is low. The outer margins of the chomata extend to the poles in the inner four to five volutions. In the outer volutions, the chomata are asymmetrical and are three to four times as wide as high.

Remarks.—*Fusulinella fugax* is a primitive species of the genus, and the diaphanotheca is visible only in the outer volutions of mature specimens. The slight septal fluting further indicates that this form is primitive. *F. fugax* is only slightly more advanced than *Profusulinella apodacensis*, n. sp., a form that it resembles closely in general shape and size. One of the major differences between these forms is that the spirotheca of *Fusulinella fugax* contains a thin diaphanotheca. Also, several minor differences become evident when the statistical data are compared.

In regard to spirothecal structure, *Fusulinella fugax* is closely similar to *Fusulinella? primaeva* (SKINNER) from the basal part of the Big Saline group of central Texas. The latter form is intermediate in development between typical *Profusulinella* and typical *Fusulinella*. However, a four-layered spirotheca is developed in the outer volutions of types of *F.? primaeva* sent to me by JOHN W. SKINNER. Because *F.? primaeva* has a diaphanotheca developed in its outer volution, I am referring

it, for the present at least, questionably to *Fusulinella*. *Fusulinella fugax* is not closely similar to any other described American form.

Occurrence.—*Fusulinella fugax* is abundant in Bed 10, Section 11, lower part of the type section of the Fra Cristobal formation in the Mud Springs Mountains, New Mexico.

Fusulinella acuminata THOMPSON

Plate 32, figure 3; Plate 34, figures 1-19

Fusulinella acuminata THOMPSON, 1936, Jour. Paleontology, vol. 10, p. 101, pl. 13, figs. 5-7.

Fusulinella acuminata THOMPSON (1936) was described originally from South Dakota. The following description is based entirely on New Mexico specimens. The shell is small and elongate fusiform, possessing a straight axis of coiling, pointed poles, and uniform lateral slopes. Mature specimens of five and one-half to six volutions are 1.0 to 1.4 mm wide and 2.8 to 3.8 mm long. The form ratio is 2.6 to 2.9, averaging 2.8 for five specimens. The first volution of specimens having a minute proloculus is subellipsoidal in shape, and that of specimens having a large proloculus is fusiform in shape. The second to third volutions are inflated fusiform, and those beyond the third are elongate fusiform. The average form ratios of the first to the sixth volution in five specimens are 1.5, 1.7, 2.3, 2.5, 2.8, and 2.9, respectively.

The proloculus is minute in many specimens, but it is larger in others. The outside diameter of the proloculus is 81 to 130 microns, averaging 100 mi-

Measurements of *Fusulinella acuminata* Thompson, in millimeters

Specimen	L.	W.	Ratio	Diam. proloc.	Height of volutions						Form ratio of volutions					
					1	2	3	4	5	6	1	2	3	4	5	6
1	2.77	1.04	2.7	.077	.032	.053	.085	.125	.129	.141	1.3	1.7	2.2	2.3	2.9	
2	3.78	1.35	2.8	.129	.038	.050	.081	.109	.141	.181	1.5	2.0	2.3	2.7	2.9	
3	3.24	1.17	2.8	.085	.028	.044	.065	.093	.137	.170	1.5	1.9	2.4	2.6	2.8	
4	3.24	1.13	2.9	.101	.037	.044	.057	.089	.121	.182	1.2	1.9	2.4	2.4	2.9	
5	3.42	1.31	2.6	.145	.053	.073	.093	.125	.170	.218	1.8	1.8	2.2	2.6	2.8	
6	.....	0.94	.....	.081	.036	.044	.069	.101	.141	.....	.....	.....	.....	.....	.....
7	.....	1.24	.....	.085	.028	.044	.057	.081	.121	.141	.....	.....	.....	.....	.....
8	.....	1.08	.....	.101	.040	.053	.081	.109	.141	.....	.....	.....	.....	.....	.....

SPECIMEN	Thickness of spirotheca						Septal count							Tunnel angle (degrees)				
	1	2	3	4	5	6	1	2	3	4	5	6	7	3	4	5	6	7
1012	.024	.020	.040	.040	.....	.....	.....	.....	.....	.....	.....	.....	18	20	32	.....
2012	.024	.028	.044	.036	.....	.....	.....	.....	.....	.....	.....	.....	23	27	35	.....
3008	.012	.020	.032	.028	.....	.....	.....	.....	.....	.....	.....	.....	18	23	27	35
4012	.016	.032	.028	.036	.....	.....	.....	.....	.....	.....	.....	.....	20	27	29	.....
5012	.028	.032	.028	.....	.....	.....	.....	.....	.....	.....	.....	.....	21	31	31	42
6008	.016	.016	.024	.028	10	15	16	19	22	.....	.....	.....	22	31	35	50
7016	.018	.020	.020	.028	11	13	18	18	20	24	26	.....	.....	.....	.....	.....
8	11	13	22	29	25	31	31	.....	.....	.....	.....	.....

rons for eight specimens. The average heights of the chambers near the path of the tunnel in the first to the sixth volution of eight specimens are 37, 51, 74, 104, 138, and 172 microns, respectively. The shell expands at a uniform rate. The chambers are lowest immediately above the tunnel, and they increase in height slowly and uniformly poleward from the tunnel.

The spirotheca is typical of the genus. The diaphanotheca is first observed near the end of the third volution and can be seen throughout the length of the shell in the outer volutions. The average thicknesses of the spirotheca in the first to the sixth volution of seven specimens are 8, 13, 21, 27, 33, and 34 microns, respectively. The tectoria decrease in thickness poleward from the edges of the chomata.

The septa are closely spaced. The average septal counts of the first to the seventh volution in three specimens are 10, 14, 17, 18, 21, 24, and 29, respectively. The septa are fluted in the extreme polar regions, but they are plane across the central half of the shell.

The tunnel is narrow in the inner four volutions, and it is low and broad in the outer volutions. The average tunnel angles of the third to the seventh volution in five specimens are 20, 23, 28, 35, and 42 degrees, respectively. Chomata are low, relatively narrow, and asymmetrical. Their tunnel side is steep, and their poleward slope is low.

Remarks.—The chomata of *Fusulinella acuminata* are the smallest in cross section area of any species of *Fusulinella* from the Mud Springs group of New Mexico. The elongate fusiform shape of the shell and the small chomata of this form serve to distinguish it from other American species. The only difference between the New Mexico specimens and the types from South Dakota is that the types have much larger proloculi.

Occurrence.—The type specimens of *Fusulinella acuminata* came from the lower part of the Minnelusa formation of South Dakota. The above description is based on specimens from Bed 12, Section 11, and Bed 20, Section 21, Fra Cristobal formation, Mud Springs Mountains, New Mexico. Probably conspecific specimens are abundant in Bed 38, Section 17, Powwow Canyon, Texas.

Fusulinella proxima, new species

Plate 33, figures 9-20

Fusulinella proxima, n. sp., is widely distributed in New Mexico and probably in Texas. The shell is relatively large and elongate fusiform. The poles are pointed, the axis of coiling is slightly irregular, and the lateral slopes are slightly concave. Mature specimens of seven and one-half to eight and one-half volutions are 3.8 to 4.3 mm long and 1.5 to 1.8 mm wide. The form ratio is 2.3 to 2.8, averaging 2.5 for five specimens. The first volution is ellipsoidal to subspherical. The second to third volutions are elongate ellipsoidal, but beyond the third volution the shell is fusiform and has pointed poles and concave lateral slopes. The average form ratios

of the first to the eighth volution in five specimens are 1.2, 1.5, 1.8, 2.0, 2.3, 2.4, 2.3, and 2.3, respectively.

The proloculus is small. Its average outside diameter is about 90 microns for seven specimens. The shell expands somewhat uniformly in the first seven volutions. The seventh and eighth volutions are about the same height. The average heights of the first to the ninth volution in seven specimens are 29, 42, 59, 80, 104, 131, 162, 179, and 178 microns, respectively. The heights of the chambers are about the same throughout the length of the shell, excepting in the extreme polar regions. There the chambers increase in height sharply.

The septa are closely spaced. The average septal counts of the first to the seventh volution in three specimens are 10, 16, 19, 21, 25, 28, and 26, respectively. The septa are closely fluted in the extreme polar regions. The fluting extends approximately half the distance from the poles to the tunnel borders. Fluting decreases in intensity rapidly toward the center of the shell.

The spirotheca is relatively thick. It has a distinct diaphanotheca in the outer four to five volutions of mature shells. The average thicknesses of all layers of the spirotheca of the first to the ninth volution in seven specimens are 10, 13, 14, 21, 27, 30, 30, 35, and 40 microns, respectively. The diaphanotheca is distinct from the fourth volution to maturity. It extends almost throughout the length of the shell in the outer two volutions of mature specimens.

The tunnel is broad and is relatively high. The average tunnel angles of the fourth to the ninth volution in five specimens are 15, 16, 20, 31, 35, and 41 degrees, respectively. The path of the tunnel is only slightly irregular from the second volution to maturity. In a few specimens, however, the first volution is coiled at a large angle to the coiling of the outer volutions. The chomata are massive. In the inner five volutions, the chomata extend almost to the top of the chambers, and they extend from the tunnel to the poles. In the outer volutions, the chomata are asymmetrical, high, and about three times as wide as high.

Remarks.—*Fusulinella proxima* is one of the largest American species of the genus. In general development and chomata structure, it resembles *F. fugax* somewhat closely. However, *F. proxima* is considerably larger at maturity, has more highly fluted septa, and has a more elongate shell. *F. proxima* can be distinguished from *F. acuminata* by its more inflated shell, more massive and broader chomata, slightly less fluted septa, and different shell outline.

Occurrence.—The type specimens of *Fusulinella proxima* came from Bed 17, Section 11, in the upper part of the type section of the Fra Cristobal formation, Mud Springs Mountains. Conspecific specimens are abundant in the upper part of the Fra Cristobal formation at Derry and at Silver City.

Measurements of *Fusulinella proxima* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions								
					1	2	3	4	5	6	7	8	9
1.	3.78	1.49	2.5	.105	.028	.040	.061	.081	.097	.145	.162	.202	.....
2.	3.96	1.71	2.3	.077	.024	.036	.048	.069	.093	.121	.154	.178	.178
3.	4.32	1.80	2.4	.089	.032	.040	.053	.081	.105	.117	.154	.158	.....
4.	2.70	1.08	2.5	.089	.032	.044	.069	.093	.113	.141	.....	.....	.....
5.	3.60	1.30	2.8	.081	.028	.053	.069	.093	.113	.137	.182	.....	.....
6.	.....	1.40	.....	.097	.028	.048	.061	.073	.109	.125	.170	.....	.....
7.	.....	1.30	.....	.101	.028	.036	.053	.069	.097	.133	.150	.....	.....
8.	.....	1.04	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Specimen	Form ratio of volutions								Thickness of spirotheca									
	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	9
1.	1.1	1.4	1.9	2.1	2.3	2.1	2.5	.....	.....	.012	.016	.024	.028	.032	.032	.036	.....	.....
2.	1.3	1.6	1.9	1.9	2.0	2.2	2.0	2.1	.....	.012	.016	.016	.028	.028	.032	.036	.048	.040
3.	1.1	1.5	1.7	2.0	2.1	2.2	2.2	2.5	.....	.008	.012	.016	.016	.024	.036	.028	.020	.....
4.	1.4	1.4	1.9	2.0	2.2	2.6	.....	.....	.....	.012	.012	.016	.020	.028	.016	.....	.....	.....
5.	1.1	1.6	1.8	2.1	2.7	2.8	.....	.....	.....	.....	.016	.024	.032	.032	.....	.....	.....
6.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.008	.016	.016	.020	.028	.032	.036	.....	.....
7.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.012	.008	.008	.012	.016	.024	.028	.016	.....

SPECIMEN	Septal count							Tunnel angle (degrees)					
	1	2	3	4	5	6	7	4	5	6	7	8	9
1.	20	22	31	32	.....
2.	16	21	17	25	41
3.	15	15	16	20	.....
4.	13	18	.....	.....	.....
5.	15	18	23	.....	.....
6.	10	15	18	19	23	27	25	.....	.....	.....	.....	.....
7.	10	17	18	20	26	27	27	.....	.....	.....	.....	.....
8.	11	17	21	23	26	29	.....	.....	.....	.....	.....	.....

***Fusulinella famula*, new species**

Plate 32, figures 4, 5; Plate 38, figures 1-8

The shell of *Fusulinella famula*, n. sp., is small and highly inflated fusiform. It has bluntly pointed poles and a straight axis of coiling. The lateral slopes are convex in the inner six to seven volutions. Mature specimens of eight to nine and one-half volutions are 3.0 to 4.0 mm long and 1.8 to 2.4 mm wide. The form ratio is 1.4 to 2.0. The average form ratios of the first to the ninth volution of four specimens are 1.4, 1.6, 1.6, 1.6, 1.6, 1.7, 1.7, 1.8, and 2.0, respectively. Thus, the shell increases in relative length only slightly with growth of the individual.

The proloculus is small; its outside diameter is 80 to 140 microns, averaging 107 microns for seven specimens. The shell expands about uniformly. The average heights of the first to the ninth volution immediately above the tunnel of seven specimens are 46, 58, 80, 96, 118, 140, 172, 183, and 206

microns, respectively. The chambers increase in height only slightly poleward from the tunnel.

The spirotheca is relatively thick. The average thicknesses of all four layers of the spirotheca immediately above tunnel in the first to the ninth volution of six specimens are 8, 17, 23, 30, 34, 35, 41, 35, and 28 microns, respectively. However, as the tectoria are of different thicknesses across the chambers, the above figures are only close approximations. The diaphanotheca are clearly visible from the fourth volution to maturity. In some parts of the outer volutions, the lower part of the upper tectorium is only slightly more dense than the diaphanotheca. The diaphanotheca is not visible in the polar regions, even in the outer volutions of mature specimens.

The septa are closely spaced in most parts of the shell. However, they are irregularly and widely spaced in some parts of the shell. The upper part of the septa is slightly thicker than the overlying spirotheca. However, the lower regions of the septa

are of about the same thickness as the spirotheca. The average septal counts of the first to the eighth volution of three specimens are 11, 17, 21, 23, 29, 30, 32, and 40, respectively. The septa are closely fluted in the extreme polar regions, but they are almost plane in the central part of the shell.

The tunnel is more than one-third as high as the chambers, and its path is slightly irregular throughout the shell. The average tunnel angles of the fourth to the ninth volution in four specimens are 11, 13, 14, 15, 19, and 17 degrees, respectively. The chomata are large. They leave only a minute circular lateral opening at the tops of the chambers in the inner eight volutions of specimens with nine volutions. The tunnel side of the chomata is vertical to overhanging, but the poleward slope is low. Chomata extend completely to the poles in the second to the sixth volution of mature specimens.

Remarks.—*Fusulinella famula* belongs to a group of fusulinids that had its beginning in lower Middle

Pennsylvanian time, and occurs from there into the middle part of the Middle Pennsylvanian. The group includes *Profusulinella fittsi* THOMPSON from the Atoka formation, several undescribed species of *F. leyi* THOMPSON from the Hell's Canyon formation of Colorado, *F. iowensis* THOMPSON from the Cherokee shale of Iowa, and *F. iowensis* var. *stouti* THOMPSON from the Mercer limestones of Ohio. All these forms are characterized by massive broad chomata and narrow irregular tunnels.

Fusulinella from the lower Middle Pennsylvanian, *Fusulinella famula* resembles somewhat closely *F. leyi* THOMPSON [described by THOMPSON (1945) as a variety of *F. iowensis*]. However, *F. famula* has more massive and broader chomata, is larger at maturity, has less highly and intensely fluted septa, and has a considerably thinner diaphanotheca but thicker tectoria. Both the development of the diaphanotheca and the intensity of the septal fluting indicate that *F. leyi* is more advanced biologi-

Measurements of *Fusulinella famula* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions								
					1	2	3	4	5	6	7	8	9
1	3.24	1.76	1.8	.113	.040	.052	.073	.085	.109	.145	.130	.178	
2	4.03	2.03	2.0	.081	.040	.048	.073	.085	.101	.117	.173	.170	.206
3	2.16	1.40	1.5	.089	.040	.057	.077	.081	.113	.129	.158		
4	2.81	1.44	2.0	.097	.032	.053	.053	.073	.101	.129	.145	.162	
5		2.16		.129	.044	.069	.073	.105	.129	.141	.177	.202	
6		1.85		.101	.044	.069	.101	.121	.129	.158	.181		
7		2.12		.137	.040	.060	.101	.125	.145	.161	.222	.202	
8	2.95	2.07	1.4										
9	3.78	2.39	1.6										

Specimen	Form ratio of volutions									Thickness of spirotheca									
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1	1.6	1.6	1.7	1.7	1.6	1.7	1.8	1.8			.008	.016	.024	.040	.053	.040	.053	.049	
2	1.1	1.4	1.6	1.7	1.8	2.0	1.9	1.9	2.0		.008	.016	.024	.020	.028	.032	.040	.040	.028
3	1.4	1.8	1.8	1.4	1.5	1.5	1.5					.016	.024	.036	.036	.028			
4	1.3	1.5	1.5	1.4	1.7	1.7	1.7					.012	.012	.036	.032	.032	.028		
5																			
6												.024	.040	.028	.032	.040			
7										.020				.032	.024	.032	.053	.016	

SPECIMEN	Septal count								Tunnel angle (degrees)					
	1	2	3	4	5	6	7	8	4	5	6	7	8	9
1										9	12	14	17	19
2										10	13	15	14	20
3											12	13	13	
4										15	13	14	15	
5		12	18	20	22	31	27	29						
6		11	17	23	31	33	32	32						
7		11	17	20	24	24	32	34	40					

in width rapidly from the second to the third volutions. Chomata are asymmetrical. Their tunnel sides are almost vertical, and their poleward slopes are low. In the outer three volutions, the chomata are about three times as wide as high. In the second to fourth volutions, the chomata extend into the polar regions with rapidly decreasing height.

Remarks.—*Fusulinella juncea* is closely similar to *F. furnishi* THOMPSON from the Minnelusa formation of South Dakota. They may be varieties of the same species. Some of the major differences between these forms are that in *F. juncea* the shell is smaller at maturity, it is more tightly coiled, and its central part is more highly inflated. However, in most other features, these two forms are similar.

Occurrence.—*Fusulinella juncea* is abundant in the bottom part of Bed 26, Section 21, and in Bed 23, Section 11, in the upper part of the Cuchillo Negro formation, Mud Springs Mountains. This form has been identified from the upper part of the Mud Springs group in the Magdalena and Oscura Mountains and questionably from the east side of the Nacimiento Mountains of northcentral New Mexico.

Fusulinella devexa, new species

Plate 32, figures 6, 10; Plate 35, figures 1-15;
Plate 36, figures 7-10, 12-17

Fusulinella devexa, n. sp., is the most abundant species in the Cuchillo Negro formation. Its shell is small and elongate fusiform, having sharply pointed poles, slightly concave lateral slopes, straight axis of coiling, and inflated central area. Mature specimens of seven to eight and one-half volutions are 3.8 to 4.0 mm long and 1.5 to 1.7 mm wide. The form ratio is 2.3 to 2.6, averaging 2.5 for five specimens. The shell is ellipsoidal in the first and second volutions, inflated fusiform in the following three volutions, and inflated elongate fusiform in the outer volutions. The average form ratios of the first to seventh volution in six specimens are 1.2, 1.6, 2.1, 2.2, 2.3, 2.4, and 2.6, respectively.

The proloculus is minute, and its outside diameter measures 60 to 135 microns, averaging 91 microns in seventeen specimens. The shell expands uniformly. The average heights of the chambers above the tunnel in the first to the eighth volution of nine specimens are 31, 45, 60, 79, 108, 134, 170, and 178 microns, respectively. The chambers increase in height in the polar regions of the outer volutions.

The spirotheca is thin, and it is composed of four layers. The diaphanotheca is relatively thick in the outer three volutions. It is not clearly visible, however, in the inner three volutions. The diaphanotheca seemingly is not developed in the outer one-half of the last volution, indicating that the

diaphanotheca formed later than the tectum. The average thicknesses of the diaphanotheca in the fourth to the eighth volution of nine specimens are 7.3, 9.8, 13.3, 16.0, and 17.0 microns, respectively. The diaphanotheca thins toward the poles, but it is recognizable to the poles in the first half of the ultimate volutions of mature specimens.

The septa are thin. The diaphanotheca of the spirotheca extends downward almost to the base of the septa on the posterior side of the tectum. However, it extends only a short distance down the septa on the anterior side of the tectum. The septa are almost normal to the spirotheca. The average septal counts of the first to eighth volution in four specimens are 9, 12, 16, 20, 22, 23, 24, and 22, respectively. The septa are irregularly fluted in the extreme polar regions, and they are irregularly undulated almost to the edges of the tunnel in the outer three volutions of mature specimens.

The tunnel is low and broad in the outer volutions. It is narrow in the inner volutions. The average tunnel angles in the third to eighth volution of five specimens are 24, 24, 25, 28, 30, and 30 degrees, respectively. Chomata are present in all parts of the shell excepting the last part of the outer volution. Their tunnel side is vertical to overhanging, and their poleward slope is low in the inner volution and steep in the outer two volutions. Chomata extend almost to the poles in the inner three to four volutions. They are about as wide as high in the first one-third of the outer volution of mature specimens.

Remarks.—*Fusulinella devexa* is similar in some respects to *F. juncea*, n. sp. However, the latter form has a larger form ratio, larger shell, less massive chomata, and wider tunnel angle in its outer volution. The specimens described below as *Fusulinella* sp. A resemble *F. devexa* in general shell development. These forms may be varieties of the same species. However, statistical data show that the specimens referred to *F. sp. A* with fewer volutions are larger in size, are more loosely coiled, and have larger proloculi than *F. devexa*.

Fusulinella devexa resembles *F. proxima*, n. sp. The latter form is larger at maturity, has more massive chomata, and has a slightly larger tunnel angle in outer volutions. Also, the polar regions of *F. proxima* are not so sharply extended, and the lateral slopes of outer volutions are not so deeply concave.

Occurrence.—Specimens of *Fusulinella devexa* are exceedingly abundant in Bed 24, Section 11, and in the upper part of Bed 26, Section 21, Cuchillo Negro formation, Mud Springs Mountains.

Measurements of *Fusulinella deveza* Thompson, n. sp., in millimeters

Specimen	Length	Width	Ratio	Diameter proloculus	Height of volutions								Form ratio of volutions							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	3.99	1.52	2.6			.040	.060	.082	.135	.136	.176	.204	1.2	1.6	2.1	2.1	2.2	2.3	2.7	
2	3.82	1.47	2.6	.065	.026	.041	.054	.082	.095	.119	.166	.170	1.2	1.5	2.1	2.1	2.5	2.6	2.8	
3	3.89	1.52	2.6	.075	.034	.048	.065	.082	.092	.126	.156	.187	1.2	1.6	2.1	2.1	2.2	2.3	2.7	
4	3.65	1.45	2.5	.078	.027	.037	.058	.085	.115	.153	.173		1.3	1.6	2.2	2.4	2.7	2.7		
5	3.82	1.66	2.3	.092	.034	.048	.068	.075	.126	.136	.187	.150	1.3	1.5	2.0	2.1	2.1	2.2	2.3	2.3
6		1.64		.119	.044	.057	.054	.092	.119	.159										
7		1.56		.061	.027	.051	.065	.085	.112	.150	.180	.187								
8		1.74				.044	.051	.051	.085	.115	.150	.170								
9		0.81		.078	.027	.037	.058	.075	.092	.112										

SPECIMEN	Thickness of diaphanotheca					Septal count								Tunnel angle (degrees)						
	4	5	6	7	8	1	2	3	4	5	6	7	8	3	4	5	6	7	8	
1	.006	.008	.014	.017											24	24	22	27	37	37
2	.006	.010	.015	.017													21	30	27	24
3	.007	.008	.010	.015	.017											23	22	27	25	35
4	.007	.010	.017	.020													34	34	36	
5	.006	.010	.017	.017														24	17	24
6			.012	.010		10	16	21	25	25	26	27								
7	.008	.010	.008	.013		9	10	13	16	21	24	21	20							
8		.010	.012	.017			10	14	20	22	25	24	23							
9	.007	.010				8	11	15	18	21	18									

Measurements of *Fusulinella* sp. A, in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions							Form ratio of volutions								
					1	2	3	4	5	6	7	1	2	3	4	5	6			
1	3.40	1.18	2.9	.086	.036	.054	.068	.099	.117	.140			1.6	2.0	1.9	2.2	2.4	3.0		
2	4.92	1.46	3.4	.099	.036	.050	.068	.122	.144	.189			1.4	1.8	2.2	2.4	3.0	3.4		
3	4.16	1.36	3.1	.077	.036	.045	.081	.103	.149	.171			1.1	1.5	1.7	2.2	3.0	3.2		
4	2.40	0.90		.140	.045	.068	.081	.113	.158				1.7	2.1	2.3	2.5				
5		1.60		.095	.045	.050	.072	.108	.158	.185										
6		1.36		.095	.036	.063	.095	.131	.171	.189										
7		1.70		.108	.040	.054	.072	.104	.140	.176	.203									

Specimen	Thickness of spirotheca						Septal count							Tunnel angle (degrees)						
	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	
1	.009	.009	.014	.019	.023															
2	.009	.014	.014	.028	.023										18	18	18	22	25	
3			.014	.018											16	21	18	28	28	
4																				
5			.019	.023	.023		10	14	18	21	24	25		17	15	16	19	26	32	
6			.014	.019	.023		10	14	15	18	20	23								
7			.012	.014	.019	.023	11	16	18	24	25	28	31							

Fusulinella sp. A

Plate 36, figures 1-6, 11

Specimens here referred to as *Fusulinella* sp. A were obtained from limestones exposed in Powwow Canyon of the Hueco Mountains, Texas. They seem to represent an undescribed species. However, they are similar to the type specimens of *Fusulinella devexa* from the upper part of the Cuchillo Negro formation in Mud Springs Mountains and may be referable to that species. The specimens of *F.* sp. A are larger in corresponding volutions and therefore are more loosely coiled, have slightly larger proloculi, and have larger form ratios for corresponding volutions than the types of *F. devexa*. Also, their chomata are less massive and narrower. None of my axial sections of mature specimens of *F.* sp. A is well oriented. I am illustrating some specimens and including here statistical data on some of them.

Occurrence.—Specimens of *Fusulinella* sp. A occur in Bed 44, Section 17, Powwow Canyon, Texas.

GENUS **FUSULINA** FISCHER DE WALDHEIM, 1829

Fusulina? *insolita*, new species

Plate 32, figure 7; Plate 38, figures 9-13

Fusulinids are exceedingly abundant in the upper 8 feet of the Cuchillo Negro formation near Derry and in the Mud Springs Mountains. These include abundant specimens of *Fusulinella devexa*, n. sp., common specimens of *Eoschubertella mexicana*, n. sp., and scattered specimens of *Millerella* sp. and *Pseudostaffella needhami* THOMPSON. Scattered specimens of a form that has a relatively large proloculus, narrow and high chomata, and septa that are fluted throughout the length of the shell are associated directly with these. The septal fluting in the central one-third of the shell is not intense and does not reach the top of the chambers. However, it does form completely closed chamberlets at the base of the chambers along the sides of the chomata. These specimens are more or less gradational in nature between some forms of *Fusulinella* in the lower Middle Pennsylvanian and forms of *Fusulina* in the lower part of the upper Middle Pennsylvanian. They seem more closely related to the genotype of *Fusulina*, and I am referring them to that genus with question as *Fusulina?* *insolita*, n. sp. *F.?* *insolita* is the most primitive fusulinid now referred to *Fusulina*.

The shell of *Fusulina?* *insolita*, n. sp., is small and inflated fusiform. It has a straight axis of coiling, sharply pointed poles, and slightly concave lateral slopes. Mature specimens of six and one-half to eight volutions are 3.3 to 3.7 mm long and 1.6 to 1.8 mm wide. The first two volutions are elongate ellipsoidal, and the outer volutions retain about the same shape. The average form ratios of the first

to the sixth volution in four specimens are 1.3, 1.7, 1.7, 1.8, 1.8, and 1.9, respectively. The first two volutions of some specimens are tightly coiled at an angle of about 90 degrees to the outer two volutions.

The proloculus is small, and its outside diameter measures 82 to 146 microns, averaging 117 microns for four specimens. Specimens having highly asymmetrical first two volutions have small proloculi of only 20 microns. The shell expands at a relatively uniform rate. The average heights of the chambers above the tunnel in the first to seventh volution of four specimens are 50, 71, 106, 139, 173, 200, and 221 microns, respectively. The chambers are of essentially the same height throughout the length of the shell.

The spirotheca are thick, and they are composed of thick upper and lower tectoria, a tectum, and a diaphanotheca. All layers of the spirotheca immediately above the tunnel of a typical specimen have a combined thickness of about 28.8, 34.0, 34.0, 57.8, 47.6, 68.0, and 61.2 microns in the first to seventh volution, respectively. The diaphanotheca is visible in the second to the third volution. The average thicknesses of the diaphanotheca plus the tectum in the third to seventh volution of four specimens are 6.8, 10.0, 13.6, 18.0, and 20.4 microns, respectively. The tectoria are of about the same thickness throughout the length of the shell, but the diaphanotheca is thin in the polar regions.

The septa are fluted almost to the tops of the chambers in the polar region, forming closed chamberlets about half as high as the chambers in the end one-fourth of the shell. The septa are broadly fluted in the region of the tunnel and there are no chamberlets above the tunnel. The septal counts of the first and second volutions in specimens having a minute proloculus are about 8 and 13, respectively.

The tunnel is narrow and is one-third to one-half as high as the chambers. Its path is highly irregular. The average tunnel angles of the third to the seventh volution in four typical specimens are 16, 20, 21, 23, and 24 degrees, respectively. The chomata are high and narrow. Their tunnel slope is steep throughout the shell. Their poleward slope is steep in the outer three volutions and is low in the inner three volutions.

Remarks.—*Fusulina?* *insolita* belongs to a group of fusulinids found in the middle part of rocks of Middle Pennsylvanian age of several areas in America, including *Fusulinella uintaensis* THOMPSON and *F. leyi* THOMPSON from the Hell's Canyon formation and *Fusulina pristina* THOMPSON from the lower part of the Youghall formation of Colorado. All these forms are more or less intermediate in development between typical *Fusulinella* and typical *Fusulina*. The septal development of *F.?* *insolita* more nearly resembles that of *Fusulina pristina*. However, its spirothecal development is

more primitive than that of *Fusulinella vintaensis* and *F. leyi*. *Fusulina? insolita* possibly is the ancestral stock from which many American *Fusulina* were developed.

Occurrence.—Specimens of *Fusulina? insolita* are rare in Bed 24, Section 11, Cuchillo Negro formation, Mud Springs Mountains, where it is associated with abundant *Fusulinella devera*, *Pseudostaffella needhami*, *Eoschubertella mexicana*, and abundant specimens of *Millerella*.

Measurements of *Fusulina? insolita* Thompson, n. sp., in millimeters

SPECIMEN	L.	W.	Ratio	Diam. prol.	Height of volutions							Form ratio of volutions						
					1	2	3	4	5	6	7	1	2	3	4	5	6	
1.....	2.43	1.28	1.9	.082	.041	.061	.105	.146	.204				1.5	1.9	2.0	2.0	1.9	
2.....	3.38	1.86	1.8	.132	.047	.068	.100	.143	.175	.210	.221		1.1	1.6	1.5	1.7	1.9	1.9
3.....	3.68	2.16	1.7	.108	.051	.078	.116	.136	.170	.204			1.2	1.5	1.6	1.7	1.7	1.7
4.....	3.28	1.81	1.8	.146	.061	.078	.105	.129	.143	.187			1.6	1.7	1.8	1.8	1.9	2.0
5.....	3.38	2.16	1.6															
6.....	2.70	1.47	1.8															

SPECIMEN	Thickness of diaphanotheca					Septal count		Tunnel angle (degrees)				
	3	4	5	6	7	1	2	3	4	5	6	7
1.....		.012	.013	.014					28	24	28	
2.....	.006		.013	.020	.023			15	17	20	24	
3.....			.013	.017	.017				17	18	19	24
4.....		.008	.013	.020				18	19	22	21	
5.....												
6.....						8	13					

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EXPLANATIONS OF PLATES

**UNIVERSITY OF KANSAS
PALEONTOLOGICAL CONTRIBUTIONS**

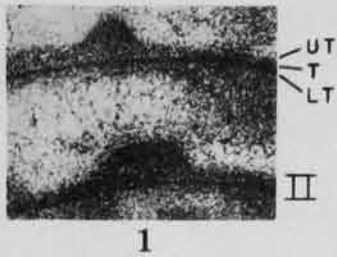
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EXPLANATION OF PLATE 1
SPIROTHECAL STRUCTURES

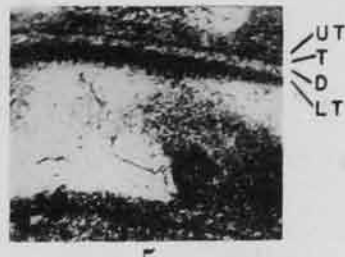
All illustrations on this plate are unretouched photographs of axial sections, except 12 which is of a sagittal section, and all of them are $\times 100$. Roman numerals refer to those shown on Figure 3. Letters indicate T = tectum, D = diaphanotheca, K = keriotheca, UT = upper tectorium, and LT = lower tectorium.

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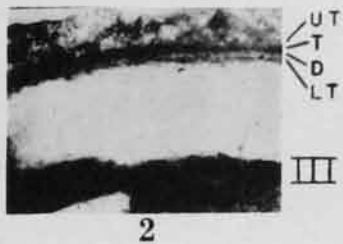
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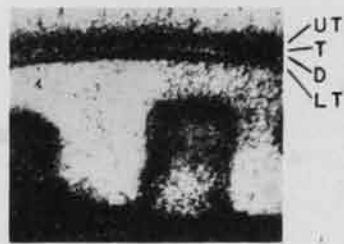
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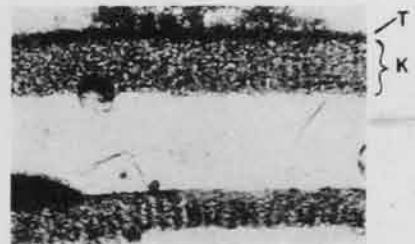
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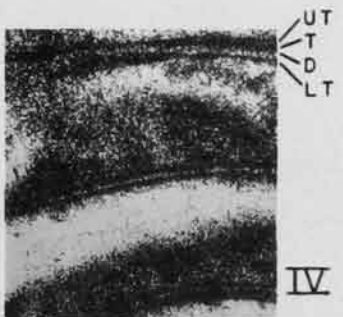
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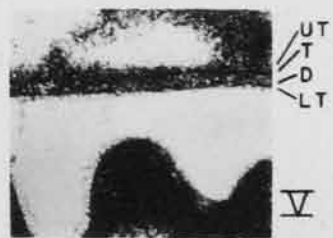
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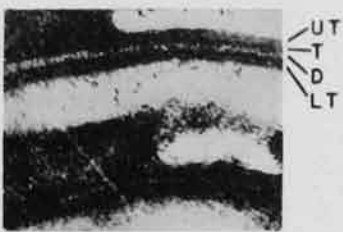
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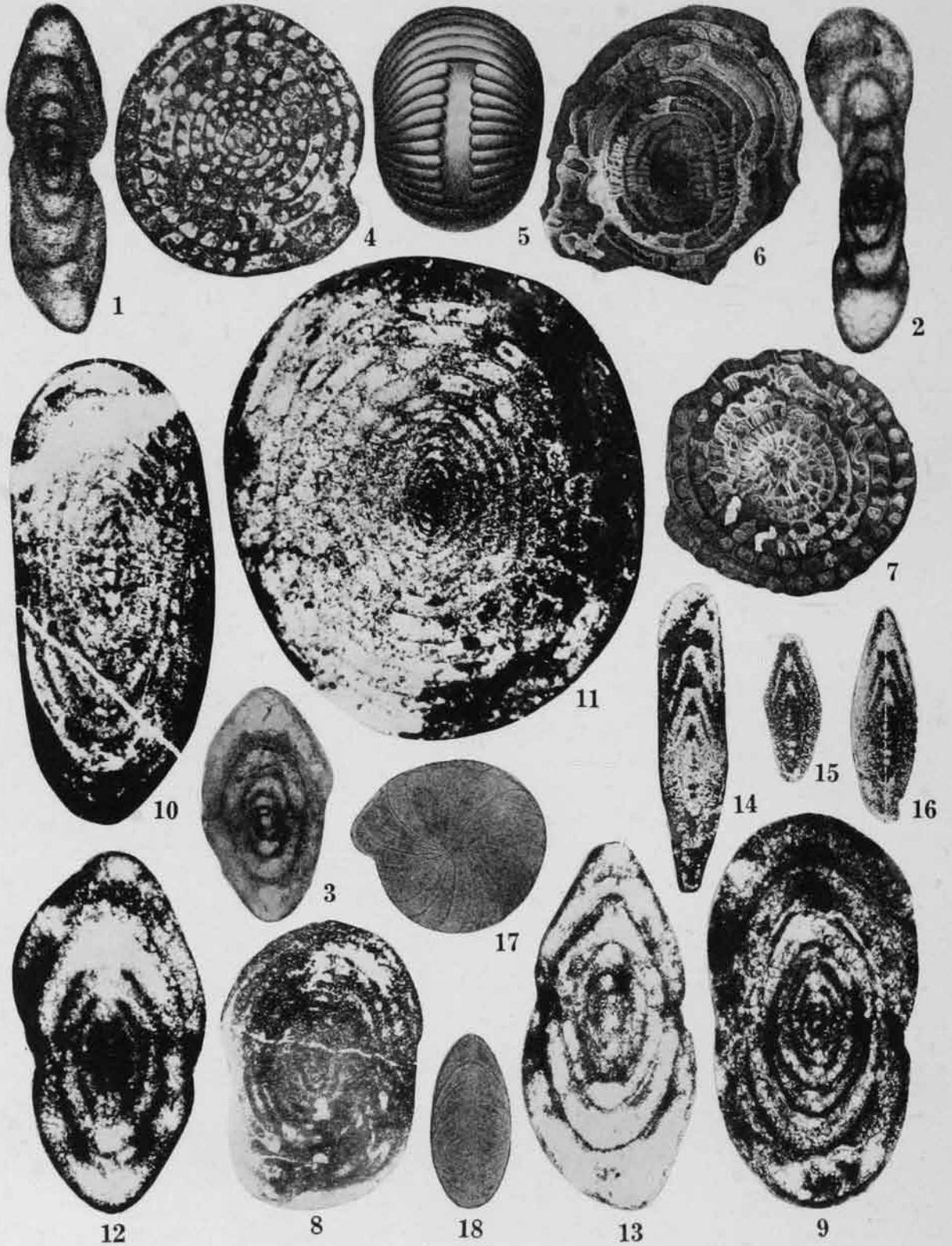
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THOMPSON—American Fusulinids

EXPLANATION OF PLATE 2

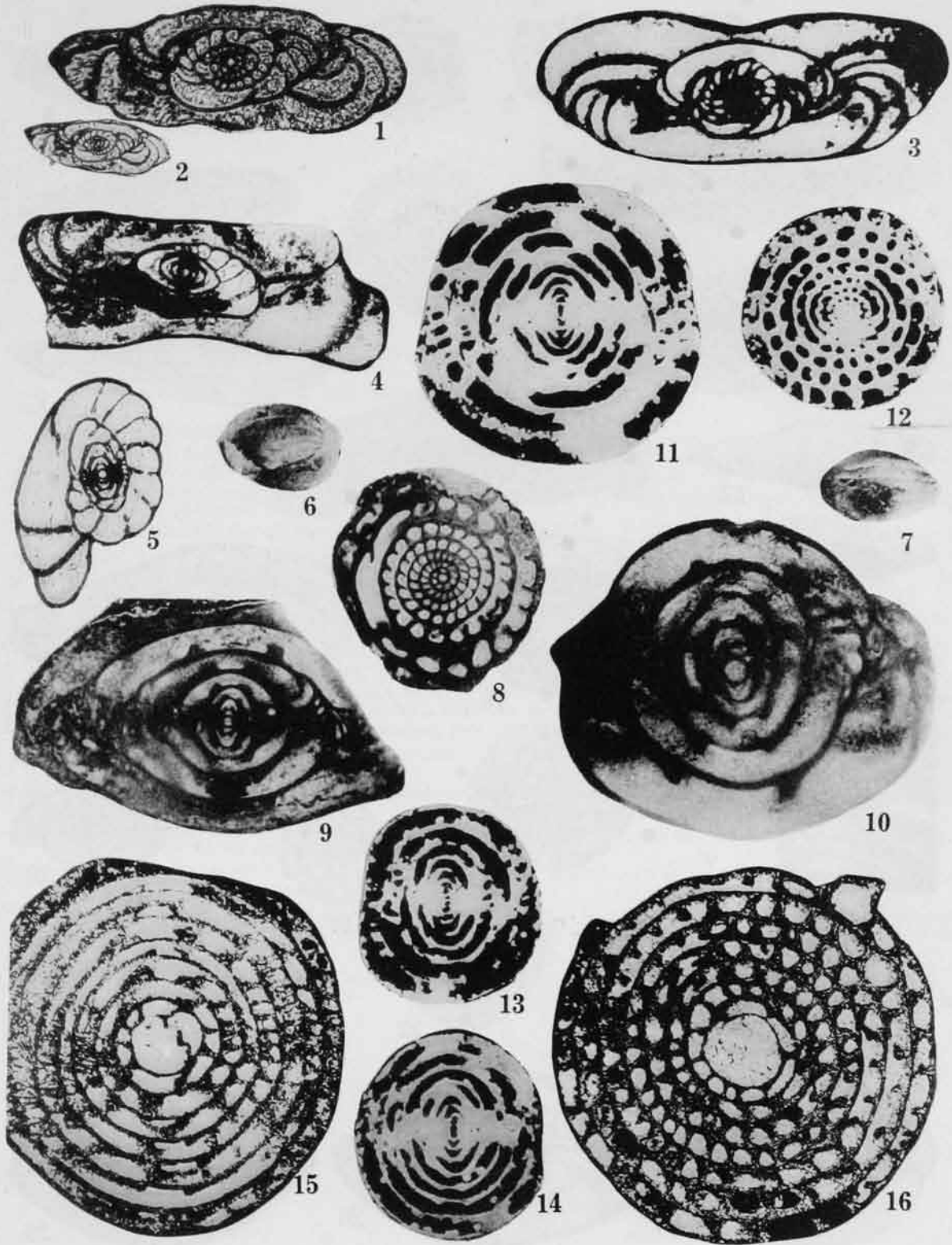
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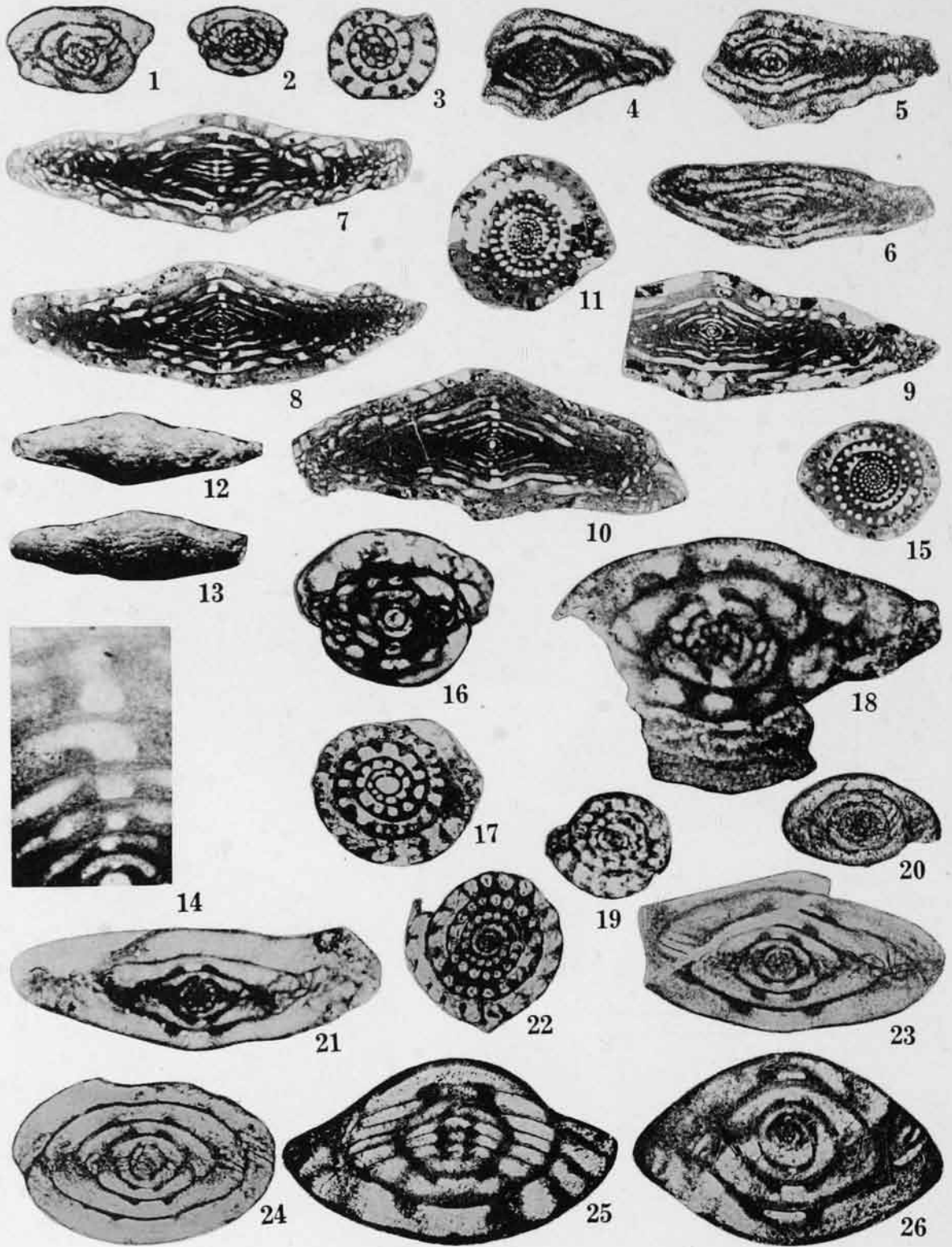
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EXPLANATION OF PLATE 4

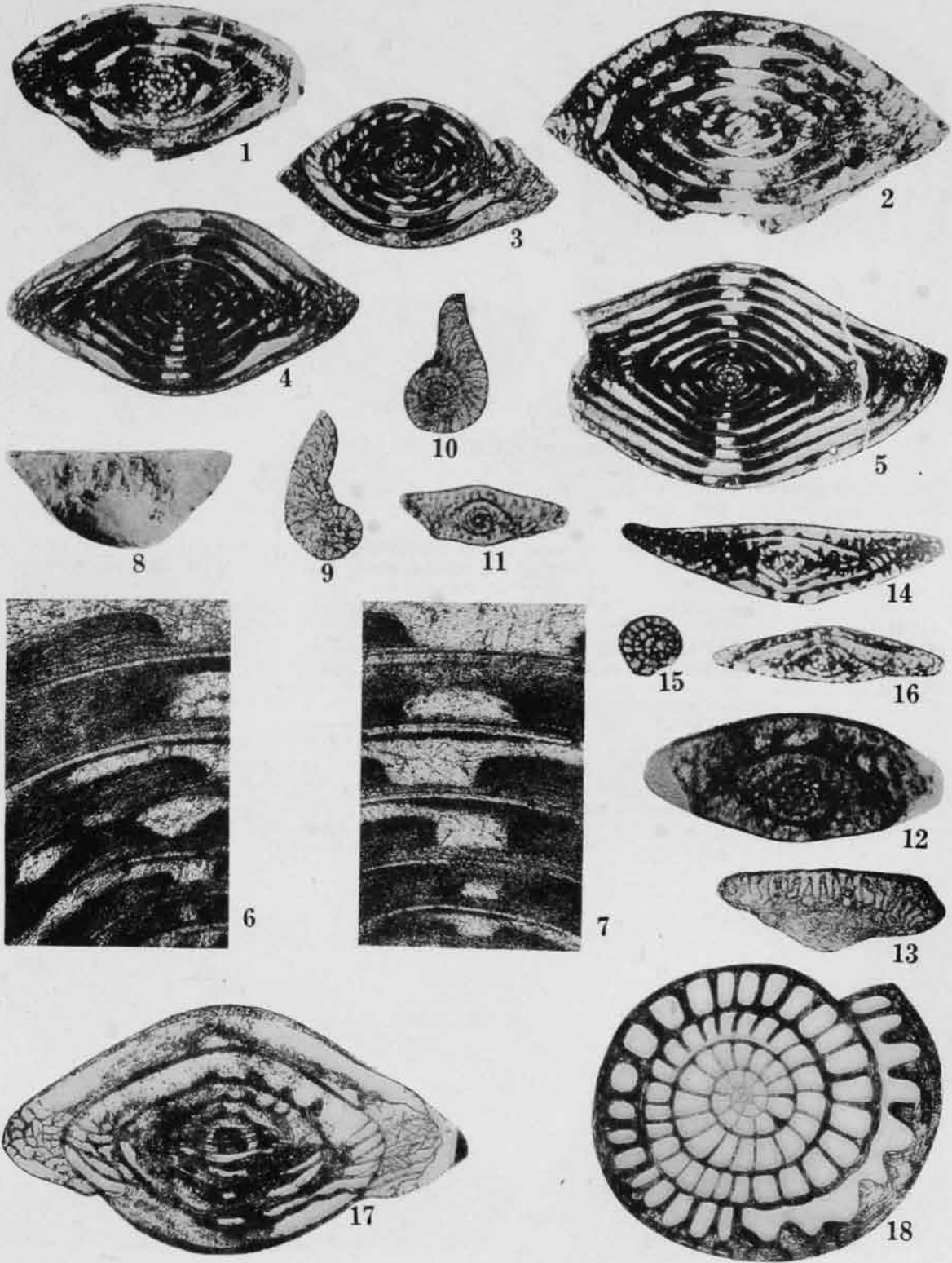
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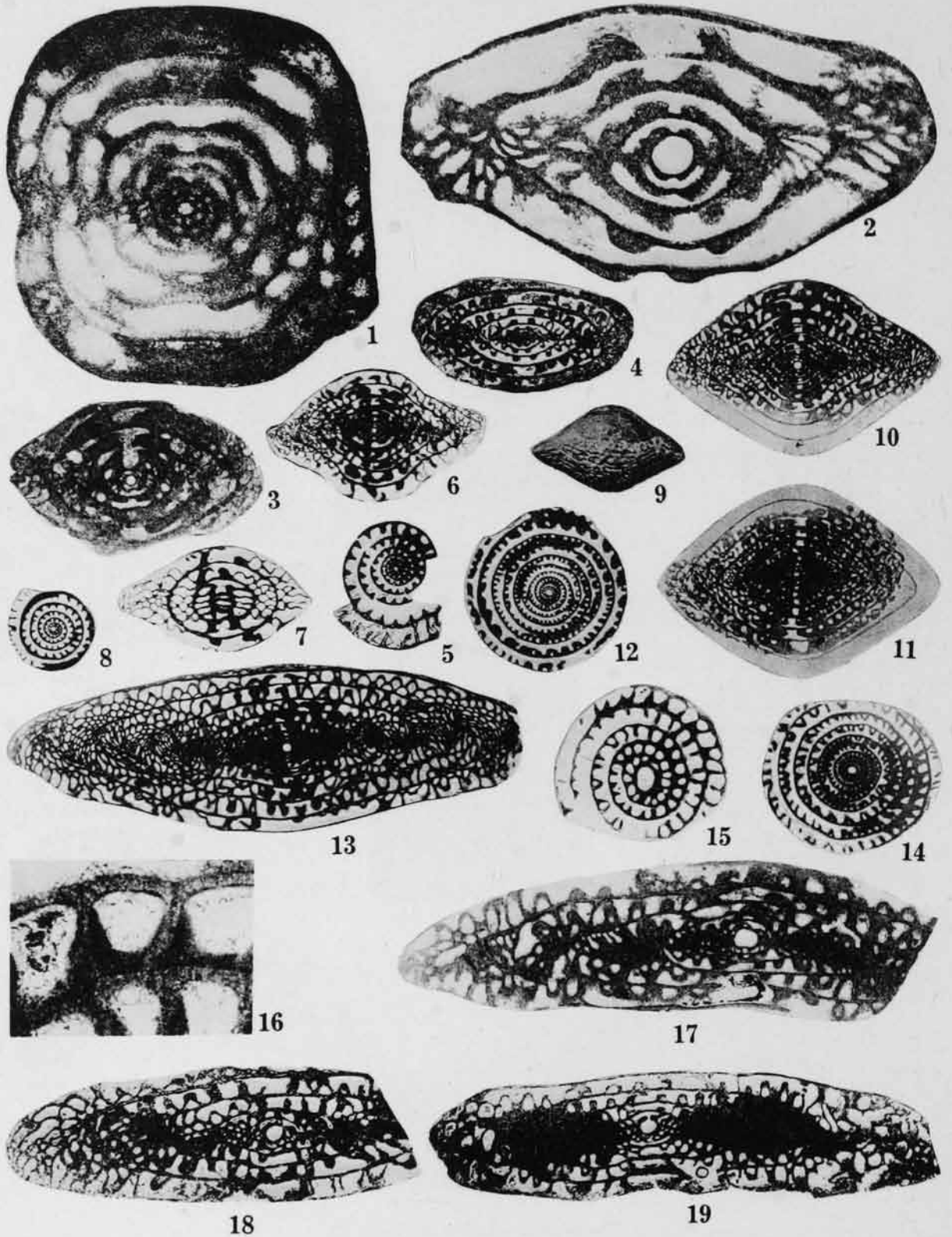
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THOMPSON—American Fusulinids

EXPLANATION OF PLATE 6

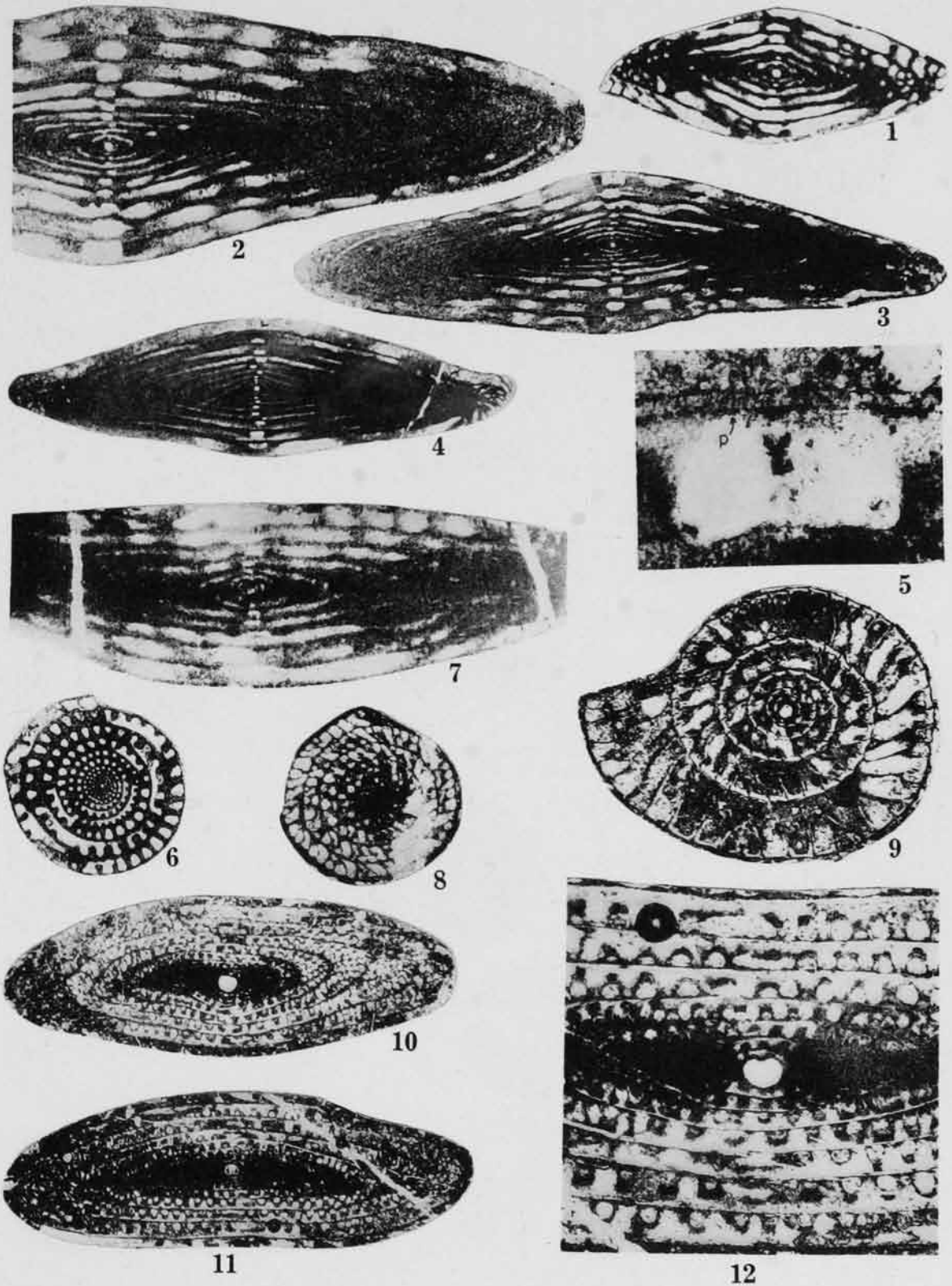
SUBFAMILY FUSULININAE

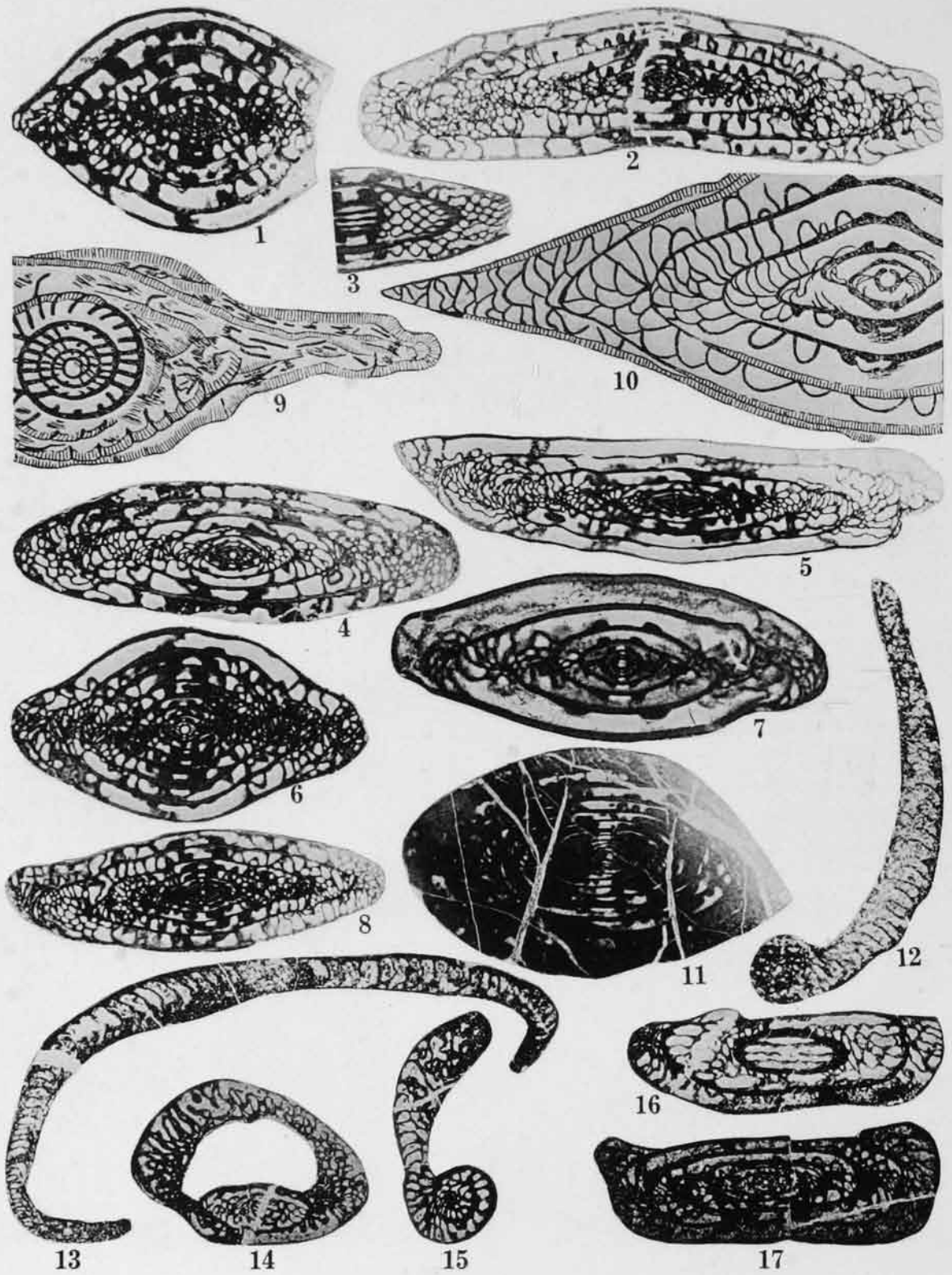
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EXPLANATION OF PLATE 8

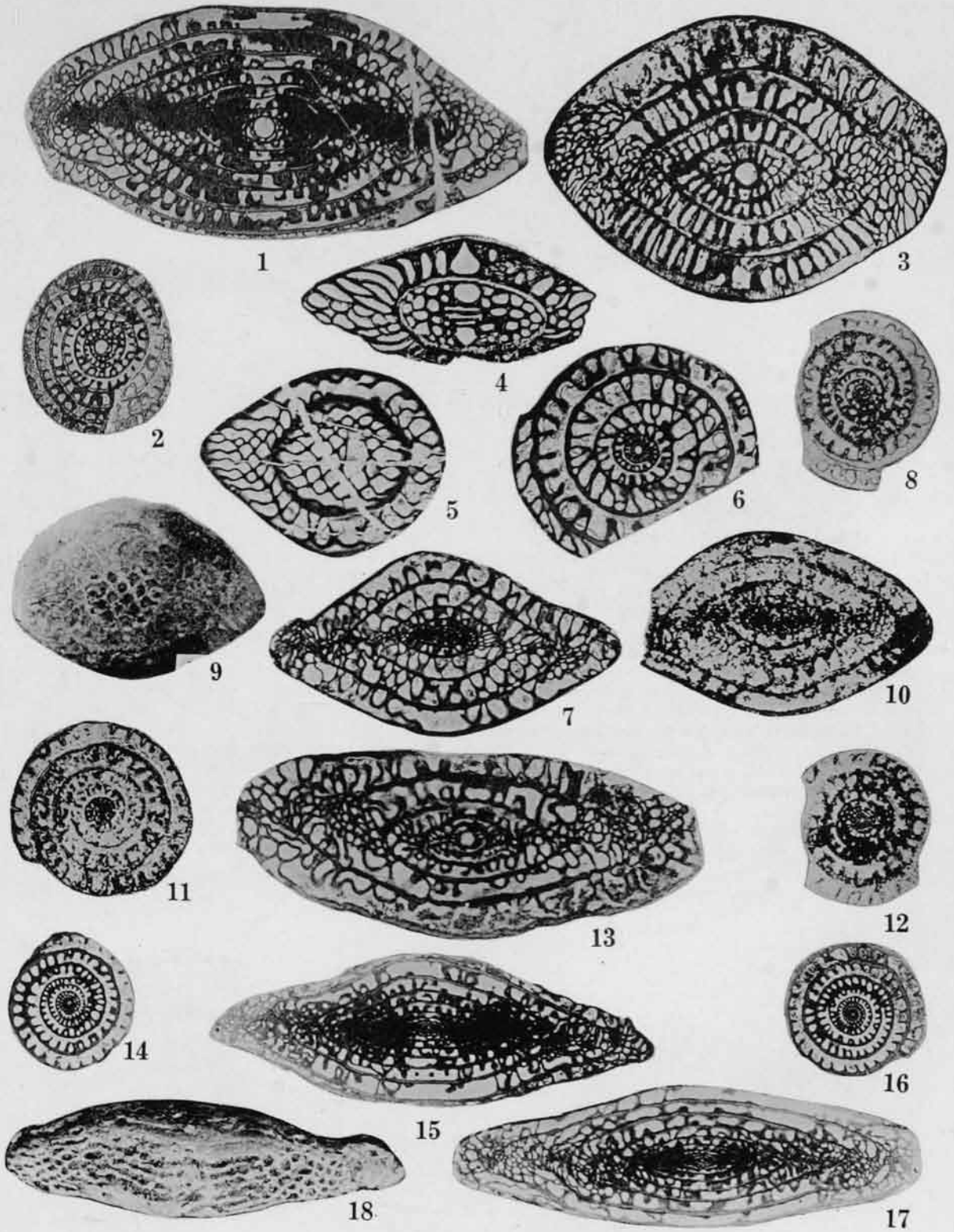
SUBFAMILY SCHWAGERININAE

FIGURE		PAGE
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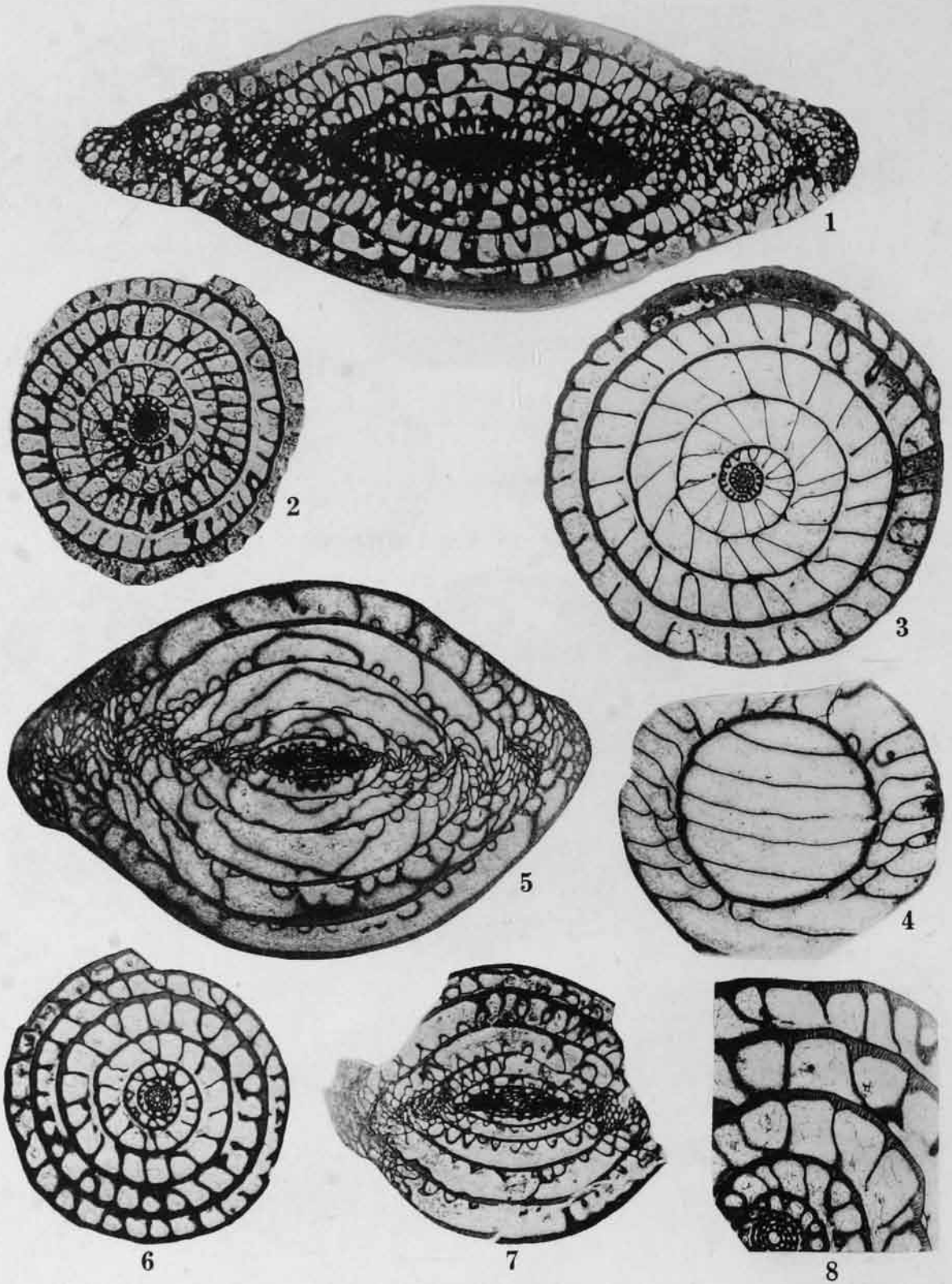
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SUBFAMILY SCHWAGERININAE

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EXPLANATION OF PLATE 10

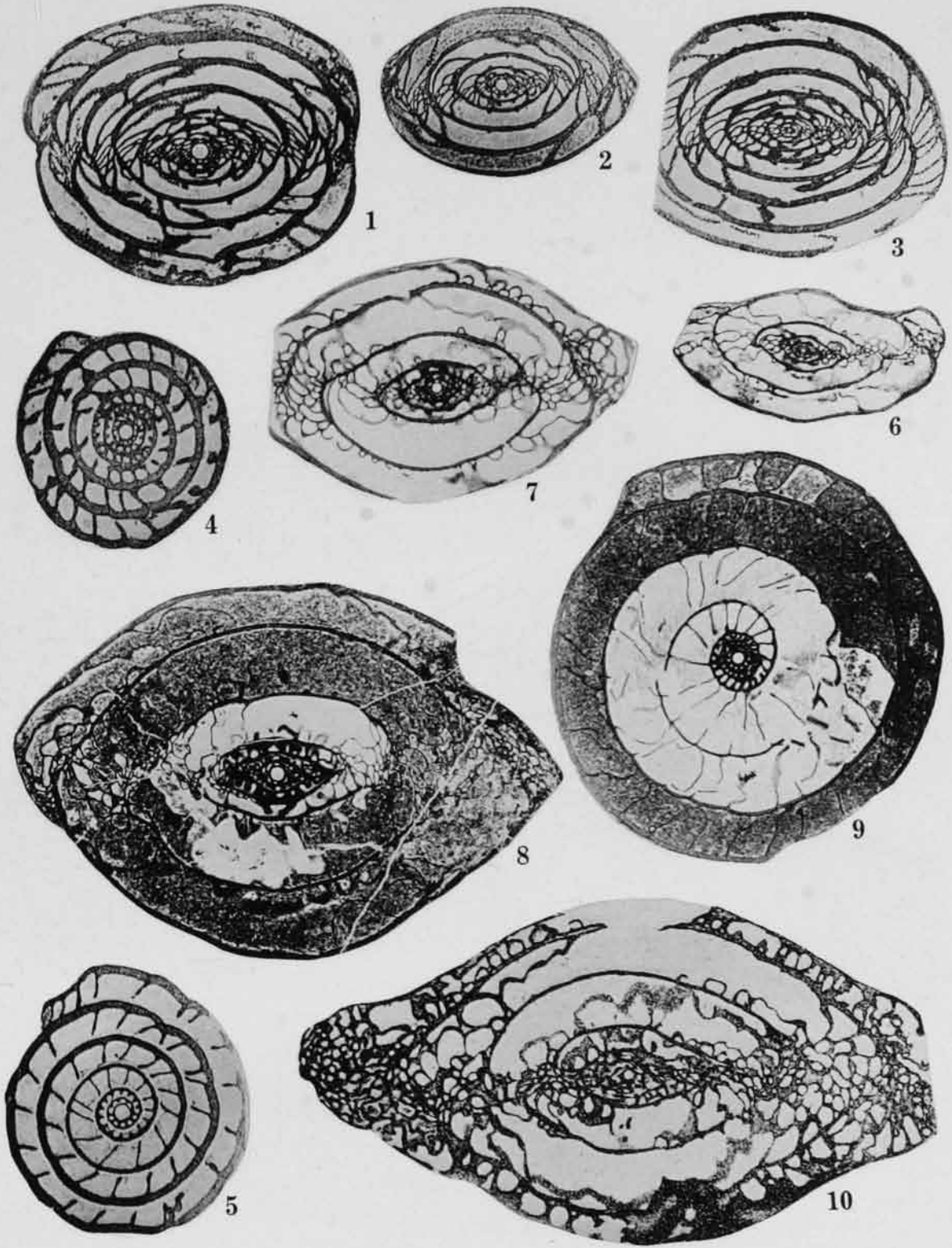
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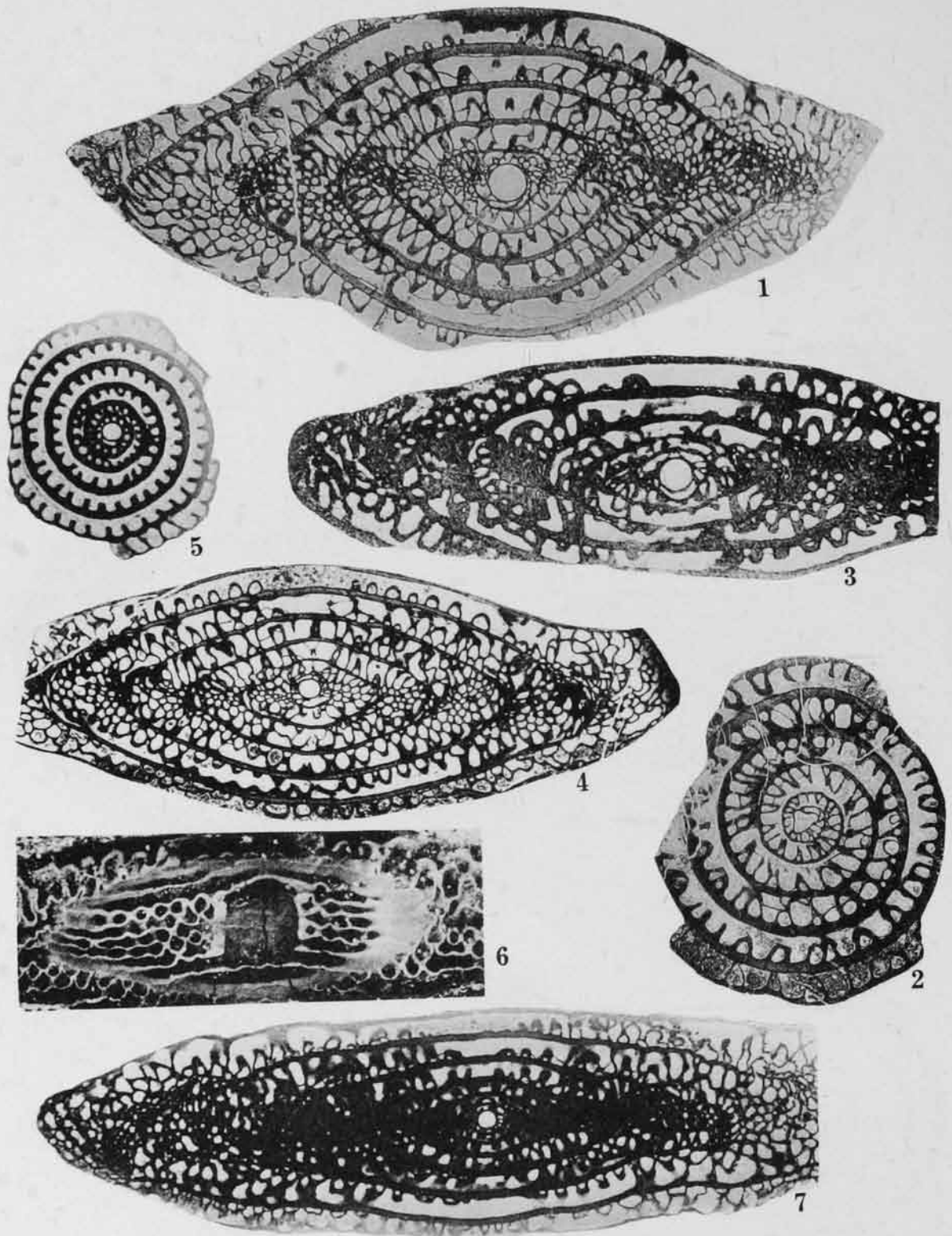
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1, 2— <i>Pseudofusulina chiapasensis</i> (THOMPSON & MILLER), 1944. 1, Axial section; 2, sagittal section; both syntypes, $\times 10$. Gruperá formation, Chiapas, Mexico.	
3— <i>Pseudofusulina fusiformis</i> (SCHELLWIEN & DYHRENFURTH), 1909. Genotype of <i>Leeina</i> GALLOWAY, 1933. Axial section of the holotype, $\times 15$. Permian, Safed-ku Mountains, near Navnou, Darwas. (After SCHELLWIEN & DYHRENFURTH, 1909.)	
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EXPLANATION OF PLATE 13

PROLOCULAR SHAPES, KERIOTHECAL STRUCTURES, AND
DEVELOPMENT OF CUNICULI

FIGURE

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SHAPES OF PROLOCULI.

- 1, 2—*Pseudofusulina gigantea* (DEPRAT), 1913. 1, Axial section showing spherical proloculus, $\times 30$; 2, sagittal section showing irregular proloculus and depressed area around aperture, $\times 30$. Permian, French Indo-China. (After DEPRAT, 1913.)
- 3—*Parafusulina? japonica* (GÜMBEL), 1874. Sagittal section showing quadrate proloculus and depressed proloculus aperture, $\times 45$. Akasaka, Japan. (After DEPRAT, 1914.)
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- 6—*Schwagerina? parumvoluta* (DEPRAT), 1913. Axial section showing depressed area around proloculus aperture, $\times 35$. (After DEPRAT, 1913.)

KERIOTHECAL STRUCTURE.

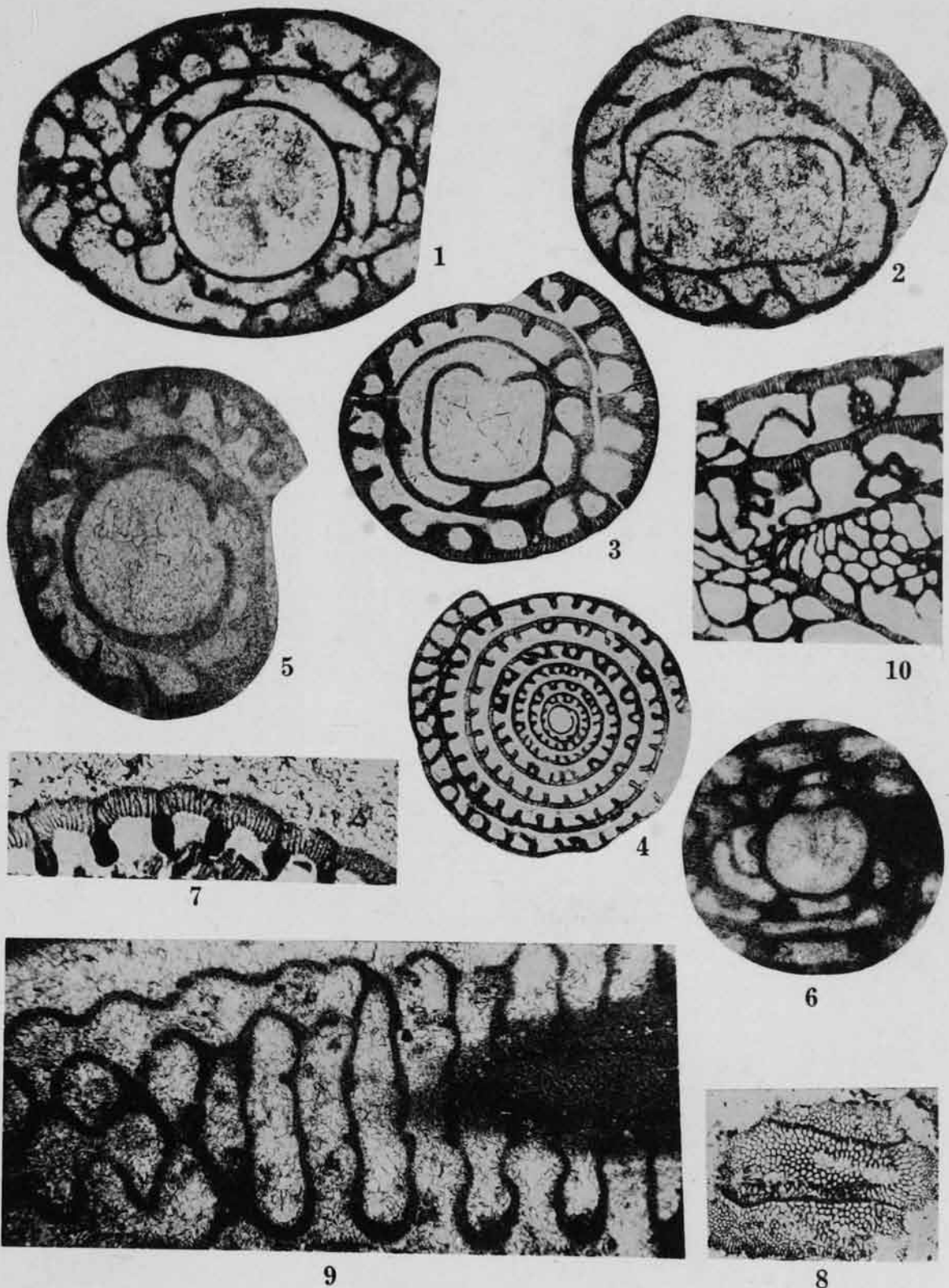
- 7, 8—*Schwagerina rutschi* THOMPSON, 1936. 7, Enlarged part of a sagittal section showing structure of spirotheca, $\times 40$; 8, tangential section cutting the spirotheca showing the gradation of the alveoli, $\times 40$. Lower Permian, Telok Gedang, Sumatra.

DEVELOPMENT OF CUNICULI.

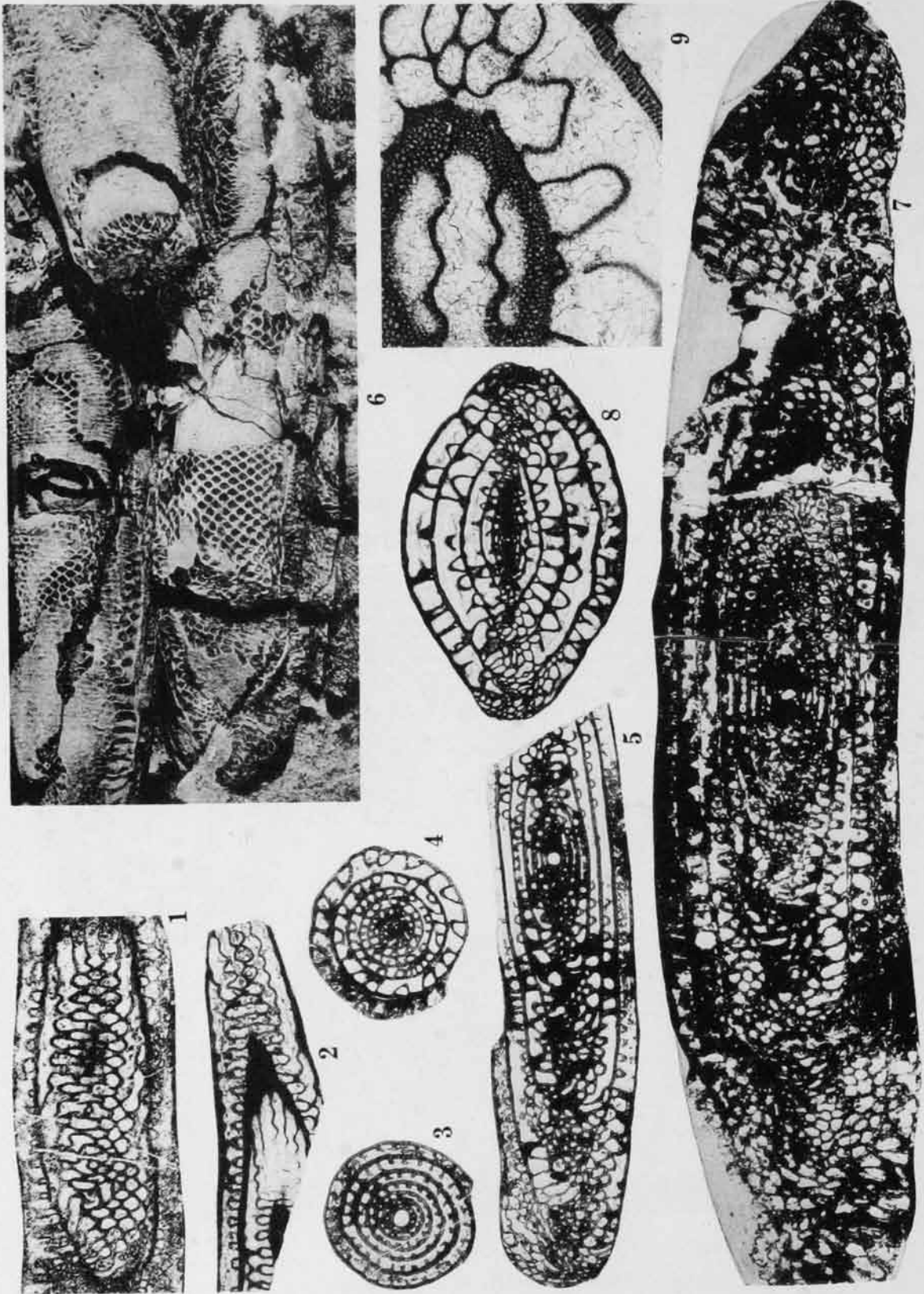
- 9—*Parafusulina nosonensis* THOMPSON & WHEELER, 1946. (See, also, Plate 14.) Enlarged part of a tangential section of a paratype showing rudiments of salients of septa left after excavation of cuniculi, about $\times 45$. Nosoni formation, California.

SEPTAL PORES.

- 10—*Triticites ventricosus* (MEEK & HAYDEN), 1858. Enlarged part of an axial section that shows the numerous and closely spaced septal pores, $\times 30$. Hughes Creek shale, Manhattan, Kansas.



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EXPLANATION OF PLATE 14

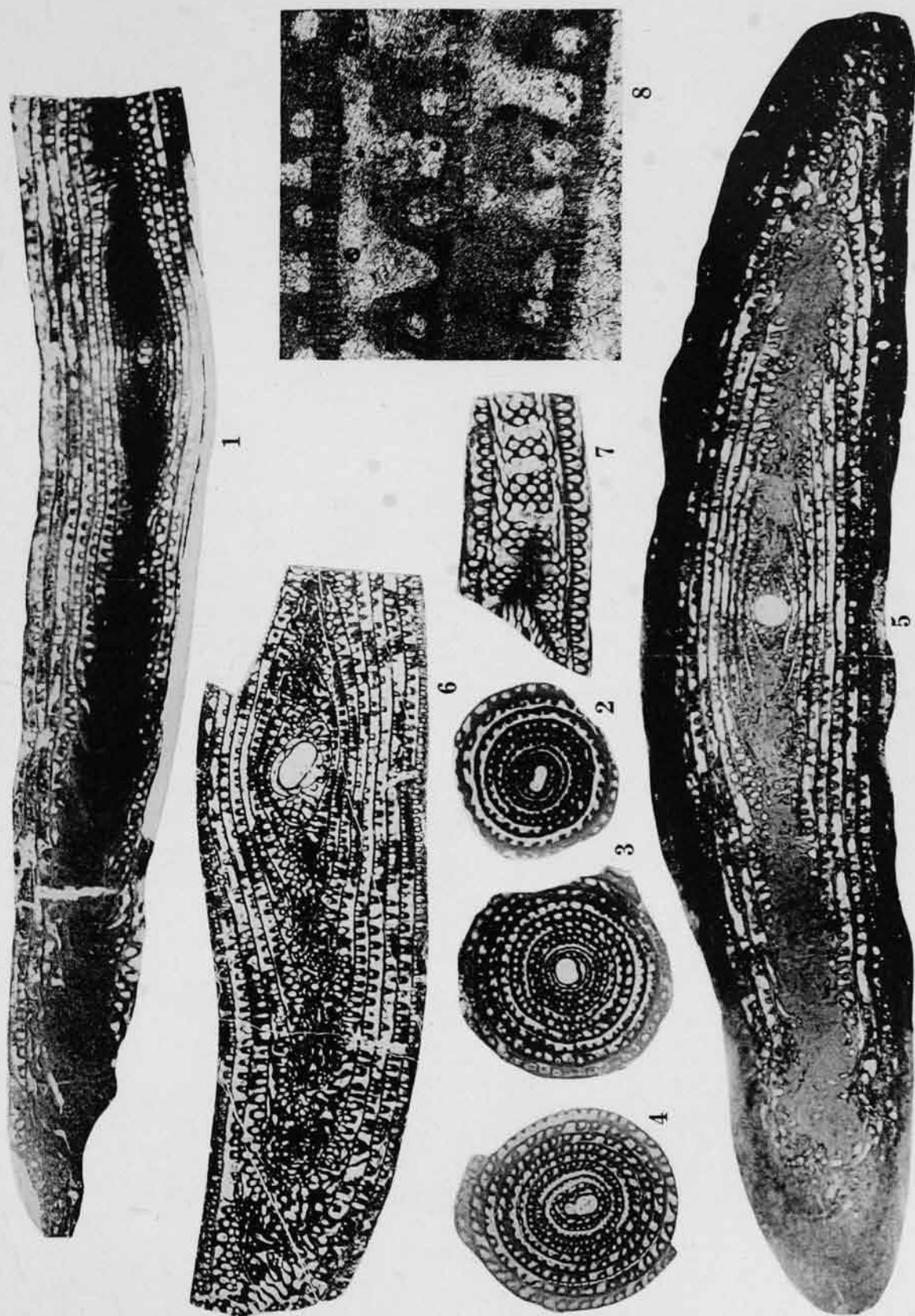
SUBFAMILY SCHWAGERININAE

FIGURE	PAGE
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1-5— <i>Parafusulina nosonensis</i> THOMPSON & WHEELER, 1946. (<i>See, also</i> , Plate 13.) 1, 2, Tangential sections of paratypes showing development of cuniculi, $\times 10$; 3, sagittal section of a paratype, $\times 10$; 4, parallel section of a paratype, $\times 10$; 5, axial section of the holotype, $\times 10$. Nosoni formation, California.	
6, 7— <i>Parafusulina wordensis</i> DUNBAR & SKINNER, 1931. GENOTYPE. 6, Highly mineralized paratypes showing etched structural features of shell, $\times 5$; 7, axial section of a highly mineralized paratype, $\times 10$. Word formation, Glass Mountains, Texas. (After DUNBAR & SKINNER, 1937.)	
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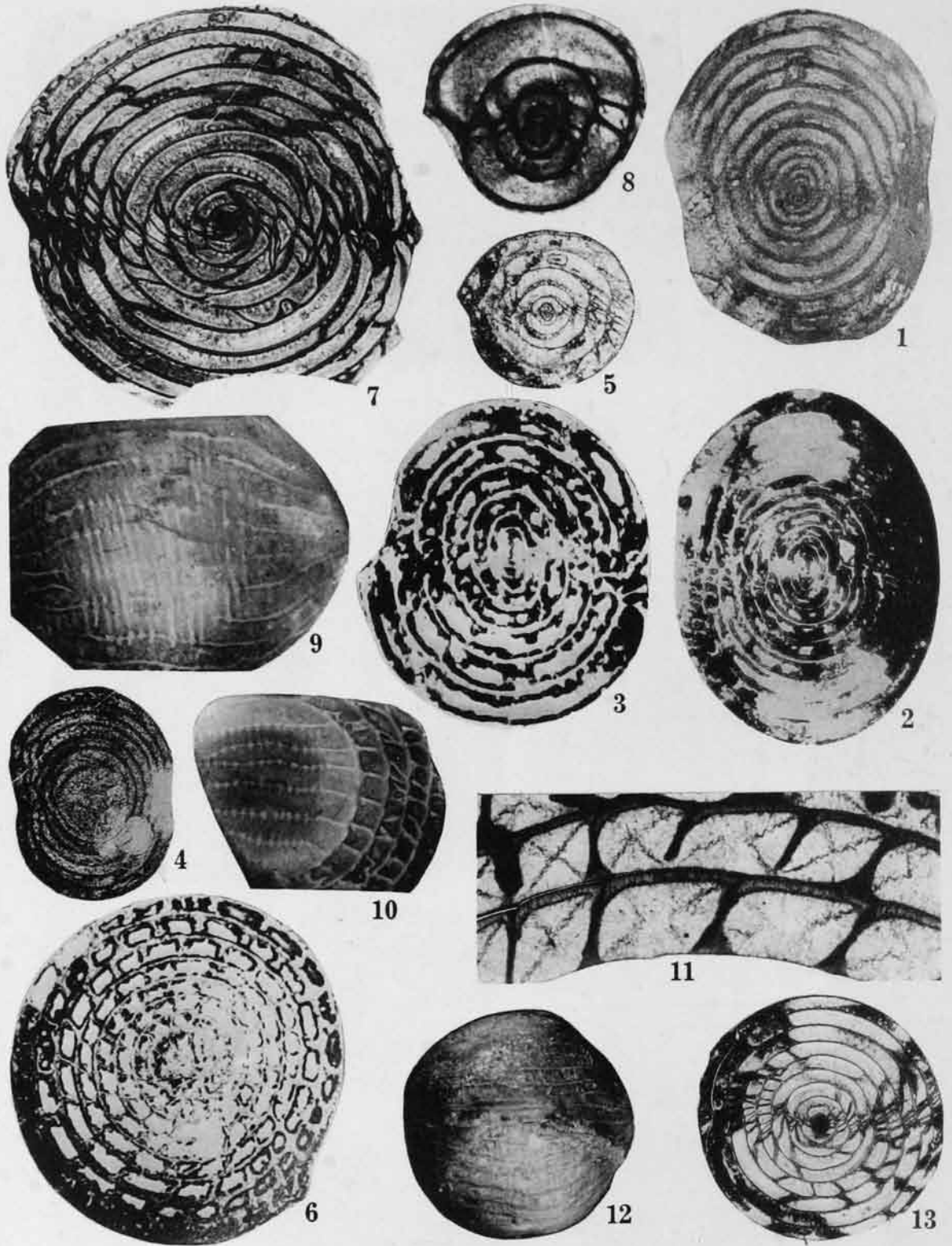
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1, 2— <i>Polydioxodina shumardi</i> DUNBAR & SKINNER, 1931. 1, Axial section of a topotype, $\times 10$; 2, sagittal section of a syntype, $\times 10$. Upper Delaware Mountain formation, Texas. (After DUNBAR & SKINNER, 1937.)	
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6-8— <i>Polydioxodina afghanensis</i> THOMPSON, 1946. 6, Axial section of holotype, $\times 10$; 7, tangential section of a paratype showing multiple tunnels, $\times 10$; 8, enlarged part of axial section showing structure of spirotheca, $\times 100$. Bamian limestone, Afghanistan.	



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THOMPSON—American Fusulinids

EXPLANATION OF PLATE 16

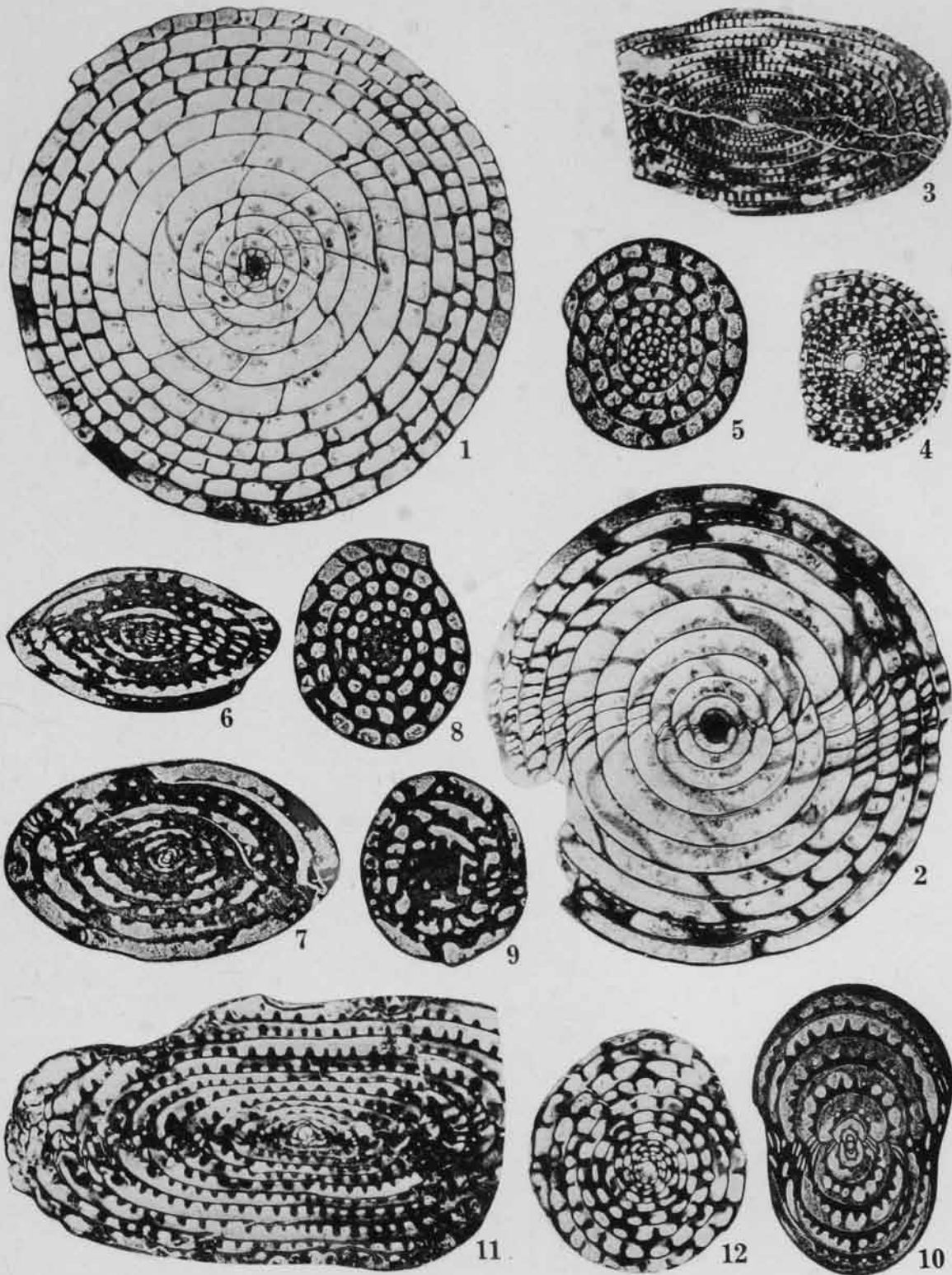
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2, 3, 5— <i>Eoverbeekina intermedia</i> LEE, 1933. GENOTYPE. 2, Axial section of the holotype, $\times 15$; 3, axial section of a paratype, $\times 30$; 5, sagittal section of a paratype, $\times 15$. Kweichow, China. (After LEE, 1933.)	
5— <i>Eoverbeekina cheni</i> THOMPSON & FOSTER, 1937. Axial section of a syntype, $\times 10$. Yanghsin limestone, Mt. Omei, Szechuan, China.	
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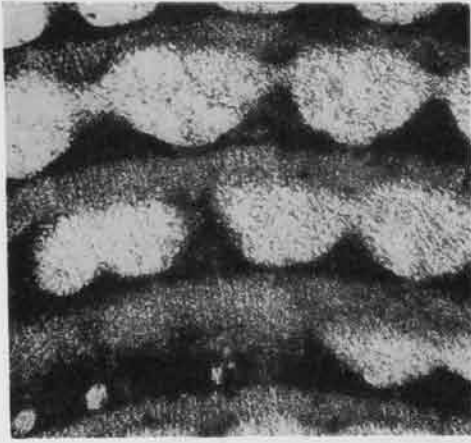
EXPLANATION OF PLATE 17

SUBFAMILY VERBEEKININAE

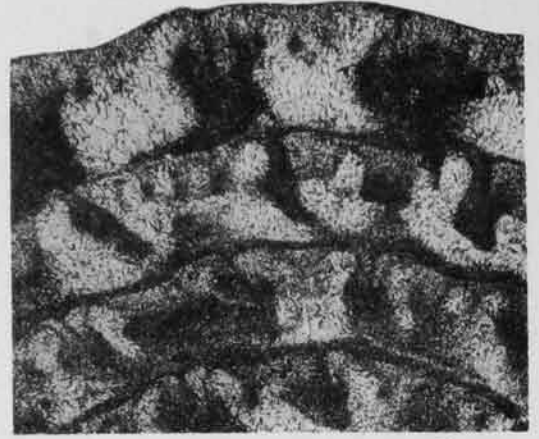
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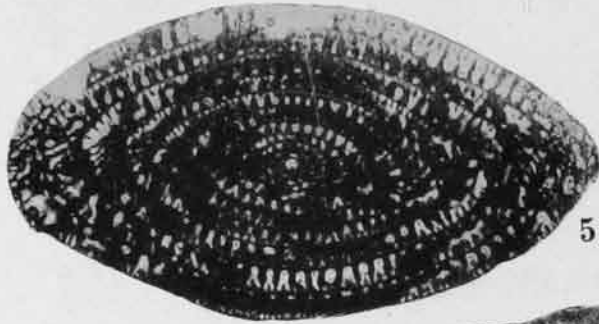
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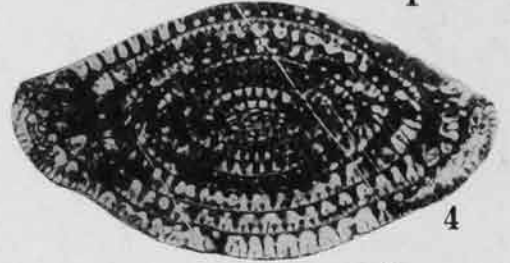
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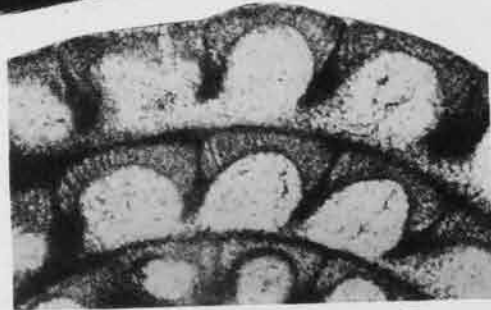
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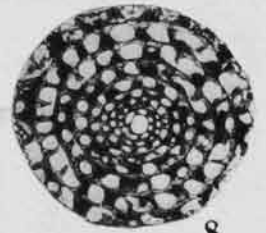
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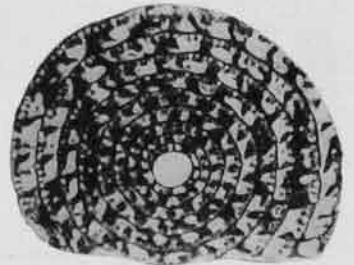
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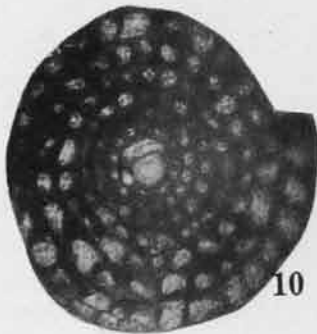
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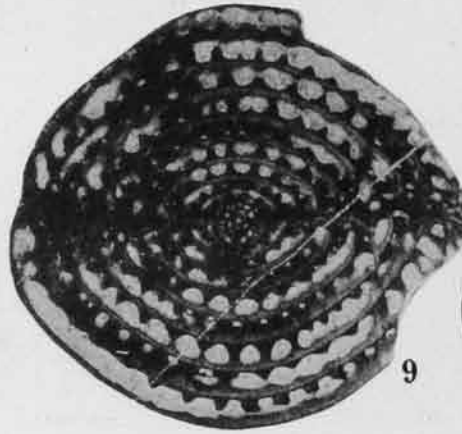
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EXPLANATION OF PLATE 18

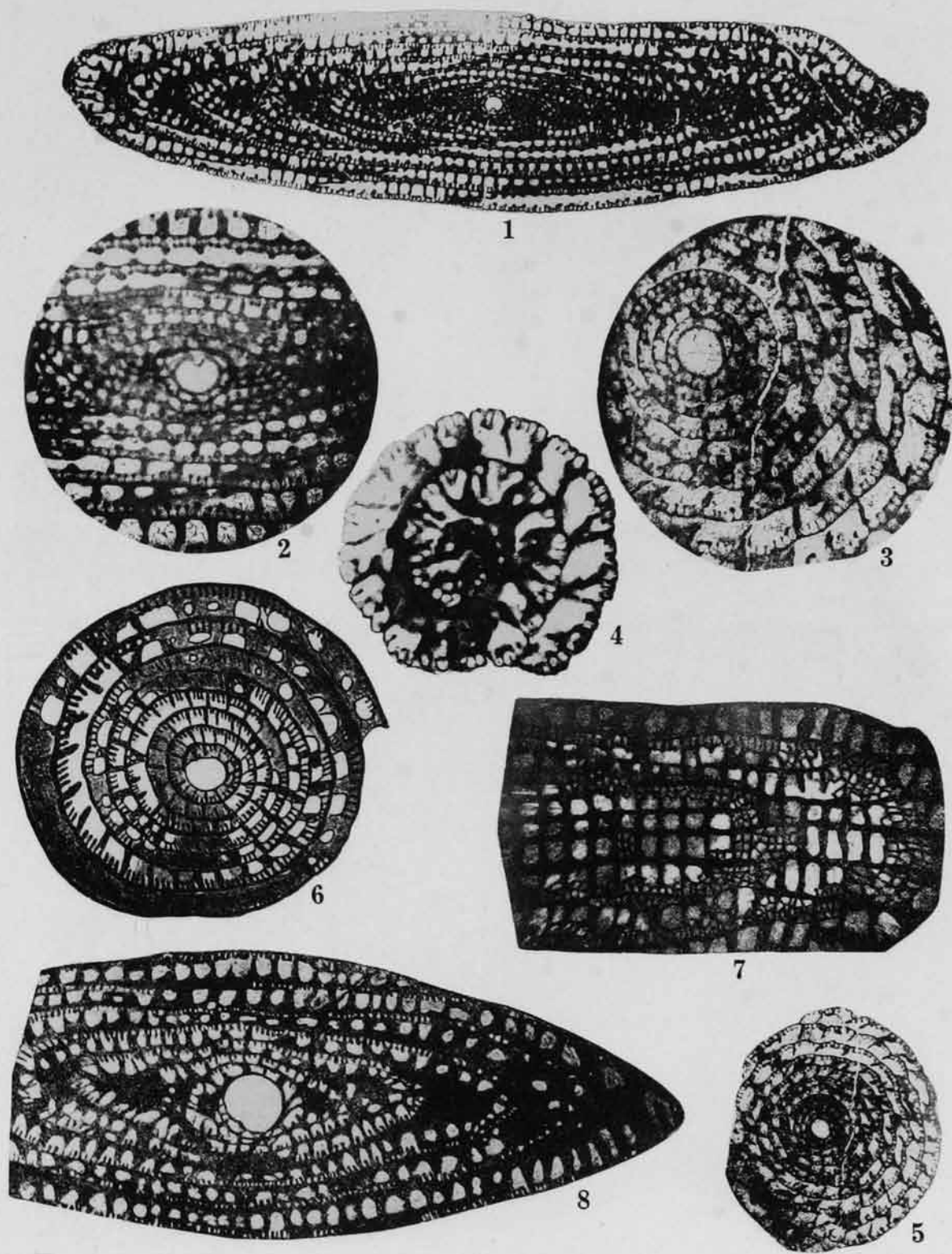
SUBFAMILY NEOSCHWAGERININAE

FIGURE		PAGE
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10, 11	— <i>Cancellina primigena</i> (HAYDEN), 1909. GENOTYPE. 10, Sagittal section of a paratype, $\times 20$; 11, axial section of the holotype, $\times 17$. Bamian limestone, Afghanistan. (After HAYDEN, 1909.)	

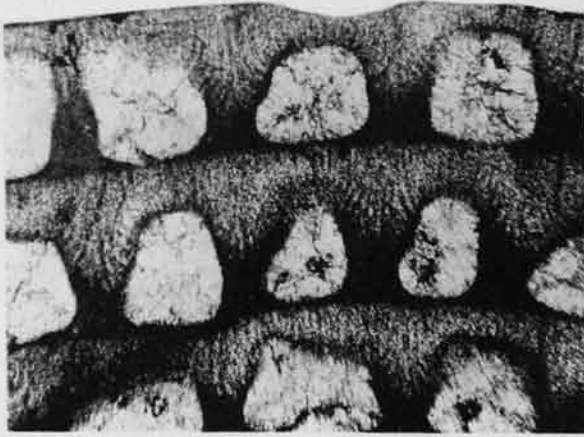
EXPLANATION OF PLATE 19

SUBFAMILY NEOSCHWAGERININAE

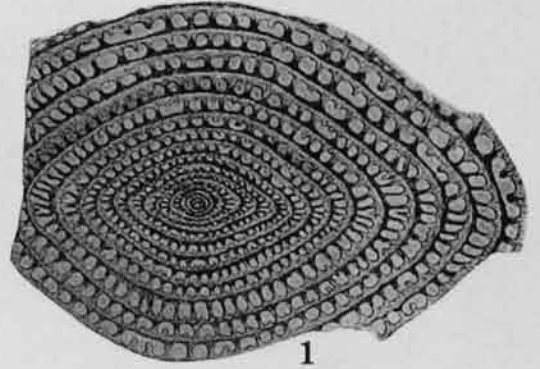
FIGURE	PAGE
GENUS SUMATRINA VOLZ, 1904	64
1-5— <i>Sumatrina longissima</i> DEPRAT, 1914. 1, Axial section, $\times 15$; 2, enlarged part of an axial section, $\times 45$; 3, enlarged part of a sagittal section, $\times 45$; 4, enlarged part of a parallel section, $\times 45$; 5, sagittal section, $\times 15$; all syntypes. Cambodge, French Indo-China. (After DEPRAT, 1914.)	
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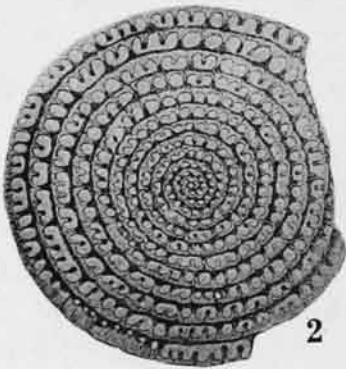
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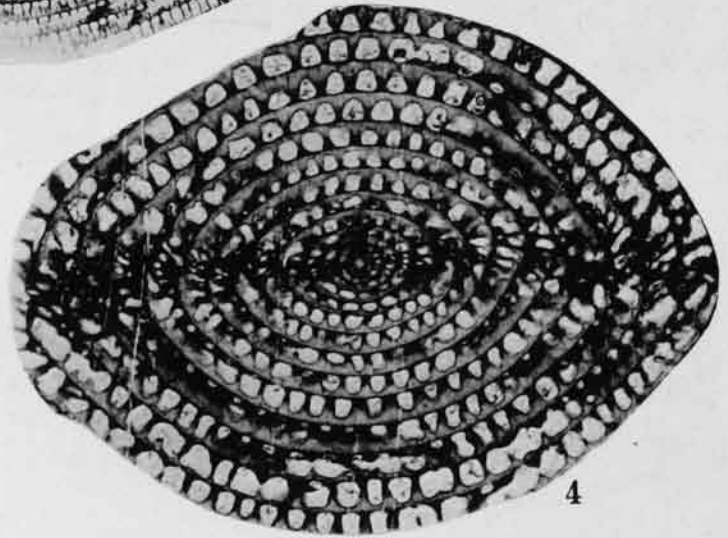
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SUBFAMILY NEOSCHWAGERININAE

FIGURE	PAGE
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1, 2— <i>Neoschwagerina craticulifera</i> (SCHWAGER), 1883. GENOTYPE. 1, Axial section of the holotype, $\times 20$; 2, sagittal section of a paratype, $\times 20$. (After SCHWAGER, 1883.)	
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5, 6— <i>Lepidolina multiseptata</i> (DEPRAT), 1912. GENOTYPE. 5, Axial section, $\times 15$; 6, tangential section of a syntype, $\times 10$. 5 from Upper Permian, Akasaka, Japan; 6 from Upper Permian, Cambodge, French Indo-China. (5 after DEPRAT, 1914; 6 after DEPRAT, 1912.)	

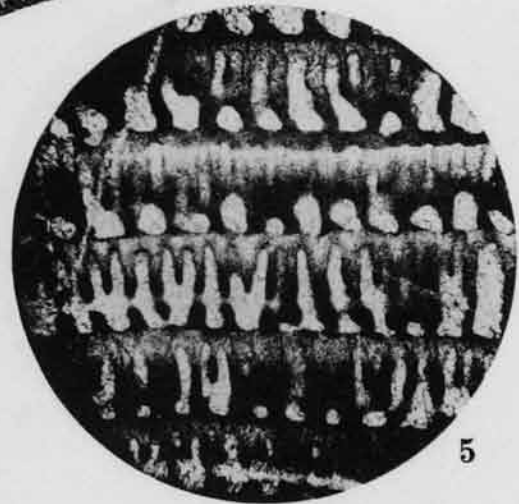
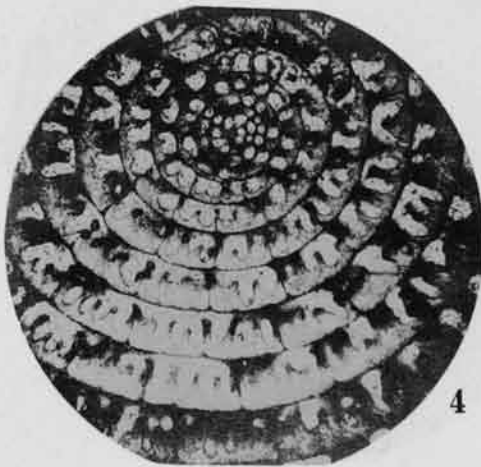
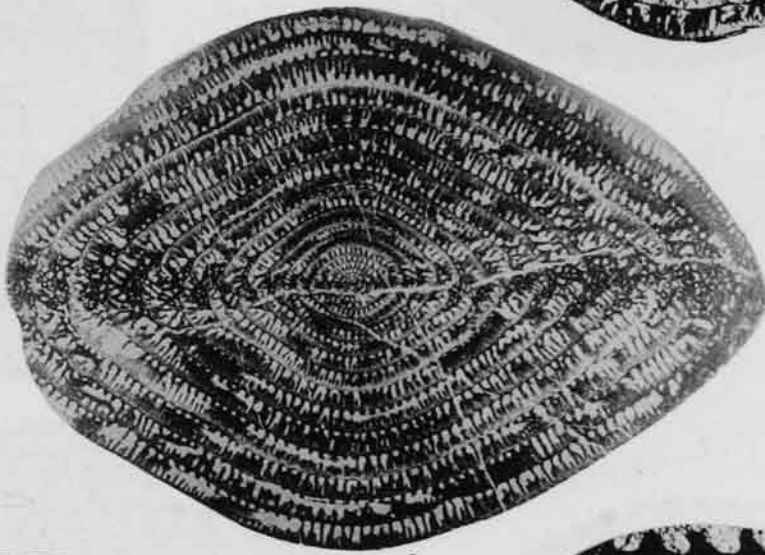
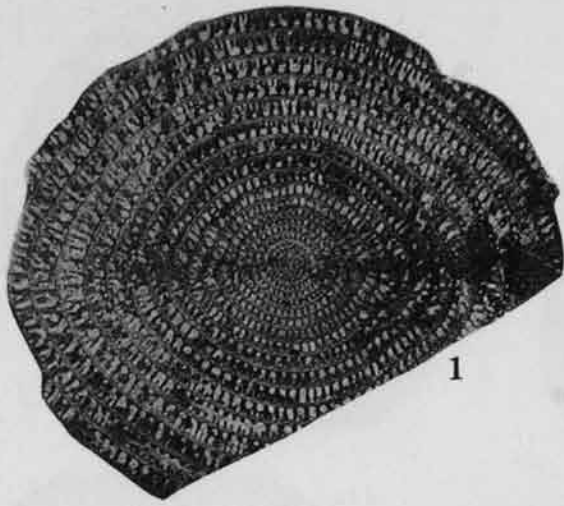
EXPLANATION OF PLATE 21

SUBFAMILY NEOSCHWAGERININAE

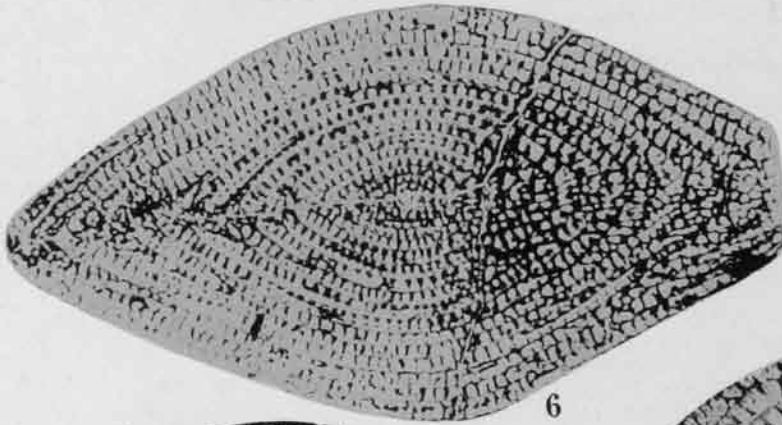
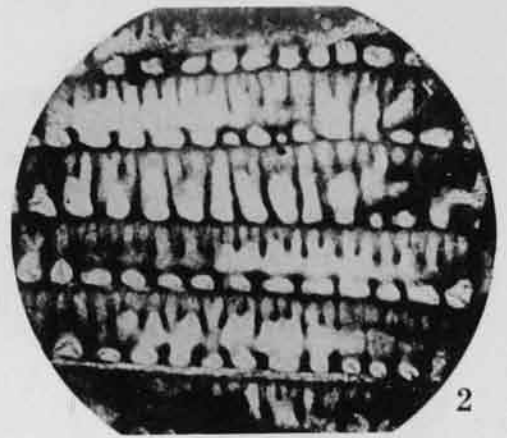
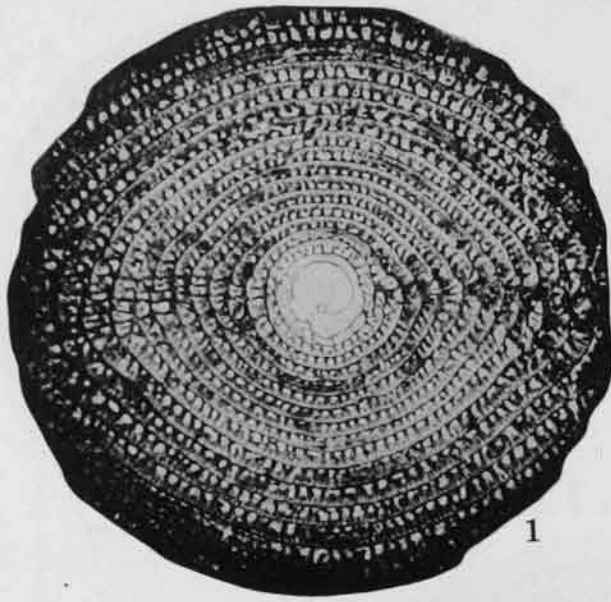
FIGURE

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| GENUS <i>YABEINA</i> DEPRAT, 1914 | 65 |
| 1— <i>Yabeina packardi</i> THOMPSON & WHEELER, 1942. Axial section of a syntype, $\times 10$. Upper Permian, Oregon. | |
| 2-5— <i>Yabeina inouyei</i> DEPRAT, 1914. GENOTYPE. 2, Sagittal section of a paratype, $\times 10$; 3, axial section of the holotype, $\times 10$; 4, enlarged part of 2; 5, enlarged part of an axial section. Upper Permian, Akasaka, Japan. (After DEPRAT, 1914.) | |



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EXPLANATION OF PLATE 22

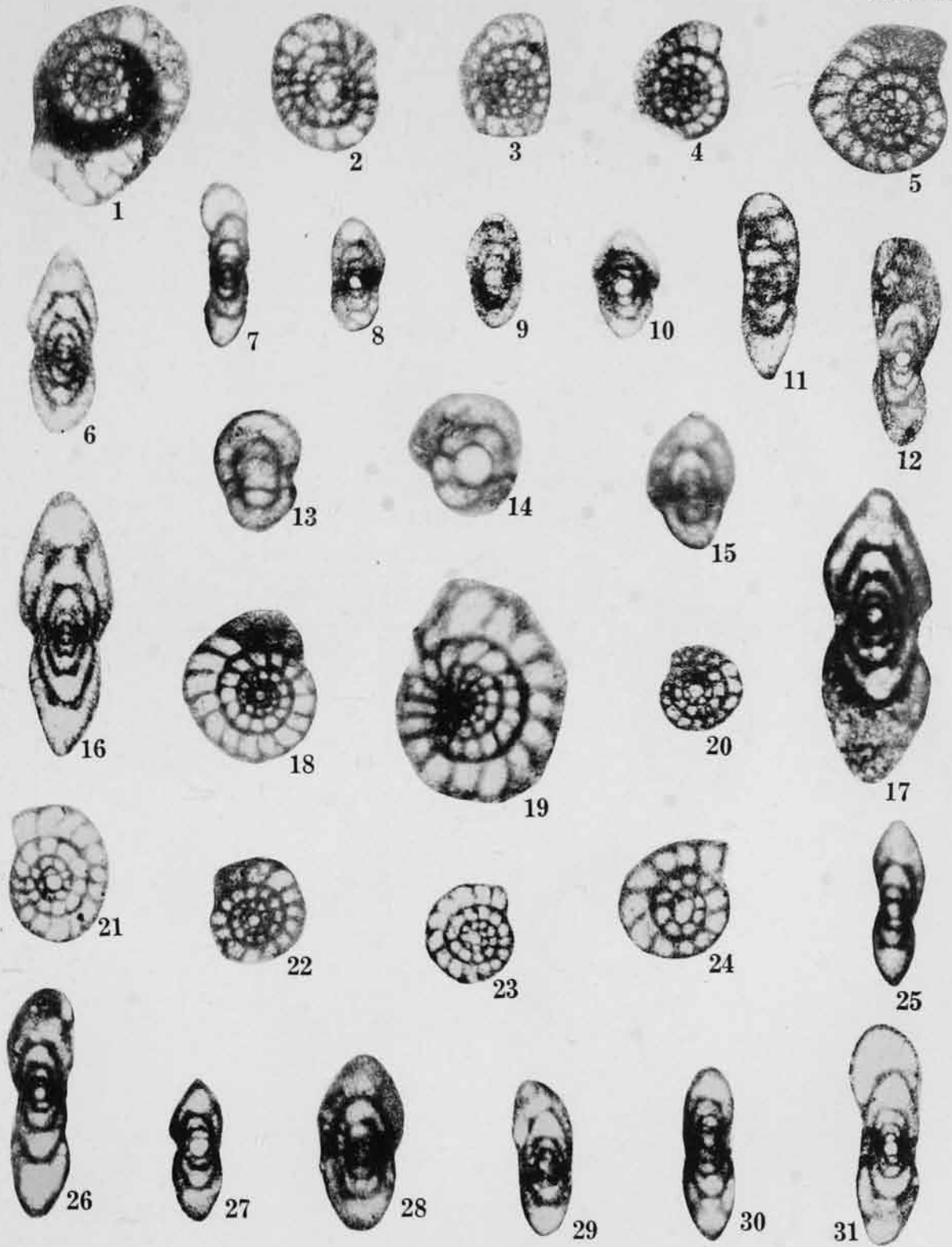
SUBFAMILY NEOSCHWAGERININAE

FIGURE	PAGE
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1-5— <i>Lepidolina multiseptata</i> (DEPRAT), 1912. GENOTYPE. 1, Axial section of the holotype, $\times 10$; 2, enlarged part of an axial section, $\times 45$; 3, enlarged part of a sagittal section, $\times 45$; 4, part of a sagittal section, $\times 15$; 5, part of a sagittal section of a paratype, $\times 10$. 1, 2, 5, from Upper Permian, Cambodge, French Indo-China; 3, 4, from Upper Permian, Akasaka, Japan. (1, 5 after DEPRAT, 1912; 2-4 after DEPRAT, 1914.)	
6— <i>Lepidolina kwangsiana</i> (LEE), 1933. Genotype of <i>Colania</i> LEE, 1933. Axial section of the holotype, $\times 15$. (After LEE, 1933.)	

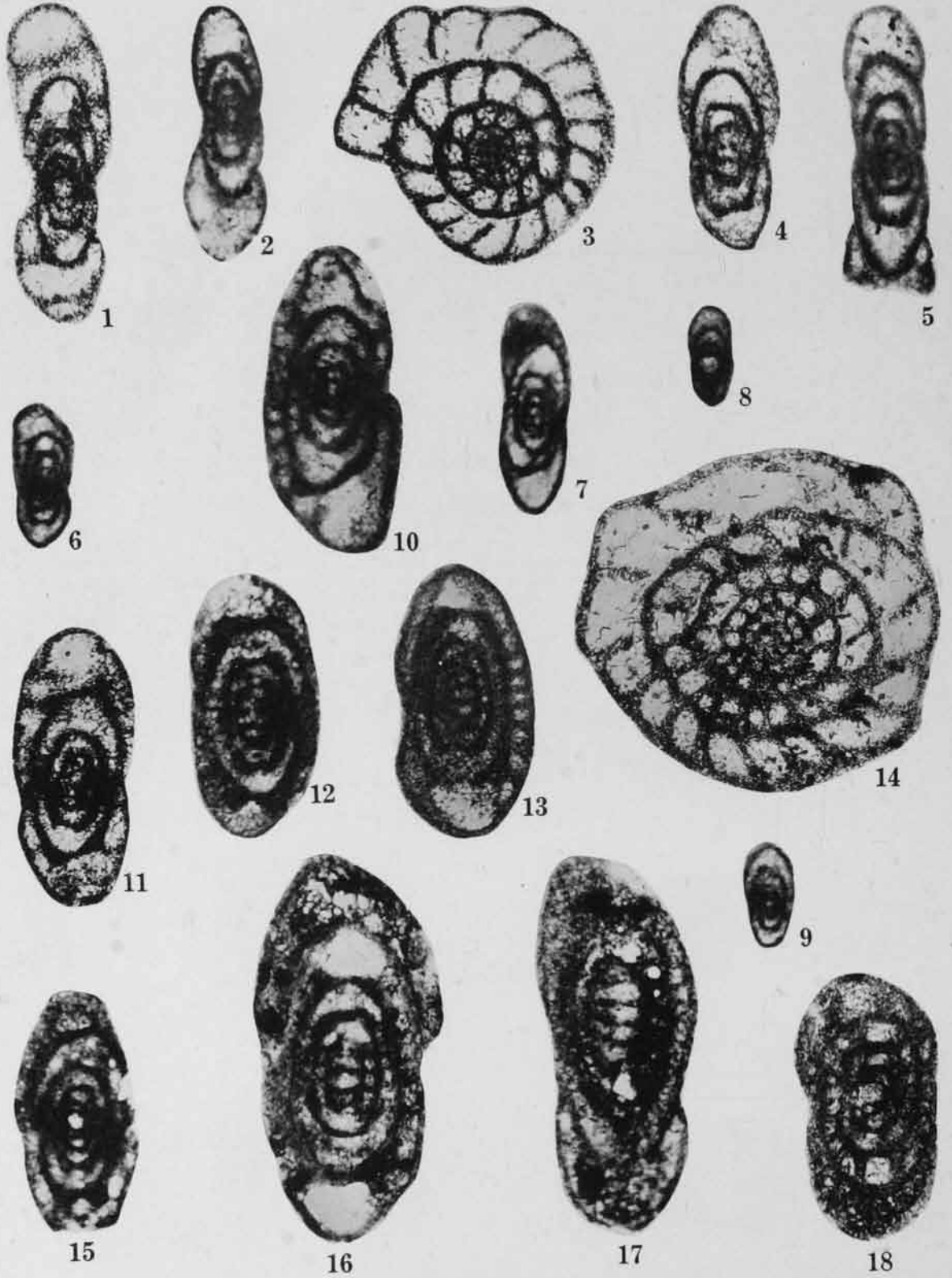
EXPLANATION OF PLATE 23

GENUS MILLERELLA

FIGURE	PAGE
1-12, 16-31— <i>Millerella marblensis</i> THOMPSON, 1942. (See, also, Plates 2, 24.).....	76
1-5 18-24, Sagittal sections, $\times 100$; 6-12, 16, 17, 25-31, axial sections, $\times 100$. 1-5, 7-12 are from Bed 1, Section 19, east of Derry, New Mexico; 6, 16 are from Bed 10, Section 21; 17 is from Bed 11, Section 21, Mud Springs Mountains; 18-20 are from Bed 5, Section 19, east of Derry; 21-24, 26-31 are from Bed 8, Section 21; and 25 is from Bed 6, Section 21, Mud Springs Mountains. Arrey formation.	
13-15— <i>Millerella?</i> sp. 13, Tangential section; 14, sagittal? section; 15, axial section; all $\times 100$. From Bed 1, Section 19, east of Derry, New Mexico. Arrey formation.	



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EXPLANATION OF PLATE 24

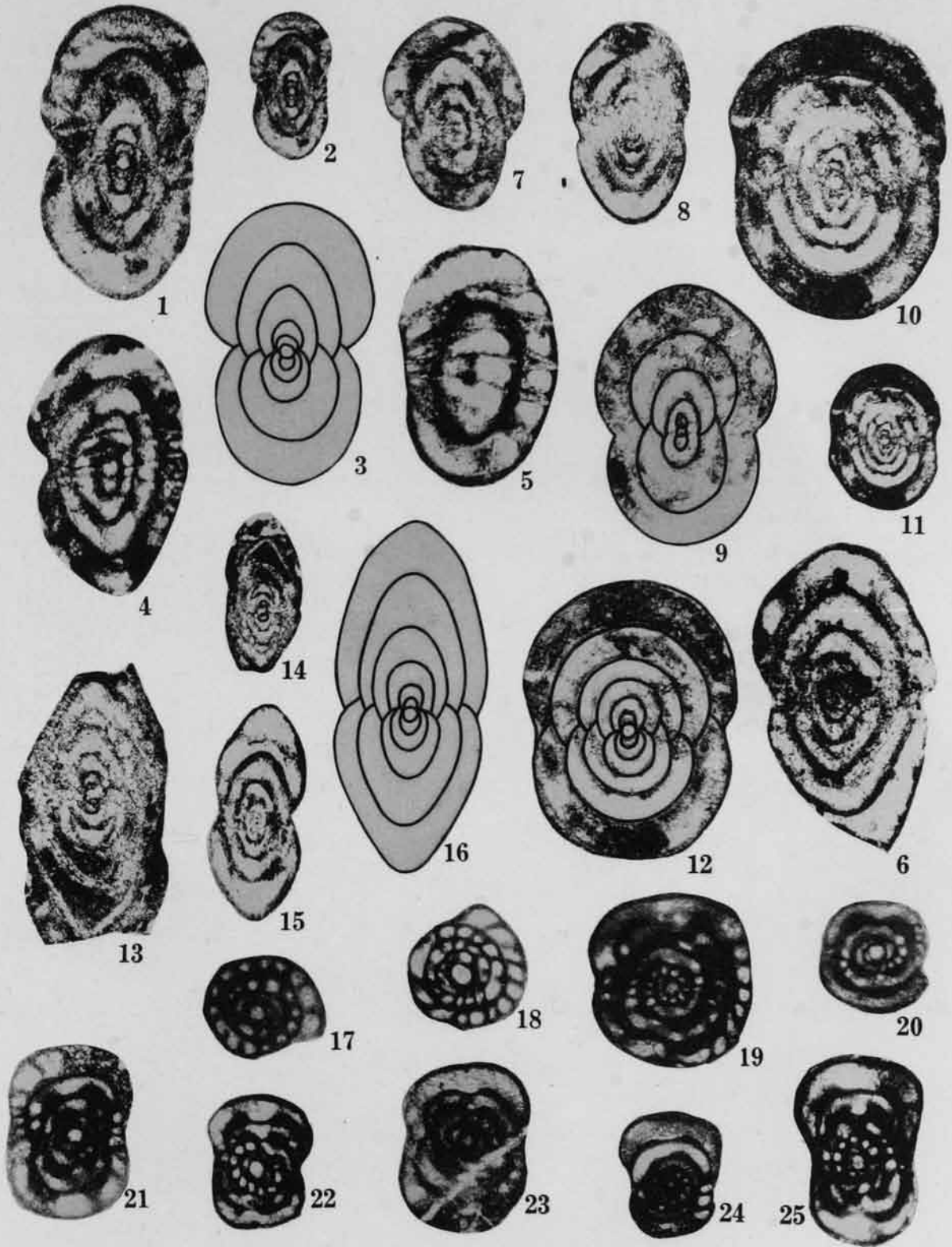
GENUS MILLERELLA

FIGURE	PAGE
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1, 2, 4-9, Axial sections, $\times 100$; 3, sagittal section, $\times 100$. 1, 3, 5 are from 240 feet above the base of Bed 8, 2 is from 170 feet above the base of Bed 8, 7-9 are from 130 feet above the base of Bed 8, and 4 is from 54 feet above the base of Bed 8, Section 52, Powwow Canyon, Texas. La Tuna limestone?	
10-15— <i>Millerella inflecta</i> THOMPSON, 1945.	76
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1-6— <i>Staffella depressa</i> , n. sp.....	77
1, 2, Axial section of the holotype, $\times 40$ and $\times 20$, respectively; 3, profile outline of holotype, $\times 40$; 4, oblique section of a paratype, $\times 40$; 5, oblique tangential section, $\times 40$; 6, axial section of a paratype, $\times 40$. All from 17 feet above the base of Bed 34, Section 17, Powwow Canyon, Texas.	
7-12— <i>Staffella powwovens</i> , n. sp.....	78
7-9, Axial sections of paratypes (9 retouched), $\times 40$; 10, 11, axial section of the holotype, $\times 40$ and $\times 20$, respectively; 12, retouched photograph of the holotype, $\times 40$. All from Bed 33, Section 17, Powwow Canyon, Texas.	
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17-25— <i>Pseudostaffella needhami</i> THOMPSON, 1942.....	80
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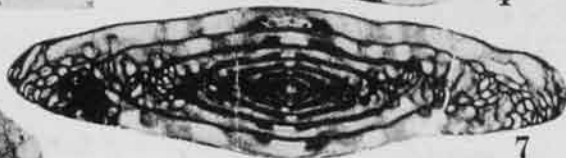
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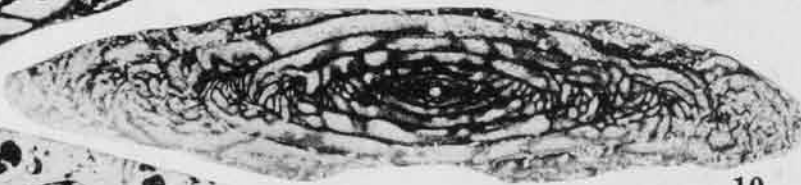
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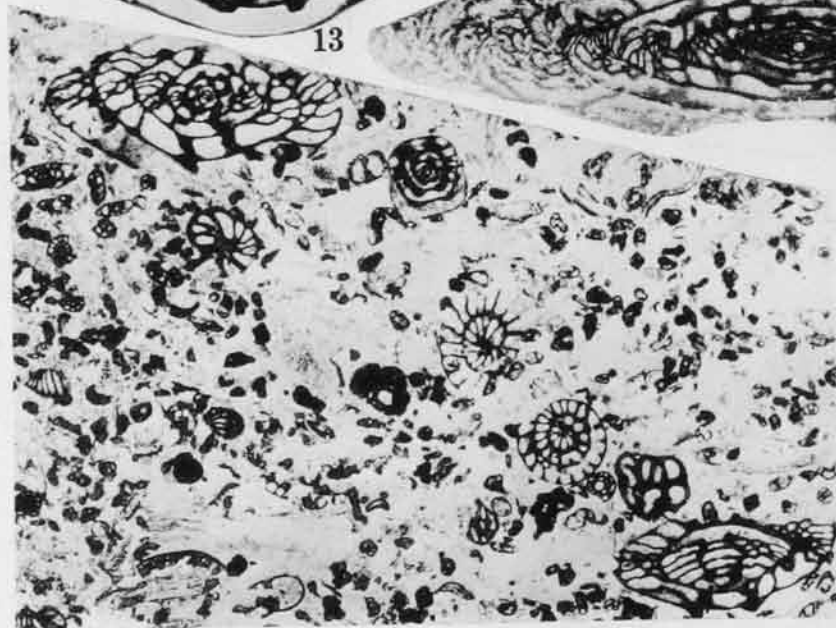
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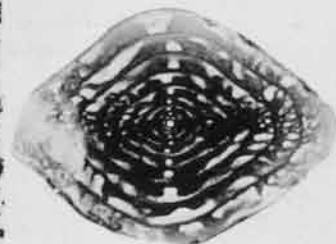
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EXPLANATION OF PLATE 26

GENERA FUSIELLA, PROFUSULINELLA, AND FUSULINELLA

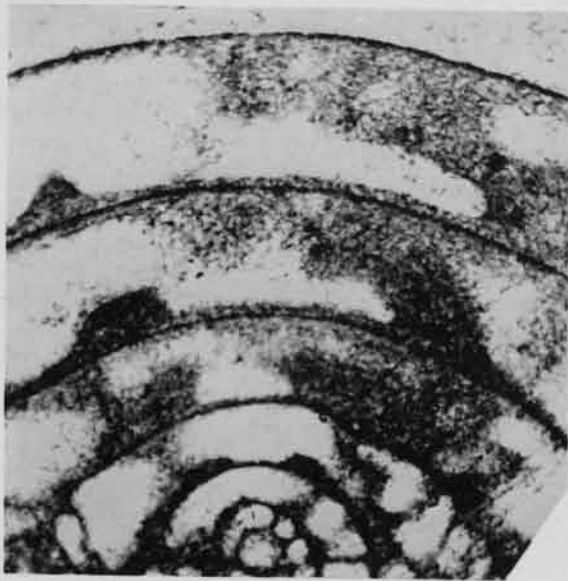
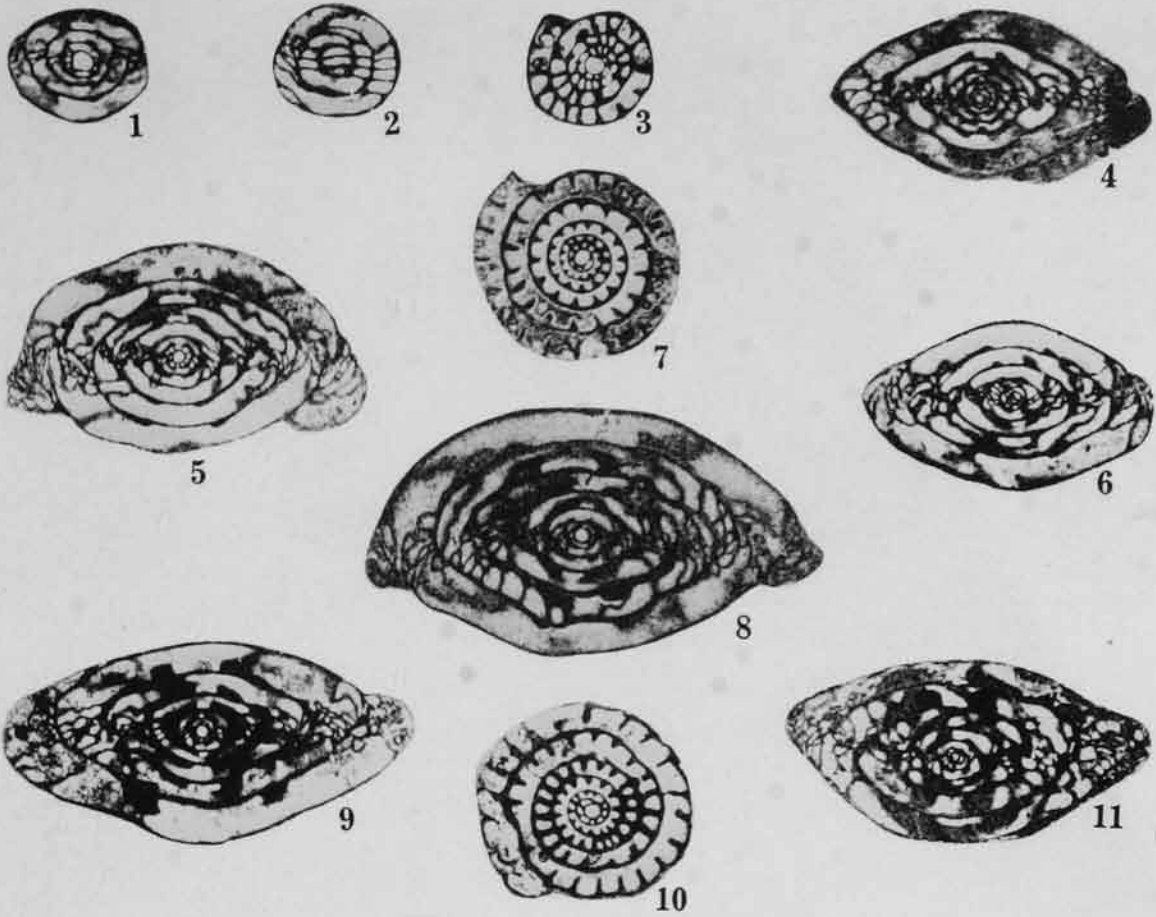
Nine previously described American species of *Profusulinella* and *Fusulinella* are illustrated here for direct comparison with Eurasian forms of *Fusiella*, *Profusulinella*, and *Fusulinella*.

- 1, 2—*Profusulinella aljutovica* RAUSER-CERNOUSOVA, 1938. 1, Enlarged part of axial section showing structure of spirotheca, $\times 100$; 2, thin section of limestone containing several sections of *P. aljutovica* associated with forms of *Pseudostaffella* and *Müllerella*, $\times 20$. Depth of 515.9-518.65 meters, Well No. 402, Samara Bend, Russia. Moscovian.
- 3—*Fusulinella prolifica* THOMPSON, 1935. Axial section of a syntype, $\times 20$. About 200 feet above the base of the Atoka formation, Oklahoma.
- 4—*Fusulinella?* *primaeva* (SKINNER), 1931. (See, also, Plate 1.) Axial section of a syntype, $\times 20$. Base of Big Saline limestone, Pflugger Bluff, Llano River, Texas.
- 5—*Fusulinella bocki* MÖLLER, 1878. (See, also, Plate 6.) Axial section of a topotype, $\times 40$. Kresty, Government of Twer, Russia.
- 6—*Fusiella typica* LEE & CHEN, 1930. (See, also, Plate 4.) Axial section of a paratype, $\times 20$. Anshan, Hohsien, Anhui, China.
- 7—*Fusulinella dakotensis* THOMPSON, 1936. Axial section of a syntype, $\times 20$. Black Hills, South Dakota. Minnelusa formation.
- 8—*Fusulinella velmae* THOMPSON, 1936. Axial section of a syntype, $\times 20$. Hartville Uplift, Wyoming. Reclamation group.
- 9—*Fusulinella protensa* THOMPSON, 1936. Axial section of a syntype, $\times 20$. Hartville Uplift, Wyoming. Reclamation group.
- 10—*Fusulinella furnishi* THOMPSON, 1936. Axial section of a syntype, $\times 20$. Black Hills, South Dakota. Minnelusa formation.
- 11—*Profusulinella fittsi* (THOMPSON), 1935. Axial section of a syntype, $\times 40$. About 100 feet above the base of the Atoka formation, Oklahoma.
- 12—*Fusulinella iowensis* THOMPSON, 1934. Axial section of the holotype, $\times 20$. Lower Cherokee shale, Iowa.
- 13—*Fusulinella llanoensis* (THOMAS), 1931. Axial section of a topotype, $\times 20$. Pflugger Bluff, Llano River, Texas. Big Saline limestone.

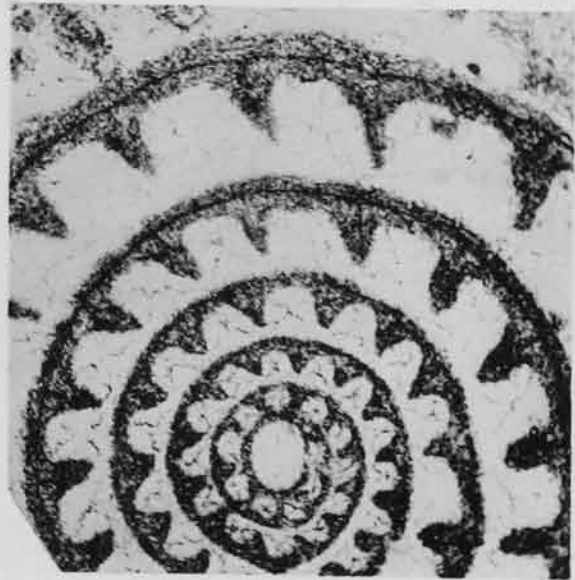
EXPLANATION OF PLATE 27

GENUS **PROFUSULINELLA**

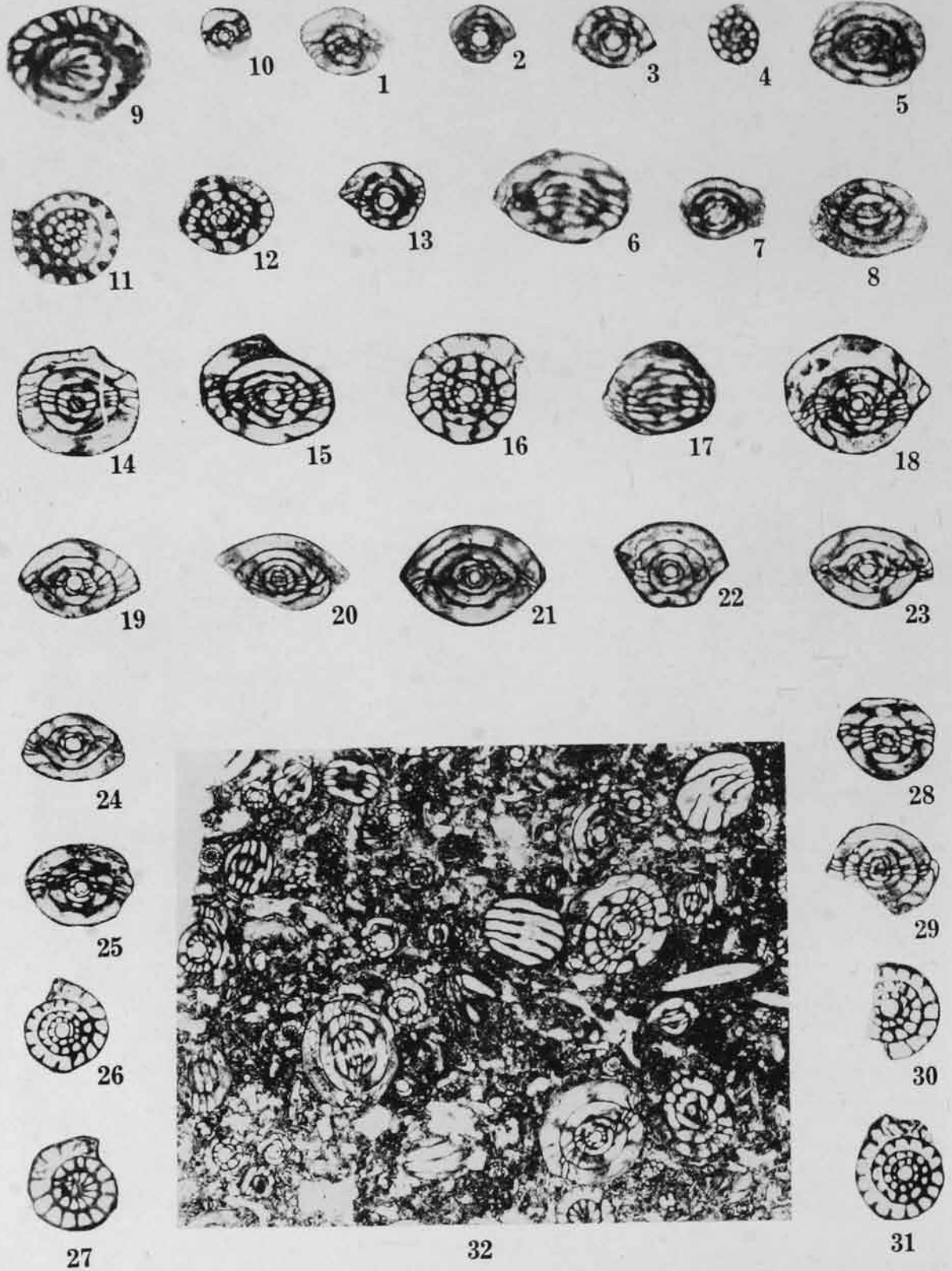
FIGURE	PAGE
1-3— <i>Profusulinella copiosa</i> , n. sp. (See, also, Plate 28.).....	80
1, Axial section of a paratype, $\times 20$; 2, tangential section of a paratype, $\times 20$; 3, sagittal section of a paratype, $\times 20$. Sixty feet above the base of Bed 25, Section 17, Powwow Canyon, Texas.	
4— <i>Profusulinella munda</i> , n. sp. (See, also, Plate 30.).....	82
Axial section of a paratype, $\times 20$. Seventeen feet above the base of Bed 34, Section 17, Powwow Canyon, Texas.	
5, 6, 12— <i>Profusulinella decora</i> , n. sp. (See, also, Plate 29.).....	83
5, 6, Axial sections of paratypes, $\times 20$; 12, enlarged part of an axial section of a paratype showing structure of spirotheca, $\times 100$. 5 is from 35 feet above the base of Bed 35, 6 and 12 are from 15 feet above the base of Bed 35, Section 17, Powwow Canyon, Texas.	
7, 8, 13— <i>Profusulinella regia</i> , n. sp. (See, also, Plates 1, 30.).....	83
7, Sagittal section of a paratype, $\times 20$; 8, axial section of a paratype, $\times 20$; 13, enlarged part of a sagittal section showing structure of spirotheca, $\times 100$. From 35 feet above the base of Bed 35, Section 17, Powwow Canyon, Texas.	
9, 10— <i>Profusulinella apodacensis</i> , n. sp. (See, also, Plate 31.).....	85
9, Axial section of a paratype, $\times 20$; 10, sagittal section of a paratype, $\times 20$. Both are from Bed 5, Section 11, Mud Springs Mountains, New Mexico. Apodaca formation.	
11— <i>Profusulinella spicata</i> , n. sp. (See, also, Plate 31.).....	86
Axial section of a paratype, $\times 20$. From Bed 16, Section 21, Mud Springs Mountains. Apodaca formation.	



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EXPLANATION OF PLATE 28

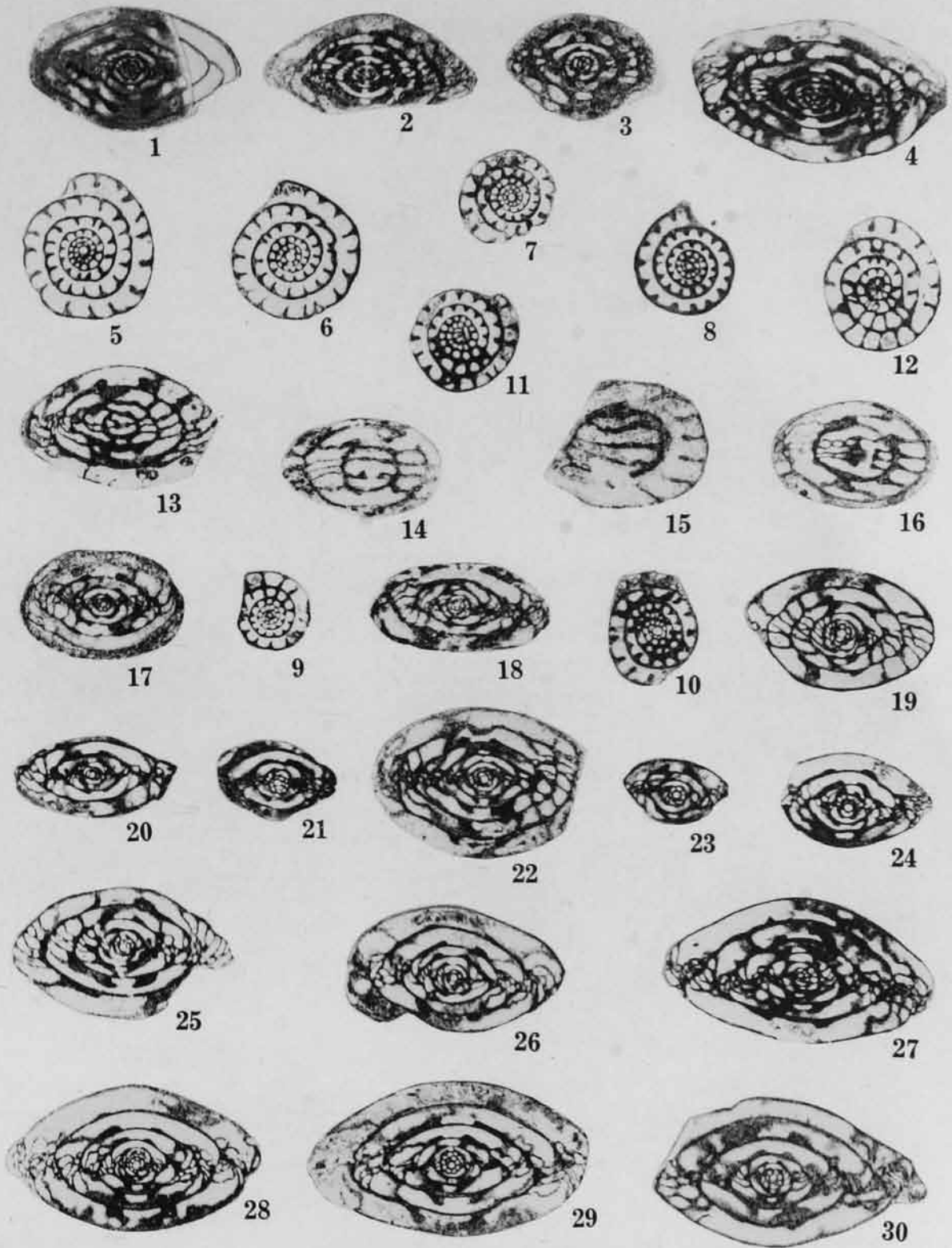
GENERA *EOSCHUBERTELLA* AND *PROFUSULINELLA*

FIGURE	PAGE
1-8— <i>Eoschubertella mexicana</i> , n. sp.	79
1, 6, 8, Tangential sections of paratypes, $\times 40$; 2, 3, 7, axial sections of paratypes, $\times 40$; 4, parallel section of a paratype, $\times 40$; 5, axial section of the holotype, $\times 40$. Bed 24, Section 11, Mud Springs Mountains, New Mexico. Upper part of the Cuchillo Negro formation.	
9-13— <i>Eoschubertella?</i> sp.	
9, 10, 12, Oblique sections, $\times 40$; 11, parallel section, $\times 40$; 13, axial section, $\times 40$. Bed 10, Section 21, Mud Springs Mountains, New Mexico. Arrey formation.	
14-32— <i>Profusulinella copiosa</i> , n. sp. (See, also, Plate 27.)	80
14, 17, 20, 28, 29, Tangential sections of paratypes, $\times 20$; 15, 18, 19, oblique axial sections of paratypes, $\times 20$; 16, 26, 30, 31, sagittal sections of paratypes, $\times 20$; 21, axial section of the holotype, $\times 20$; 22-25, axial sections of paratypes, $\times 20$; 27, parallel section of a paratype, $\times 20$; 32, section of limestone showing abundance of paratypes associated with forms of <i>Millerella</i> , $\times 20$. Sixty feet above the base of Bed 25, Section 17, Powwow Canyon, Texas.	

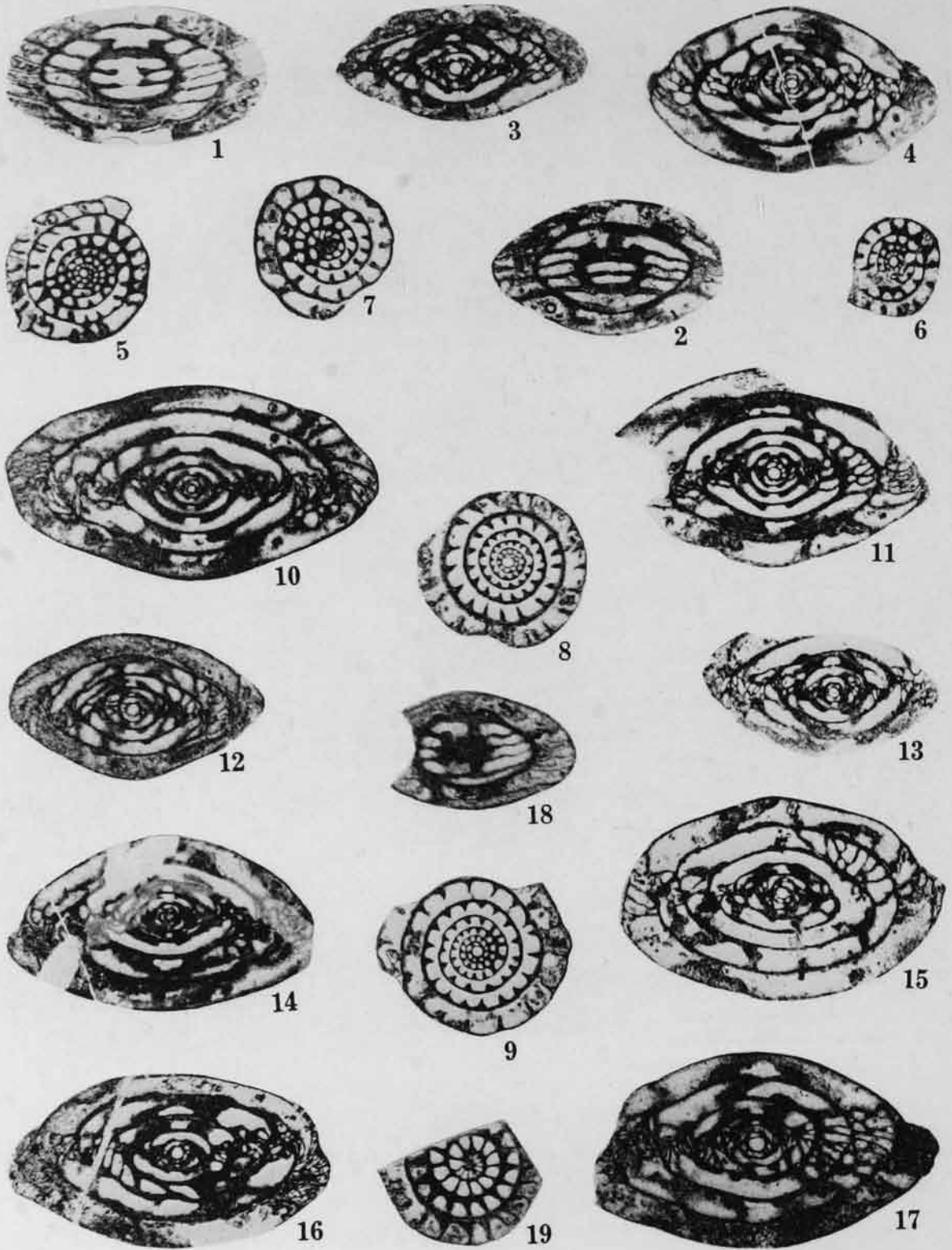
EXPLANATION OF PLATE 29

GENUS **PROFUSULINELLA**

FIGURE	PAGE
1-4— <i>Profusulinella</i> sp. A.....	87
1, 3, 4, Axial sections, $\times 20$; 2, tangential section, $\times 20$. 1-3 are from 37 feet above the base of Bed 34, and 4 is from the base of Bed 35, Section 17, Powwow Canyon, Texas.	
5-30— <i>Profusulinella decora</i> , n. sp. (See, also, Plate 27.).....	83
5-10, Sagittal sections of paratypes, $\times 20$; 11, 12, parallel sections of paratypes, $\times 20$; 13-16, tangential sections of paratypes, $\times 20$; 17-27, 29, 30, axial sections of paratypes, $\times 20$; 28, axial section of the holotype, $\times 20$. 17, 23, 26 are from the base of Bed 35 and all others are from 15 feet above the base of Bed 35, Section 17, Powwow Canyon, Texas.	



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GENUS **PROFUSULINELLA**

FIGURE	PAGE
1-7— <i>Profusulinella munda</i> , n. sp. (See, also, Plate 27.).....	82
1, 2, Tangential sections of paratypes, $\times 20$; 3, axial section of a paratype, $\times 20$; 4, axial section of the holotype, $\times 20$; 5, 6, sagittal sections of paratypes, $\times 20$; 7, parallel section of a paratype, $\times 20$. All are from 17 feet above the base of Bed 34, Section 17, Powwow Canyon, Texas.	
8-19— <i>Profusulinella regia</i> , n. sp. (See, also, Plates 1, 27.).....	83
8, 9, Sagittal sections of paratypes, $\times 20$; 10, axial section of the holotype, $\times 20$; 11-17, axial sections of paratypes, $\times 20$; 18, tangential section of a paratype, $\times 20$; 19, parallel section of a paratype, $\times 20$. All are from 35 feet above the base of Bed 35, Section 17, Powwow Canyon, Texas.	

EXPLANATION OF PLATE 31

GENUS **PROFUSULINELLA**

FIGURE	PAGE
1-9— <i>Profusulinella spicata</i> , n. sp. (See, also, Plate 27.).....	86
1, Axial section of the holotype, $\times 20$; 2-5, axial sections of paratypes, $\times 20$; 6, parallel section of a paratype, $\times 20$; 7, tangential section of a paratype, $\times 20$; 8, 9, sagittal sections of paratypes, $\times 20$. All are from Bed 16, Section 21, Mud Springs, Mountains. Apodaca formation.	
10-17— <i>Profusulinella apodacensis</i> , n. sp. (See, also, Plate 27.).....	45
10-12, Sagittal sections of paratypes, $\times 20$; 13, axial section of the holotype, $\times 20$; 14-17, axial sections of paratypes, $\times 20$. All are from Bed 5, Section 11, Mud Springs Mountains, New Mexico. Apodaca formation.	



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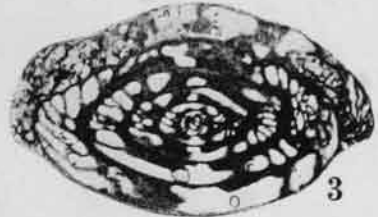
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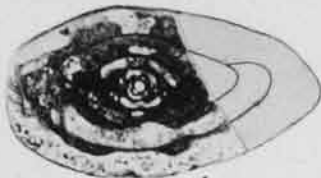
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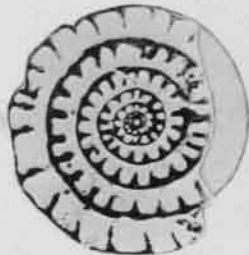
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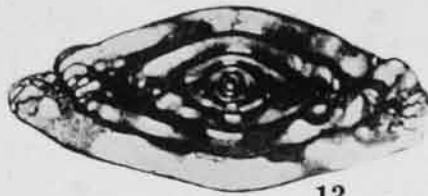
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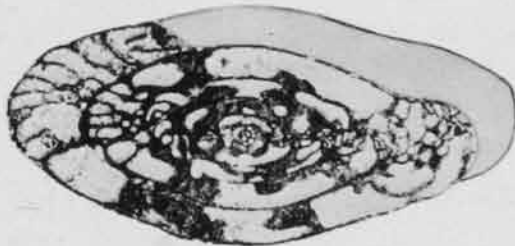
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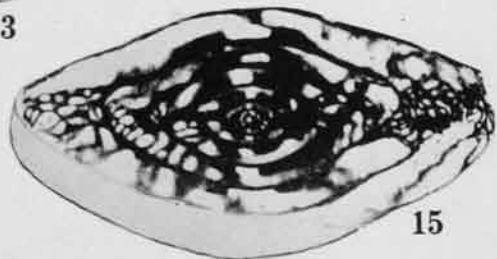
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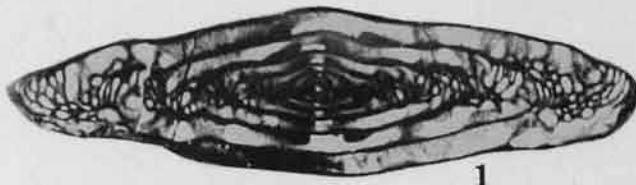
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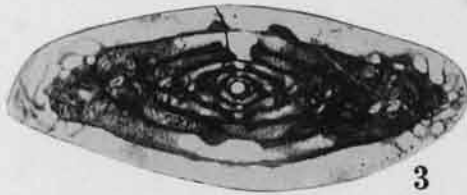
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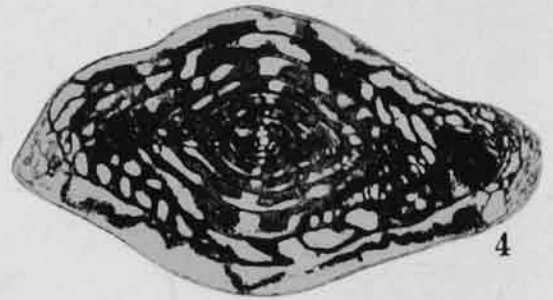
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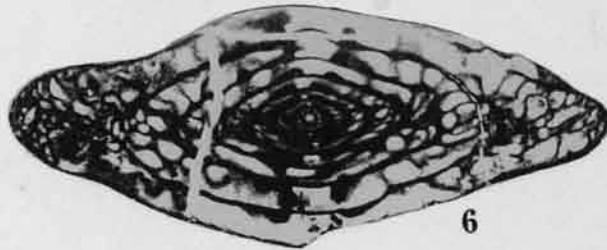
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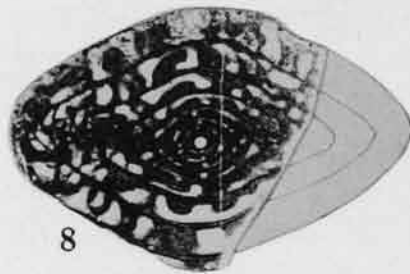
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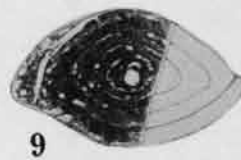
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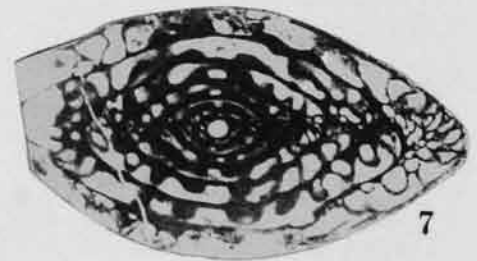
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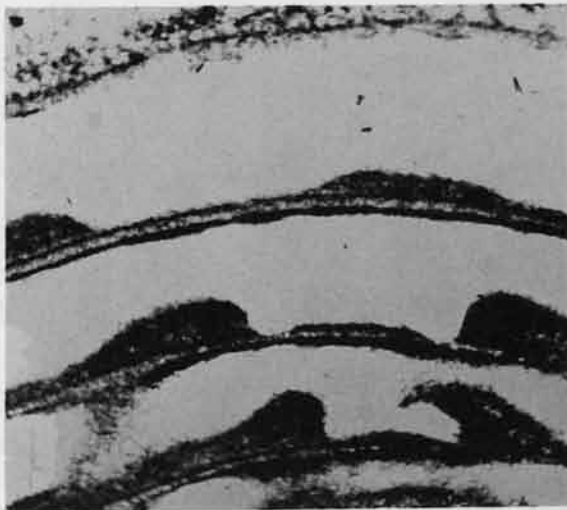
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EXPLANATION OF PLATE 32

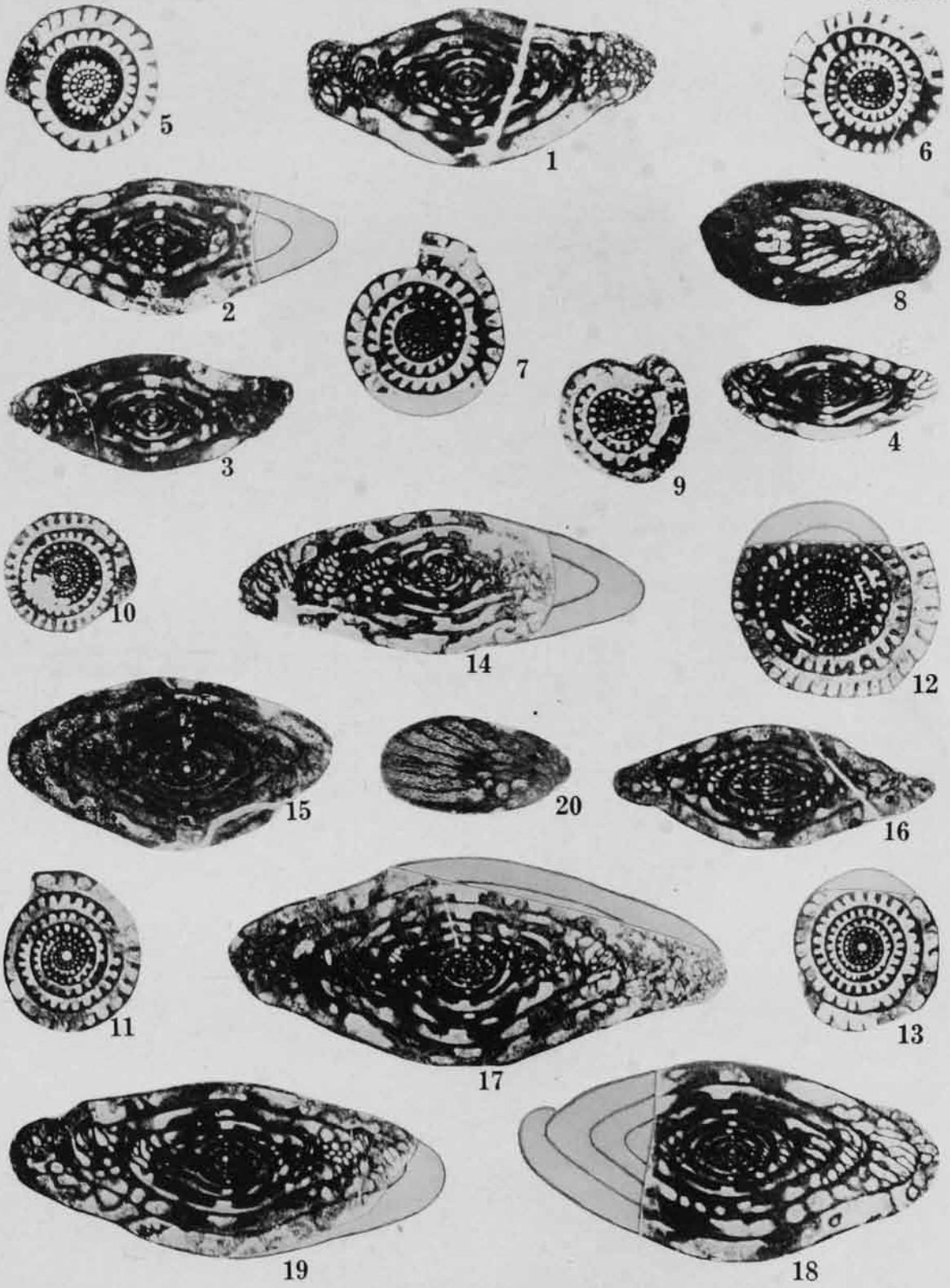
GENERA FUSULINELLA AND FUSULINA

FIGURE	PAGE
1— <i>Fusulinella juncea</i> , n. sp. (See, also, Plates 1, 37.) Axial section of a paratype, $\times 20$. From the bottom of Bed 26, Section 21, Mud Springs Mountains. Cuchillo Negro formation.	93
2— <i>Fusulinella jugax</i> , n. sp. (See, also, Plate 33.) Axial section of a paratype, $\times 20$. From Bed 10, Section 11, Mud Springs Mountains. Fra Cristobal formation.	88
3— <i>Fusulinella acuminata</i> THOMPSON, 1936. (See, also, Plate 34.) Axial section, $\times 20$. From Bed 12, Section 11, Mud Springs Mountains. Fra Cristobal formation.	89
4, 5— <i>Fusulinella famula</i> , n. sp. (See, also, Plate 38.) 4, Axial section of a paratype, $\times 20$; 5, enlarged part of a sagittal section showing structure of spirotheca, $\times 100$. From Bed 24, Section 21, Mud Springs Mountains. Cuchillo Negro formation.	91
6, 10— <i>Fusulinella deveza</i> , n. sp. (See, also, Plates 35, 36.) 6, Axial section of a paratype, $\times 20$; 10, enlargement of an axial section showing structure of spirotheca, $\times 100$. 6 is from Bed 24, Section 11; 10 is from top of Bed 26, Section 21, Mud Springs Mountains. Cuchillo Negro formation.	94
7— <i>Fusulina?</i> <i>insolita</i> , n. sp. (See, also, Plate 38.) Axial section of a paratype, $\times 20$. From Bed 24, Section 11, Mud Springs Mountains. Cuchillo Negro formation.	90
8— <i>Fusulina</i> , n. sp. Axial section, $\times 20$. From the upper part of the Warmington limestone, about 20 feet above the top of the Cuchillo Negro formation, Mud Springs Mountains.	
9— <i>Fusulinella</i> cf. <i>F. iowensis</i> THOMPSON, 1934. Axial section, $\times 20$, associated with above form of <i>Fusulina</i> , n. sp. in Warmington limestone about 20 feet above the top of the Cuchillo Negro formation, Mud Springs Mountains.	

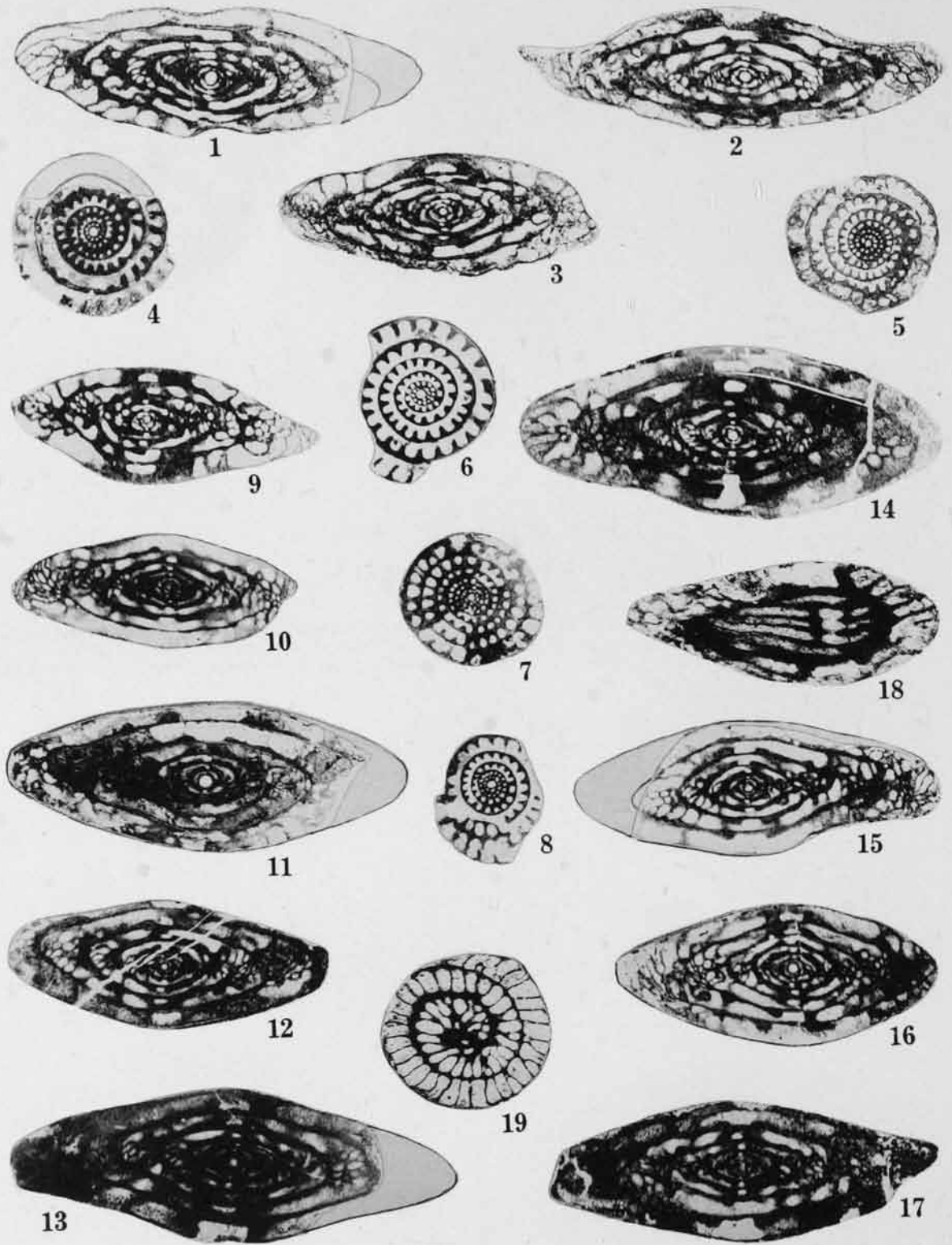
EXPLANATION OF PLATE 33

GENUS FUSULINELLA

FIGURE	PAGE
1-8— <i>Fusulinella fugax</i> , n. sp. (See, also, Plate 32.)	88
1, Axial section of the holotype, $\times 20$; 2-4, axial sections of paratypes, $\times 20$; 5-7, sagittal sections of paratypes, $\times 20$; 8, tangential section of a paratype, $\times 20$. All are from Bed 10, Section 11, Mud Springs Mountains. Fra Cristobal formation.	
9-20— <i>Fusulinella proxima</i> , n. sp.	90
9-13, Sagittal sections of paratypes, $\times 20$; 14-18, axial sections of paratypes, $\times 20$; 19, axial section of the holotype, $\times 20$. All are from Bed 17, Section 11, Mud Springs Mountains. Fra Cristobal formation.	



THOMPSON—American Fusulinids



THOMPSON—American Fusulinids

EXPLANATION OF PLATE 34

GENUS FUSULINELLA

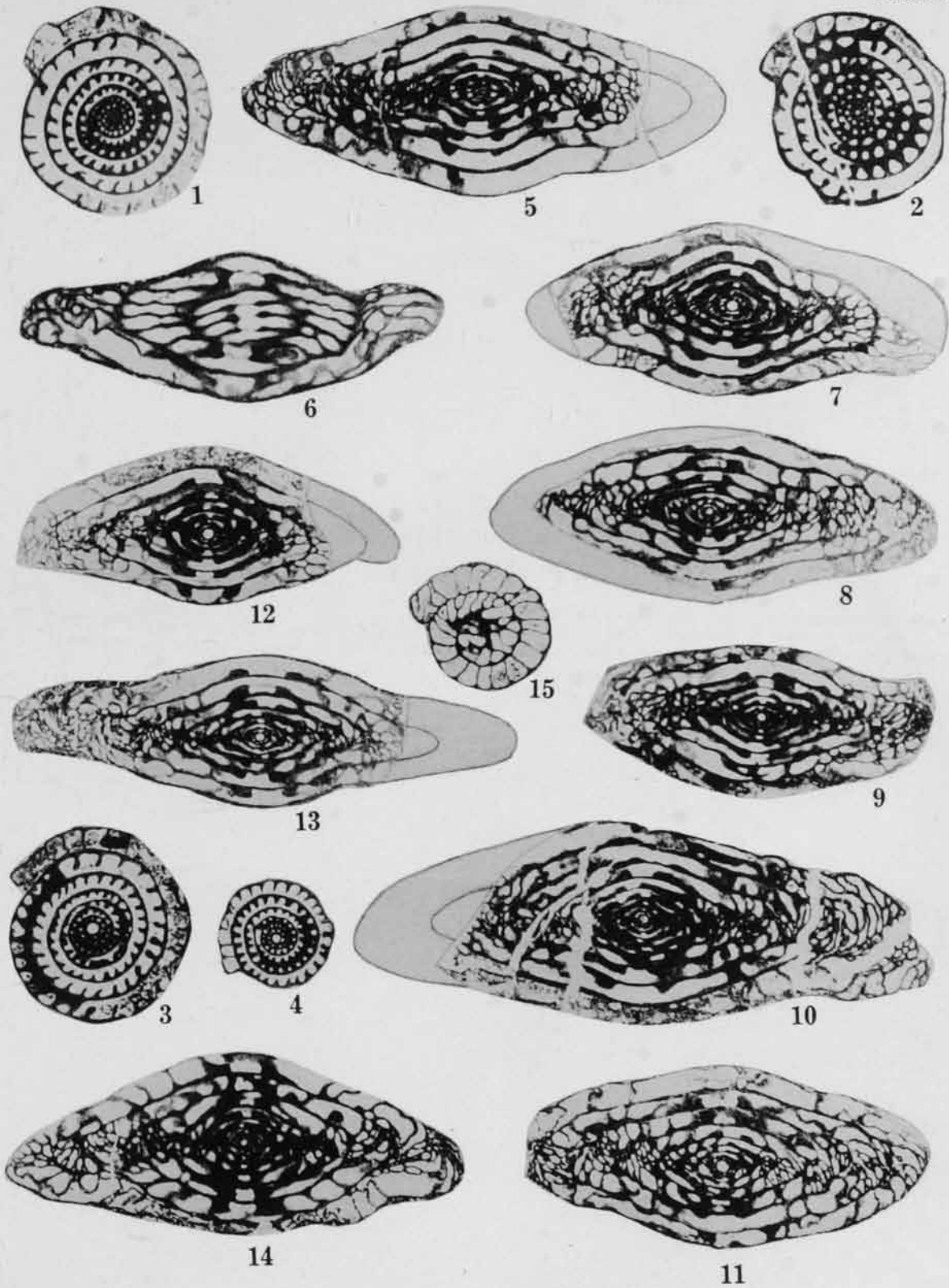
FIGURE

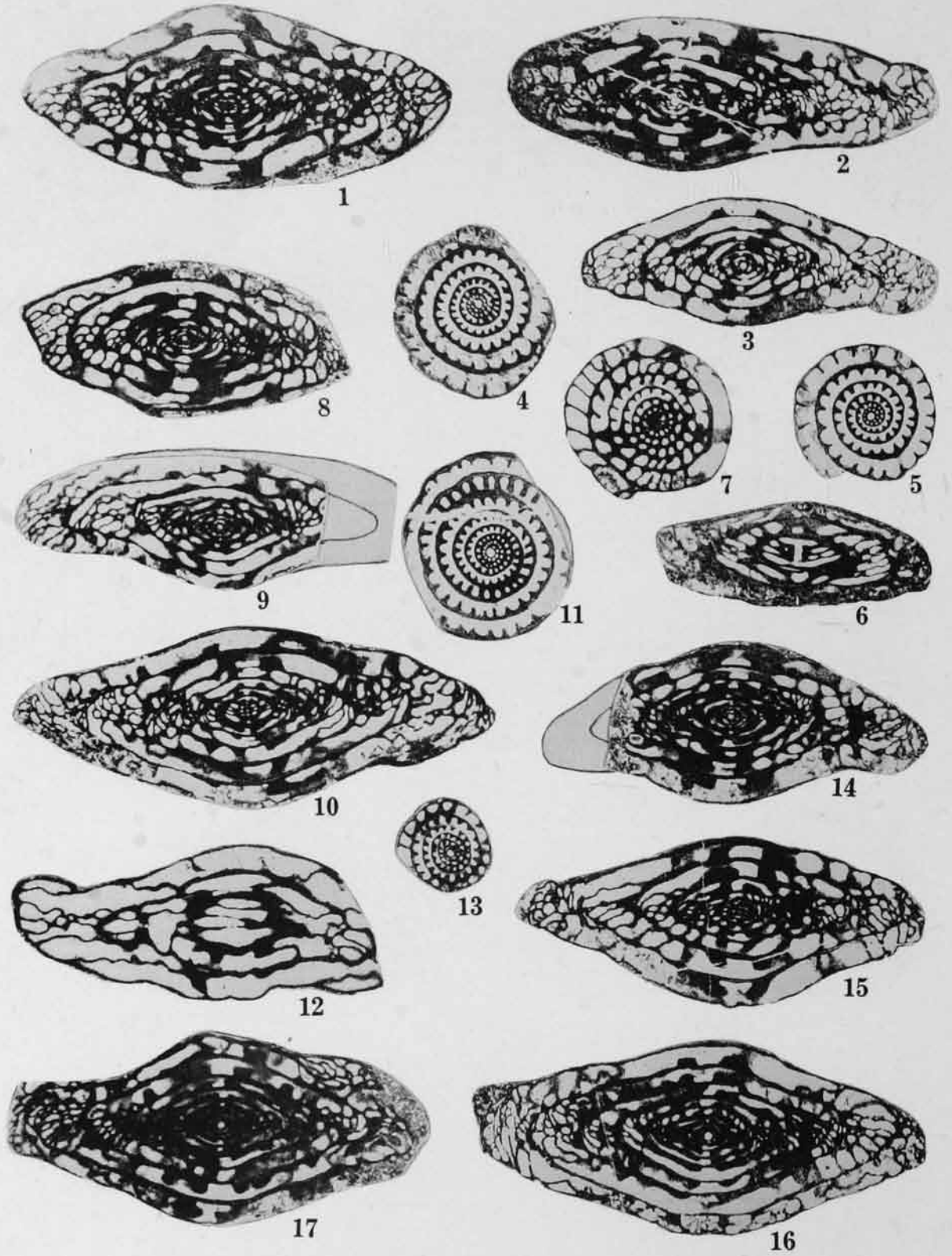
FIGURE	PAGE
1-19— <i>Fusulinella acuminata</i> THOMPSON, 1936. (See, also, Plate 32.)	89
1-3, 9-17, Axial sections, $\times 20$; 4-8, sagittal sections, $\times 20$; 18, tangential section, $\times 20$; 19, parallel section, $\times 20$. 1-3, 5 are from Bed 38, Section 17, Powwow Canyon, Texas; 4, 6, 9, 14 are from Bed 16, Section 11; 7, 8, 10-13, 15-19 are from Bed 12, Section 11, Mud Springs Mountains, New Mexico. Fra Cristobal formation.	

EXPLANATION OF PLATE 35

GENUS FUSULINELLA

FIGURE	PAGE
1-15— <i>Fusulinella deveza</i> , n. sp. (See, also, Plates 32, 36.).....	94
1-4, Sagittal sections of paratypes, $\times 20$; 5, 6, tangential sections of paratypes, $\times 20$; 7-14, axial sections of paratypes, $\times 20$; 15, parallel section of a paratype, $\times 20$. All are from Bed 21, Section 11, Mud Springs Mountains. Lower Cuchillo Negro formation.	





THOMPSON—American Fusulinids

EXPLANATION OF PLATE 36

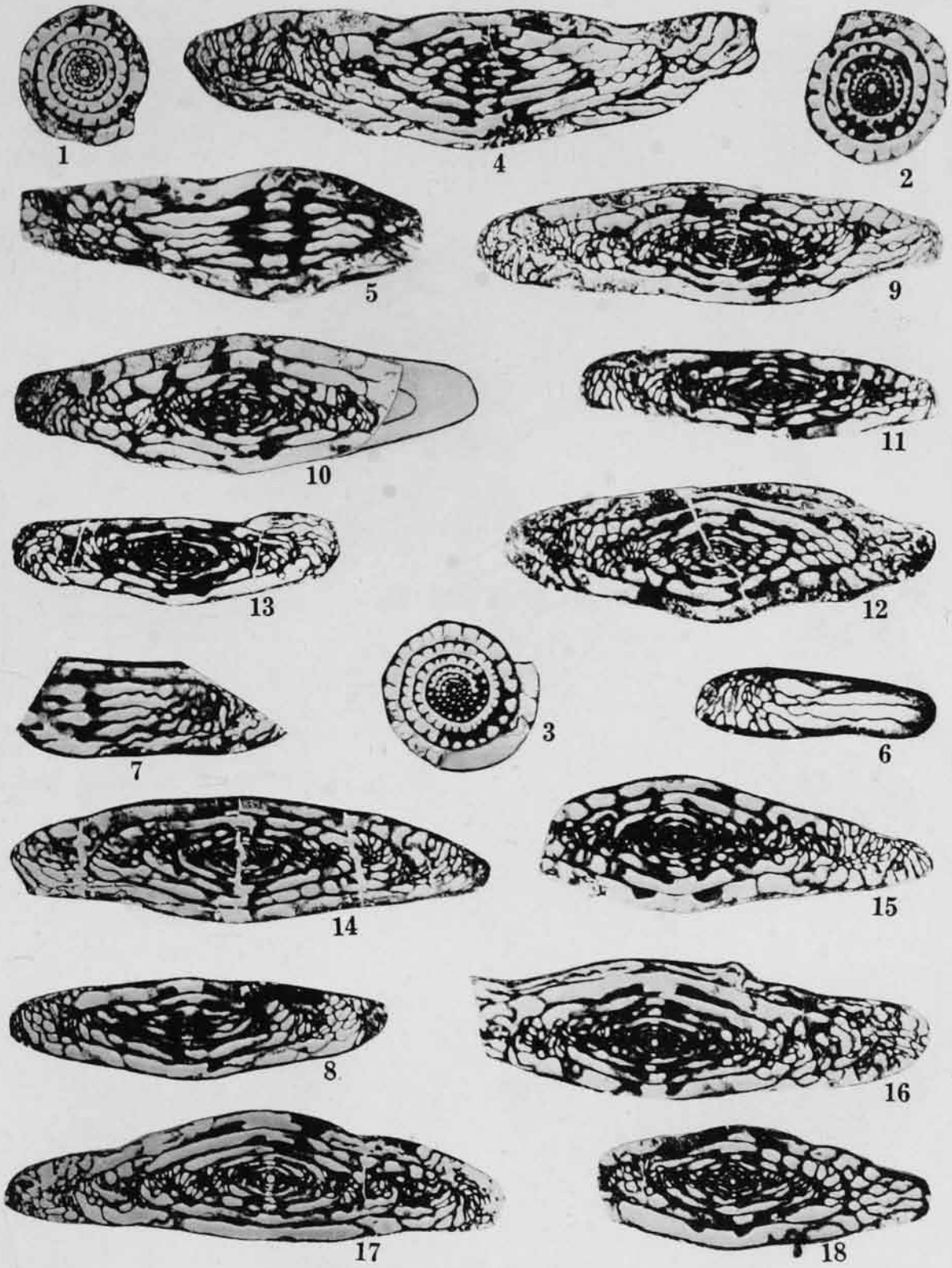
GENUS FUSULINELLA

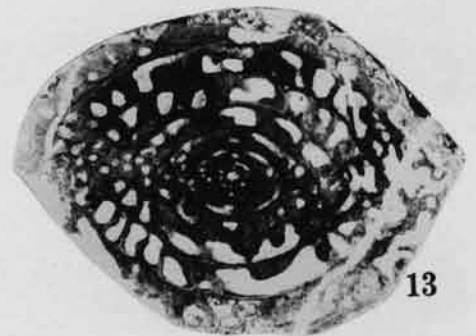
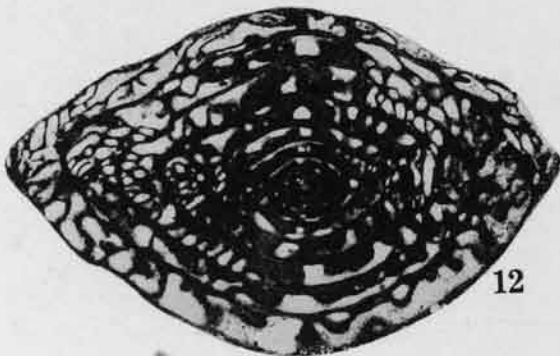
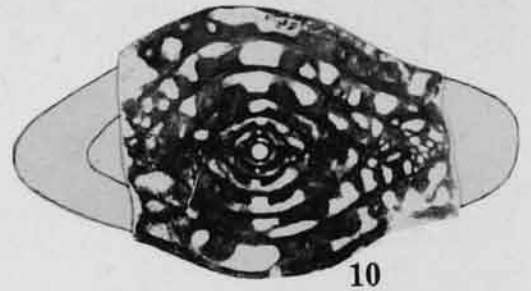
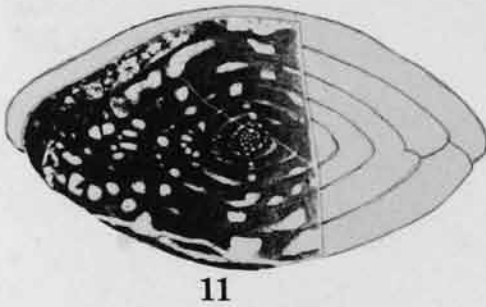
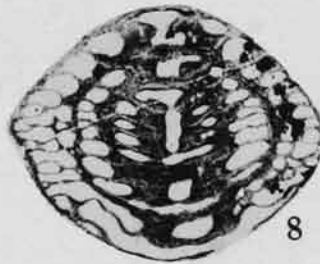
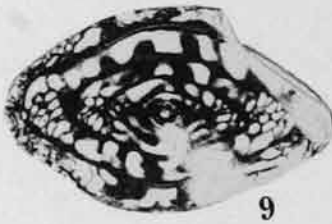
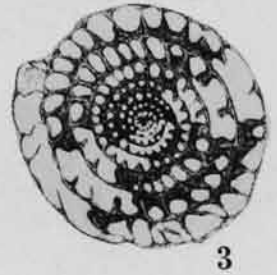
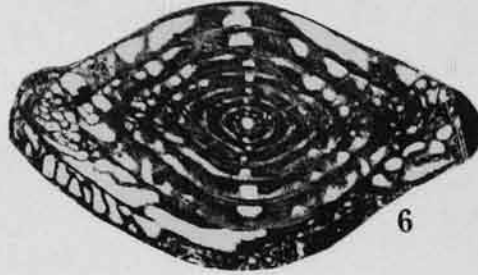
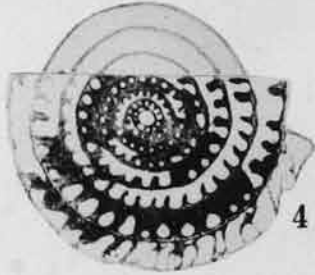
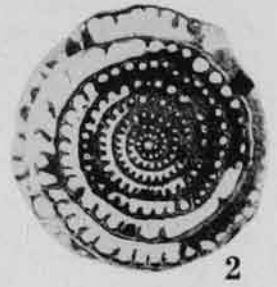
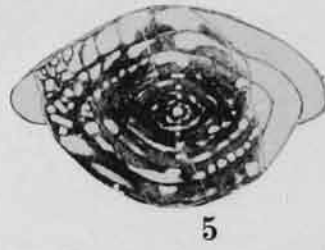
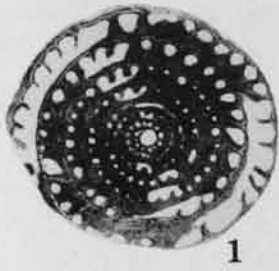
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1-6, 11— <i>Fusulinella</i> sp. A.....	96
1, 6, Tangential sections, $\times 20$; 2, 3, axial sections, $\times 20$; 4, 5, 11, sagittal sections, $\times 20$. From Bed 44, Section 17, Powwow Canyon, Texas. Cuchillo Negro formation.	
7-10, 12-17— <i>Fusulinella deveza</i> , n. sp. (See, also, Plates 32, 35.).....	94
12, 15, Tangential sections of paratypes, $\times 20$; 8-10, 14, 17, axial sections of paratypes, $\times 20$; 16, axial section of the holotype, $\times 20$; 13, sagittal section of a paratype, $\times 20$; 7, oblique section of a paratype, $\times 20$. 7, 8, 10, 12-15, 17 are from Bed 24, Section 11, Mud Springs Mountains; and 9, 16 are from the upper part of Bed 26, Section 21, Mud Springs Mountains. Upper Cuchillo Negro formation.	

EXPLANATION OF PLATE 37

GENUS *FUSULINELLA*

FIGURE	PAGE
1-18— <i>Fusulinella juncea</i> , n. sp. (See, also, Plates 1, 32.)	93
1-3, Sagittal sections of paratypes, $\times 20$; 4-8, 12, tangential sections of paratypes, $\times 20$; 9-11, 13-16, 18, axial sections of paratypes, $\times 20$; 17, axial section of the holotype, $\times 20$. 1, 2, 4, 5, 9-11 are from Bed 23, Section 11; 12, 13 are from Bed 20, Section 11, Mud Springs Mountains; 3, 6-8, 14-18 are from the lower part of Bed 26, Section 21, Mud Springs Mountains. Cuchillo Negro formation.	





EXPLANATION OF PLATE 38

GENERA **FUSULINELLA** AND **FUSULINA?**

FIGURE	PAGE
1-8— <i>Fusulinella jamula</i> , n. sp. (See, also, Plate 32.).....	91
1-4, Sagittal sections of paratypes, $\times 20$; 5, 7, axial sections of paratypes, $\times 20$; 6, axial section of the holotype, $\times 20$; 8, tangential section of a paratype, $\times 20$. All are from Bed 24, Section 11, Mud Springs Mountains. Upper Cuchillo Negro formation.	
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