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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

This study is dedicated to Dr. S. W. Williston in memory of his inspiring influence for research.

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SPECIES OF THE GENUS SCHWAGERINA AND THEIR STRATIGRAPHIC SIGNIFICANCE[1]

BY

J. W. BEEDE AND HEDWIG T. KNIKER[2]

INTRODUCTION

Species of the genus *Schwagerina* occur in most of the outcropping limestones formed in the open, connected, epicontinental seas existing at the time of the initiation of the Permian fauna and flora.

They are highly organized foraminifera, of large size, and they occupy a limited thickness of rocks. They thus form valuable horizon-markers wherever they occur.

The *Schwagerinæ* were differentiated from *Fusulina* in a definite horizon in America and Europe, and existed for longer or shorter periods, depending upon the stability of conditions in any particular region. This differentiation of the simpler forms of *Fusulina* into *Schwagerina* in one line; into *Doliolina*, followed by *Neoschwagerina* and *Sumatrina* in another line; and the giant *Fusulinæ* as a continuation of the main stem of the genus, is symbolic of changes initiated contemporaneously in the Brachiopoda, Pelecypoda, Ammonoidea, Vertebrata, plants and other forms of life which came later to characterize the fauna and flora of the Permian period.

It is the purpose of this paper to describe the known species of the genus *Schwagerina;* to discuss their relationships with the other *Fusulinæ;* their distribution throughout the Northern Hemisphere, and the analysis and correlation of the faunas with which they are associated.

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[1]Manuscript submitted for publication Sept., 1923.

[2]The senior author is responsible for all conclusions expressed in this paper. Had it not been for the careful scholarly work of Miss Kniker, which made readily available the unwieldly mass of foreign literature on the subject, this paper would not have been written.

J. W. B.

No attempt will be made to review all of the enormous mass of literature pertaining to the questions that are here involved. In fact, the mere bibliography of it would require many closely printed pages, and only a brief critical review of it would require much more space than this paper occupies. Hence, the intention is merely to analyze and correlate as briefly as possible a few typical, but critical faunas, within which all the others of similar age fall; and, in the main, agree.

If one wishes an introduction to the controversies on the subject, a good idea of its nature may be obtained from a paper entitled "The Anthracolithic or Upper Palezoic Rocks of Kansas and Related Regions," by Prosser.[3]

We wish to express our obligations to Dr. J. A. Udden for his encouragement, his kindness in furnishing the facilities, and the time for the preparation of this paper; and to express our appreciation to Dr. Charles D. Walcott, secretary of the Smithsonian Institution of Washington, D.C., and to Dr. David White, chief geologist of the United States Geological Survey, for data otherwise not available to us. We are also under obligation to Professor James Perrin Smith of Leland Stanford Junior University, and to Dr. Bruce L. Clark of the University of California, for specimens from Shasta County, California.

ANATOMICAL NOMENCLATURE

Before proceeding with the description of species, it is necessary to define the anatomical terms necessarily used in differentiating the various parts of the test. While this anatomical nomenclature has been growing up in other languages, there has been no full development of it in English. The following terms have been selected with a view to making them as simple as possible. For illustrations, see Plates I and II.

[3]Prosser, Charles S., *Journal of Geology*, XVIII, pp. 125–161, 1910.

Initial chamber.—The sphæroidal chamber, practically the center of the organism, and inclosed in the first test of the individual, whether consisting of the sexual generation, in which case it is small; or the divided form, in which case it is large.=Primoideal chamber, proloculum, embryonic chamber, etc.; *Centralkammer*, of the Germans; *loge initiale*, of the French.

Tunnel.—A relatively wide, low opening extending from the opening in the initial chamber to the outside of the last chamber of the test, in the equatorial zone where the septa fail to reach to the outer wall of the preceding whorl, but do reach it on either side=*Mundspalte* of Van Staff and others.

Basal skeleton.—A deposit of test material along the outside of the inner whorls bordering the tunnel. Nearly absent in the Schwagerinas. *Basalskelett*, of the Germans.

Outer plate.—The more opaque outer layer of the test, sometimes very thin. This plate is bent inward to form the septum (meridional septum) which separates the succeeding chambers as seen in cross-section. The *lame spirale imperforée* of Deprat; *Dachblatt* of the Germans.

Accessory skeleton.—Revolving ribs like the basal skeleton but situated between it and the poles. This does not imply that the "basal skeleton" is "basal" in the strict meaning of the term, since it is absent in some forms, notably *Schwagerina;* nor does it imply that the other spiral ribs are "accessory," though they do appear later in the history of the *Fusulininæ* than does the basal skeleton.

Inner plate.—The inner wall of *Fusulina*, and *Schwagerina*, etc., but not of *Girtyina* nor *Fusulinella*. This plate, sometimes referred to as the *perforate plate*, since it has the appearance of being perforate, lies against the lower side of the outer wall and forms the roof of the chambers. In some Asiatic *Fusulinæ*, it also extends along the whole inner side of the septum.= *Maschen-werk*, or *Weben-werk* of the Germans; *réseau alvéolaire*, or *lame spirale perforée*, of the French.

Septum.—The incurved part of the outer wall which forms the anterior side wall of the chambers, and when first formed is a curtain or wall running the length of the test, protecting the sarcode of the last chamber. In each succeeding chamber the outer plate is united to the outer plate of the preceding one at the point where it turned in to form the last septum. This union forms a slight depression lengthwise of the test. *Cloison* of the French; *Septen* of the Germans.

Axial zone.—A region occupying a smaller or larger part of the test extending to either pole from the initial chamber. This zone is composed of anastomosing folded septa, forming a more or less complicated mass of cavities and walls of varying complexity and form in different species. (Wanting in the Doliolina-Sumatrina succession.) *Filet cloisons* of the French.

Axial section.—A section cutting both poles and the initial chamber. Longitudinal section; meridional section of the French; *Axialschnitt, medianer Længsschnitt*, etc., of the Germans.

Cross-section.—Section in the plane of the equatorial diameter passing through the initial chamber. Transverse section; sagittal section, etc. *Medianer Querschnitt, medialer Sagittalschnitt, etc.*, of the Germans; *section transversale centrée* of the French.

Excentric section.—Section parallel to the cross-section, but lying between it and the poles.

Tangential section.—A section parallel to the axial section, usually near the outer margin of the test.

Diagonal section.—Any section not an axial, cross-, or tangential section.

CRITICAL DISCUSSION OF THE GENUS SCHWAGERINA S. S.

ORDER: FORAMINIFERA

Family: Nummulitidæ

Sub-family: Fusulininæ

Genus: *SCHWAGERINA Mœller*

Borelis Ehrenberg. Microgeologie, Leipzig. Tab. XXXVII, XC, figs. 1–4, 1854.

Schwagerina Mœller. Neues Jahrb., 1877, pp. 143–144. Mem. l'Acad. imp. des Scien. de St. Peterbourg, VII ser., tome XXV, pp. 69–71, 1878.

Schwager, Carboniferische Foraminiferen aus China und Japan, Richthofen's China, IV, pp. 129–132, 1883.

Schellwien, Fauna des Karnischen Fusulinenkalks. Palaeontographica, XXXIX, p. 257, 1892.

Staff und Wedekind, Der oberkarbone Foraminiferensapropelit Spitzbergens, pp. 82–123, Pl. II–IV, 1909.

Mœller's description.—Test calcareous, free, equilateral, spherical or slightly elongated transversely, and consisting of a number of spirals and completely involute volutions, of which only the last one is visible from the outside. Inside divided into thin lamella which are simple without showing the wrinkling peculiar to the preceding genus *(Fusulina)*; only when they approach the axis of the volutions they suddenly appear wave-like and strongly bent, branch and anastomose at the same time in the most varied manner, so that often some of the cells[4] originate along the axis. In height the septa are straight or somewhat curved and usually make an acute angle with the outer shell wall. Their union with the shell wall takes place in a similar fashion as in the preceding genus; that is, each septum is wedged in between the outer walls of two adjoining chambers and unites with the outer layer of the shell wall. At their lower margins the septa are supplied with semi-lunar, low, median openings whereas there is usually a similar opening in the wall of the test. Chambers simple without secondary divisions, and as a result of the small thickness of the septa, rather roomy; but the elliptical central chamber is usually small. The inrolling of the shell follows a cyclocentric and at the same time entocentric pliospiral. The shell wall is thin and punctured by pore canals which have a very small diameter and are separated from each other by even smaller intervals. The surface is covered with regular longitudinal furrows which are sometimes bent slightly, and each corresponds to an interior septum. In grown forms the shell is closed as a result of the transition from the spiral to a centric roll.

The genus has been revised by the authors cited above in each instance, and it has finally been restricted so that the following brief diagnosis will distinguish it from all other Foraminifera.

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[4]Cell is used in the common sense of the term, an enclosed space.

Generic diagnosis.—Tests imperforate, like those of *Fusulina*, but with four much more distinct growth stages which are as follows:

1. The *nepionic* stage, represented by the initial chamber.

2. The *neanic*, or *Fusulina* stage, the youthful portion of the test exhibiting phylogenetic characters. It may be subdivided into two sub-stages, the first three or four rather irregular chambers constituting the first part of this stage.

3. The *ephebic*, or adult stage, characterized by the inflated portion of the test which is very loosely wound with high septal chambers, septa very thin, long, and remotely spaced, while the walls of these volutions are thin.

4. The *gerontic*, or senile stage, where the whorls revert to the characteristics of the earlier part of the shell, in which it is more closely wound with cyclic volutions, thicker walls and septa, lower and narrower septal chambers.

These growth stages were described as such by Schellwien, phylogentic characters assigned to them, and the second stage was referred to previously by Mœller as the "Fusulina stage."

The individuals are much more highly inflated than the Fusulinas, though a few species of the latter genus are more rotund in outer appearance than the longer species of *Schwagerina*, but lack the inflated ephebic stage and thin walls. Transitional forms connecting the species of the two genera are found, notably *F. fusulinoides* Schellwien from the Carnic Alps, and also found in the Hueco Mountains of West Texas.

Occurrence.—Schwagerina limestone of the Urals and its equivalents in Eurasia and North America. In some instances persists well up into the Artinskian (above the Artinskian ammonoid horizon) as indicated by its occurrence in the Sicilian and Yun Nan Permian deposits.

Two groups of species belonging to the genus *Schwagerina* as now understood, possess different types of fusuliniform growth stages, and it is possible that the genus as it is at present defined, is diphyletic in the sense that each group may have been derived from a different ancestral type of *Fusulina*, though the final conclusion of the matter awaits the detailed determination of the actual ancestral species of one of the groups.

A number of groups of closely related foraminifera have been referred to *Schwagerina*, but have since been separated from it. They are: *Doliolina, Verbeekina, Yabeina, Neo-Schwagerina*, and *Sumatrina*. The first mentioned genus is the oldest known form. They occur near the close of the Pennsylvanian and the basal Permian and the other genera follow in regular succession to the upper Permian.

Lately Deprat again referred the genus *Verbeekina* to *Schwagerina*, first as a subgenus and later the species of *Verbeekina* were referred to *Schwagerina* s. s.[5]

In the light of the work which had preceded him, it is very difficult to see why this should be done. That he clearly recognized the fundamental difference between the two groups of shells is shown in his description of *S. amadaei*, in which he lists the characters of the two groups, naming the five species of *Schwagerina* s. s. then known to him as "forms elongated in youth"; that is, with axially elongated neanic stages; and the three known species of *Verbeekina* as "forms transverse in youth," or having the axial diameter of the neanic stage shorter than the equatorial, or transverse, diameter.

In addition to these characters, the inflated ephebic stage is wanting and the septal graph shows a very different curve.

While these differences, which hold for all the species of each of the two groups, are not all that can be pointed out, they are sufficient to show that the two groups are different enough both ontogenetically and structurally, to constitute two distinct genera. These differences may be recognized by comparing the figures of *Schwagerina* with that of *Verbeekina* on the plates.

Moreover, in his diagrammatic figures, showing the

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[5]Deprat. In four memoirs in Mém. de Sérv. Géologique de l'Indo-Chine. Vols. I-IV, 1912–1915.

characteristic shell structure of the different genera, or sub-genera as they are classed, Deprat shows *Schwagerina* as having the inner plate extending down the septum. His figure is here reproduced (Plate V, Fig. 6). As a matter of fact, no such structure is known from European or American species of *Schwagerina* s. s. If the Asiatic species have such characters—they are not clearly shown in Deprat's plates—they must be referred to a structurally different sub-genus.

However, it is true that in the gerontic stage near the end of the last whorl, the outer plate sometimes bends inward very feebly and uncertainly to form one of the last septa, and in this feeble bending the inner plate is continued out farther than usual. Sometimes, in a last rally of the vitality of the individual, another chamber or two is added to the test. In this case the outer plate of the added wall may unite with that of the preceding chamber near where the first slight inflexion occurred, with the result that an extension of the inner plate of this antecedent chamber projects along the septum beyond the junction of the outer plate of the succeeding chamber.

Still another instance in which this phenomenon may be seen is in the case of accidental injury of the test of an individual, in which the inner plate is developed a little distance down the septum. However, in no known case of all the specimens sectioned, nor in any of the figures that have been used in their reproduction. is there any basis in fact warranting Deprat's interpretation of the septal structure of *Schwagerina* s. s., unless it be his Asiatic species. This is illustrated in the plates of our species as well as in the reproduction of the figures of the European species.

Another confusing thing in Deprat's work was the description of "*Schwagerina prisca*" from the lower Moscovian, far below any previously known horizon containing species of *Schwagerina* s. s. This species has few, if any, of the characteristics of *Schwagerina* s. s., aside from its external form, which comports well with the typical species of the genus, having the ratio of diameter to length of 1:1.3.

However, its similarity to *Schwagerina* stops with this character, if we are to judge from Deprat's diagrammatic figure (Fig. 4, p. 10, 1912) and the photographs of sections of it shown on the plate, as well as by his description. The septa are thick and straight rather than thin and slightly flexuous. The inner plate extends two-thirds the distance to the extremity of each septum instead of being confined to the top of the chamber. There are not more than three instead of four stages of growth discernable; the form of the neanic stage is not typical, as it is much more nearly globular than in any known species of *Schwagerina.* Figures 10 and 11 show a well defined basal skeleton on either side of an equally well defined tunnel, which agrees with *Fusulina*, but not with *Schwagerina.*

In other words, "*Schwagerina prisca*" Deprat possesses the critical character of a *Fusulina* instead of a *Schwagerina.* Two of Deprat's figures are reproduced to show the characters of this remarkable species. As he suggests, this species may be the ancestor of the whole group of Doliolinas, but he is probably in error in concluding that it is the ancestor of *Schwagerina* s. s., for the latter is already fairly well known, and is of very different character. Since this species is very different from *Fusulina prisca* Schellwien, the name *Fusulina deprati* n. n. is proposed for "*Schwagerina prisca.*"

The elimination of this species from the Schwagerinas leaves the latter beginning with No. 13 of Deprat's Yun-Nan section, which he refers to the Uralian, and which Frech referred to the lower Dyas.

DESCRIPTION OF SPECIES

SCHWAGERINA PRINCEPS (Ehrenberg) Mœller

Plates I:III:V. Figs. 5–8:5–7, 9:6.

Borelis princeps Ehrenberg, Berichte der Kœnigl. Preuss. Akad. der Wissen zu Berlin, p. 274, 1842.

Mikrogeologie Tab. XXXVII, X, C, figs. 1–4, 1854.

Schwagerina princeps Mœller, Die spiral gewundenen Foraminiferen des russichen Kohlenkalks. Mém. l'Akad. des Sciences, St. Petersbourg, XXV, No. 9, p. 71, Pl. IX, la, b. 1878.

Schwager, Carboniferische Foraminiferen aus China und Japan, Richthofen's China, IV, p. 132, taf. XVII, figs. 1–8, 1883.

Schellwien, Fauna des Karnischen Fusulinenkalks, Palaeontographica, pp. 258–259, taf. XXI, figs 5–7, 9; XXII, figs. 4–7, 1892.

Staff, Die Anatomie und Physiologie der Fusulinen. Zoologica, XXII(p. 56, 1910. Beiträge zur Kenntniss der Fusuliniden, Jahrbuch für Min. Geol. und Pal., Beilage Band XXVII, pp. 466, 467, 473, 1909.

Deprat, Fusulinidés du Japon, de Chine et l'Indo-Chine, et classification des calcaires á Fusulines, Mém. 1, p. 38, f. 22; Pl. I, ff. 1, 3; p. 40, f. 1, 1a, 1912.

Mœller's description.—Shell not completely spherical but drawn out slightly transversely, pointed distinctly at both ends. Initial chamber ellipsoidal but very small, so that the diameter of its median cross-section is only a fortieth or even smaller fraction of that of the whole test. The form of this chamber in young individuals calls for an elongated spindle-shaped shell which assumes only gradually a more nearly globular form. The opening of the initial chamber is relatively large and its diameter represents about one-third the diameter of the chamber. The development of the volutions takes place after a cyclocentric- diplo- (if not triplo-) centric spiral whose inner part, embracing about five volutions, represents a logarithmic spiral with quotients equal to 2, but the outer part which consists of only two or three volutions, represents a conchospiral with quotients of 1.35. It is closed by a cyclic volution. Therefore, in older individuals the number of spiral walls amounts to seven or eight, of which the outer one contains thirty to thirty-five septa. The septa are straight or somewhat bent and are supplied with a low median opening whose breadth amounts to a twelfth to a fifth part of the whole breadth of the volutions, but the height has . . . smaller dimensions. The axial zone is well represented. The shell walls range up to 0.125 mm. in thickness, but the septa are not more than 0.05 mm. thick. The pore canals in the outermost whorls attain a diameter of 0.012 and are separated by distances of approximately 0.01 mm. The surface is covered with longitudinal furrows distantly separated which are bent somewhat anteriorly in the middle of the shell. It reaches a size of 6 mm. in length and 5 mm. in diameter.

MŒLLER'S STATISTICS

Number of volution	Diameter volution	Length volution	Ratio	Number of chambers	Diameter of initial chamber
1	1. mm.	2 mm.	1:2	9	
2	3.	4	1:1.33	12	
3	4.5	5	1:1.22	16	
4	5.	6	1:1.2	22	0.1 mm.
5				26	

The section is slightly excentric; and the data correspondingly inaccurate. Schellwien's figures show the following statistics for specimens described from the Carnic Alps:

Volution	Chambers	Length	Diameter initial Chamber
1	10	.1	.025 mm.
2	14	.175	
3	15	.55	
4	14	1.55	
5	19	3.97	
½ whorl 6	11	...	

Staff gives the critical ratios for *S. princeps* as 1:1.2 to 1:1.3.

It appears that Schellwien's section is not quite truly axial which shortens the polar diameter to a slight extent. This is quite apparent if Figure 9 is compared with Figure 6 of his plate (XXI).

Staff's cross-section of "*S. princeps*" on page 56 of his *Anatomie und Physiologie der Fusulinen* is in all probability taken from a specimen belonging to a different species from that figured by Schellwien, or the ones used as types by Mœller. There appear to be three or four closely wound volutions with the whole test much more closely knit than the other figures of specimens referred to this species.

The diameters of the whorls as shown in Schwager's cross-section[6] are as follows:

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[6]*Op. cit.*, Taf. XVII, f. 2, 3.

Whorl	1	.082 mm.	
	2	.16	
	3	.28	Inflation begins gradually with volution 2½. Measurements from whorl 4 taken from Fig. 2.
	4	2.85	
	5	3.78	
	6	4.43	
	7	5.78	
½	8	3.15 (6.3[7])	

It is clearly shown by Schwager's drawings that the axial section shown in Figures 1 and 3 of the same plate are not through the center of the test and that the initial chamber is not shown. As a consequence the statistics of this tangential section show nearly the reverse of what the actual conditions must be. It would be impossible to get any such cross-sections as shown in Figures 2 and 4 from an organism constructed in any such manner as illustrated in Figures 1 and 3. Figure 1 has been reproduced by Frech and by Staff.[8]

The section shown by Staff[9] as a slide from Mœller from the limestone of Bjelaja is not a typical *S. princeps*. It may possibly be either *S. yabei* or an allied species.

One is, perhaps wrongly, led to the conclusion that the subspherical Schwagerinas have been rather indiscriminately referred to *S. princeps*. What seems to be needed is to make careful collections of the European representatives of these fossils, bed by bed, from accurately measured sections, and to have large numbers of them sectioned and carefully compared; those from distant regions being treated similarly. Schellwien did this in the Carnic Alps. Deprat has done this to a very great extent for the South China and Indo-China deposits, with very remarkable and valuable results.[10]

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[7]Laethae Paleozoica, II, p. 288.

[8]Die Anatomie u. Physiologie d. Fusulinen, p. 60, f. 49.

[9]Beiträge zur Kenntniss der Fusulinen, p. 466; Di Anatomie u. Physiologie der Fusulinen, p. 56.

[10]Deprat, J., Etude comparative des Fusulinidés d'Akasaka (Japon) et des Fusulinidés de Chine et d'Indo-Chine. Mém. du Sérv. Géol. de l'Indo-Chine; and other similar titles found in Vols. III and IV, 1912–1915.

Horizon and localities.—Mœller's sectioned specimens which should be considered the types, came from "dem oberen Kohlenkalk von der Muendung des Bjelaja-Fl., zufluss der Indiga im Timengebirge" (Russia). It is the characteristic fossil of the Schwagerina limestone of eastern European Russia, where it also occurs in the lower Artinsk. It is reported from beds of the same horizon in the Donez Basin, possibly from Crimea, from the Carnic Alps, in the upper Trogkofel beds, from the "Carboniferous" in See-Tai-hu, Tche-Mo, Mi-Leu, and Yun-Nan in China, and from Bali Maaden in Persia, etc. These occurrences will be reviewed in the discussion of the distribution of the Schwagerina beds.

SCHWAGERINA ROBUSTA (Meek) Mœller

Plates IV, VIII. Figs. 1–5:2.

Fusulina robusta Meek, Geol. Surv. Cal., Pal., I. pp. 3, 4, Pl. II, ff. 3, 3a–c, 1864.

Bardot de Manry, Geologische Reise in den nördlichen Provinzen des europäischen Russlands, K. Russ. Mineral. Gesell. 2te ser., III Band, S. 239, 1868.

Brady, Fossil foraminifera from Sumatra. Geol. Mag., Decade II, Vol. II, p. 538, 1875.

Stuckenberg, Bericht ueber eine Reise in des petshoraland u. das Timangebirge. Beiträge zur Geologie Russlands, K. Russ. Mineral. Gesell., VI, p. 103, 1875.

Schwagerina princeps? Mœller, Die spiralgewundenen Foraminiferen des russischen Kohlenkalks, Mém. l'Akad. des Sciences, St. Petersbourg, 7th ser., Tome XXV, No. 9, p. 71, Pl. IX, fig. 1a–b, 1878.

Schwager, Carboniferische Foraminiferen aus China und Japan, p. 132, Pl. XVI, figs. 15, 16; Pl. XVII, figs. 1–8, 1883.

Staff, Die Fusulinen (Schellwienen) Nordamerikas, Palaeontographica, LIX, p. 185, 1912.

No free specimens of this species are at hand, and specimens have to be sectioned in the matrix which makes carefully orientated sections difficult to obtain. Meek's description of the external features of the shell is:

"Shell oval-subglobose, the longer diameter being to the shorter as 26 to 20. Surface with longitudinal, linear, slightly impressed furrows, placed at regular intervals, one over each septum and extending from end to end,—becoming a little twisted as they approach the extremities. Volutions five or six, the last or outer one being usually less conspicuous than one or two of those immediately within. . . . . Greatest length of one of the largest specimens, 0.4 inch; breadth of same, 0.32 inch. Average size, about one-fourth less.

STATISTICS OF TWO CROSS-SECTIONS

	Number of Septal chambers of 2 specimens		Diameter of initial chamber
Whorl No. 1	11	12?	
2	20	12 loose	
3	23+	12 loose	
4	15 loose	21	.3 mm.
5	20	31	
6	broken away	....	

No section was obtained sufficiently close to the axis to afford statistics of value. Sections at hand show it to be somewhat more elongate than *S. princeps*, and while there is very considerable variation in the size of the initial chamber, yet the smallest one seen is very much larger than that of *S. princeps;* and the largest still very much larger. The one figured by Staff has a relatively small chamber, but the entire first whorl of *S. princeps* could easily be placed within it.[11] The differences between the species are sufficient to prevent confusion in dealing with them.

There are probably two species, or even three of them, present in the rocks at Bass's Ranch, California, one of which is apparently quite different from the other. The more elongate form appears more like *S. kansasensis*, but our material is too limited to permit of final determination

[11]Beiträge zur Kenntniss der Fusuliniden. Neues Jahrbuch, Beilage Band XXVII, Pl. VII, f. 4, 1909.

of the species. The initial chambers of the two species are too different—without being dimorphic forms of the same species—to permit of their reference to one species.

Horizon and locality.—Schwagerina limestone, Bass's Ranch, Shasta County, California. Specimens were furnished by Dr. James Perrin Smith and Dr. Bruce L. Clark.

SCHWAGERINA FUSULINOIDES Schellwien

Plates I:III:VII. Figs. 4:1–4, 8:1–3.

Schwagerina fusulinoides Schellwien, Die Fauna des karnischen Fusulinenkalks, Palaeontographica, XXXIX, pp. 259–260, Taf. XXI, figs. 1–4, 8, 1892.
Staff, Beiträge zur Kenntniss der Fusuliniden, Jahrb. f. Min. Geol. u. Pal., Beilage Band XXVII, p. 467, Pl. VIII, figs. 11, 12, 1909.

Schellwien's description.—The form in hand is most closely related to the Fusulinas of all the Schwagerinas now known.

Form.—Spindle-shaped; from the inflated middle it slopes symmetrically to the distinctly pointed ends, which are moderately twisted. The surface is covered with shallow longitudinal furrows which are bent toward the front in the middle of the shell. The dimensions of the different individuals vary considerably in the same growth stage. Most specimens are about 3 mm. in diameter and 6 mm. broad, but some shells occur which have a height of nearly 4 mm. and a length of 9.5 mm. The relation of height to length is, as a rule, 1:2, but varies with the individuals measured from 1:1.8 to 1:2.8. The spiral of our form varies also in the heights of the volutions in different shells, so that it is not deemed necessary to state the height of the middle whorls. As in *Schwagerina princeps*, it is also characterized by the close winding of the first few volutions, the abrupt inflation of the middle whorls, and the small increase in the last whorls; however, not in the same degree as the Carnic *S. princeps* shows them. The initial chamber is regularly spherical and relatively large. It reaches a diameter of 0.25 mm. The septa, whose formation takes place in the same way as in *Fusulina*, are short and thick in the first whorls, then they become as thin as in *S. princeps*, so that they are something like 0.02 mm. in thickness, while in the last whorls they again show a thickness of 0.07. They are always more or less bent anteriorly. In the middle part of the shell they never extend to the floor. Not rarely thickenings of the septa are found, especially in the last volutions. The number of the septa is, on the average, in the second to the sixth volutions: 14, 14, 16, 21, 25. The septa are bent back and forth considerably more than in all other Schwagerinas; however, this fluting does not reach the same degree as in the true Fusulinas and it especially does not reach so high up on the septum. The development of the structure in the axial zone is quite strong. The largest number of volutions observed was 6.5. The thickness of the walls varies less than in *S. princeps*. It reached in the third volution about 0.05 mm.; in the sixth, on the other hand, 0.11 and 0.12 mm. The pores are developed as in *S. princeps*. The tunnel can be easily recognized, especially in the younger volutions, while in the later whorls it is at times not clear. Where it is clear in this region, it takes up close to half the chamber height.

Occurrence.—Uggoweitze breccias in the red and grayish-black pieces with *Fusulina pusilla* filling the rock completely.

Affinities.—*Schwagerina fusulinoides* stands in closest relationship to *S. fusiformis* Krotow. It is too bad that the illustrations given by Krotow are not very plain and do not represent any transverse section so that a comparison of both forms does not arrive at precisely the same results. Likewise, it is quite possible that examples will soon to be found which will prove that the Ural type possesses a great degree of variation, and that it includes forms that do not justify the erection of a separate species for the Carnic *Schwagerina*. According to the material at hand, which is very rich in so far as the Carnic form is concerned, there exists a decisive difference in the dimensions of the shell. In the examples of *S. fusiformis* measured by Krotow the ratio of the height to the length varies between 1:1.4 and 1:1.17; in *S. fusulinoides*, on the other hand, between 1:1.18 and 1:2.8. The latter is therefore very much longer. A second difference rests on the different conditions of the growth stages in *S. fusiformis*. According to Krotow, the youthful specimens appear more drawn out lengthwise than the older ones. In *S. fusulinoides* there exists, as in the true Fusulinas a reversed relaion of the youthful volutions. However, we have in *S. fusulinoides* a form which appears as a typical transition form between the Fusulinas and the Schwagerinas, and stands even in a closer relationship to the Fusulinas than the Uralic *S. fusiformis*, which is closer to the group of typical *S. princeps*. One can debate with respect to the Carnic form whether one should refer it to the Fusulinas or the Schwagerinas. The long-drawn-out form, the large central chamber, the fluting of the septa which never reach the floor in the median zone of these, are characteristics which belong to the Fusulinas, while the greatly changing mode of inrolling, the partly very thin septa, and the mode of septal fluting do not reach the degree found in the true Fusulinas, and demonstrate a connection with the sub-genus *Schwagerina*.

Our specimens agree very well in most respects with those described by Schellwien, except that ours show the dimorphism of alternate generations. On the whole, the initial chambers of all our specimens are about the same size as those from the Carnic Alps. In size, our specimens reach as high as 4.6 mm. by 9.9 mm., and the ratio varies from 1:2.15 to 1:2.8, the same as the external dimensions of the Carnic Alps specimens.

Statistics of specimens from the Hueco Mountains follow:

INTERSEPTAL SPACES PER WHORL

Whorl	Specimen				Thickness in mm.
	No. 1	No. 2	No. 3	Average	test
No. 1	11	11.5	13	12	.065
No. 2	17	19	17	17	.082
No. 3	21	20	16	19	.082
No. 4	23	20	27	23	.082
No. 5	28	28±	32±	29	.11

HEIGHT OF CHAMBERS

Whorl					
No. 1	......	.027mm.	.057mm.	1	inflation begins at 2.5
No. 2	.051	.115	.057	1	uncertain inflation begins at 2.25
No. 3	.24	.63	.288		
No. 4	.47	.5	.288		
No. 5	.26	.32	.22		

Another specimen furnishes the following data:

SPECIMEN NO. 20

Whorl	Chambers per whorl	Height of chambers in mm.
No. 1	15±	.058
No. 2	20	.087
No. 3	24	.35 to .89
No. 4	21	.62
No. 5	29	.35
No. 6	40±	.35

Specimen	Diameter of initial chamber in mm.	
No. 1	.147	
No. 2	.23	
No. 3		
No. 4	.23	
No. 5	1.92	
No. 6	.27	Range, from .147, microspheric form, to 1.92, the megalospheric form.

MEASUREMENTS OF AXIAL SECTIONS IN MM.

Whorl	Diameter	Length	Ratio	Diameter initial chamber
No. 1	.58	1.66	1:2	.27
No. 2	.97	2.69	1:2.66	Wall thickness .085
No. 3	3.23	6.92	1:2.14	
No. 4	3.42	9.61	1:2.81	

Total length 10:84; ratio approaches 1:3.

SPECIMEN NO. 17

Whorl	Diameter	Length	Ratio	Diameter initial chamber .92
No. 1	.19	......	1:0.38	
No. 2	.85	......	1:1.71	Thickness of wall .089
No. 3	1.62	......	1:1.31	Inflation begins at whorl 3
No. 4	2.44	......	1:1.03	
No. 5	3.07	......	1:0.87	
No. 6	4.90	......	1:2.58	
No. 6.5	4.60	......	1:2.59	

The variability of the accompanying figures is to be accounted for by the fact that the species grades into the *Fusulinas* on the one hand and into *Schwagerina* on the other.

In many cases when the more slender specimens of almost precisely the same external appearance are selected to be sectioned, one transversely and the other axially, to be mounted on the same slide for comparison, one proves to be a *Schwagerina* and the other a *Fusulina*. However, once sectioned, there is usually little difficulty in determining to which genus each belongs, though occasionally they run very closely together. In this respect the relation is no closer to *Fusulina* than is the case in the specimens from the Carnic Alps. It is a protean species. Some of our sections are almost perfect duplicates of Schellwien's sections from the beds of the Carnic, or Eastern Alps.

It is not improbable that Figure 8 on Plate XXI of Schellwien's illustrations represents an immature specimen of *S. uddeni* n. sp.

Horizon and locality.—Beds above the unconformity between the Magdalena and Manzano stages, in the Hueco Mountains east and southeast of Hueco Tanks, Tex., they probably extend as high stratigraphically as the beds at the top of Juan Peak.

SCHWAGERINA FUSIFORMIS Krotow

Plate VIII. Figs. 1, 7, 8.

Schwagerina fusiformis Krotow, Mém. Com. Geologique, St. Petersbourg, p. 439, VI, Pl. II, 1888.

Staff, Beiträge zur Kenntniss der Fusuliniden, N. Jahrb., Beilage Band XXVII, pp. 503–505, 1909.

Palaeontographica, LIX, Monograph Fusulinen, p. 178, fig. 8, 1912.

Krotow's description.—A spindle-shaped shell pointed at the ends, gradually becoming thicker toward the middle, which is regularly arched. The young specimens are more elongated than the adult ones. The ends of the shell are coiled. The surface is covered by curved longitudinal furrows, which are separated by rather wide, somewhat arched spaces. The central chamber is rather large and has an elliptical outline; the coiling forms a complicated spiral. The shell of grown individuals consists of six volutions; in the last one there are 27 to 28 septa; in the fifth, 22; in the fourth, 15 to 16. The partition walls are much thinner than the shell and are either straight or curved in various manners and connected with the walls of the shell at different angles. At times the septa become thicker in their lower portion. The middle opening (tunnel) is rather high. The walls of the shell approach 0.1 mm. in thickness and the septa approach 0.03 mm. The polar zone is not complex. The largest specimen is 6.25 mm. long and 3.75 mm. in diameter. The average ratio is 1:1.7. This form is distinguished from *S. robusta* Meek by its form and its smaller number of septa in the last volutions.

Krotow's figures are reproduced but are of such a nature that they are hardly distinguishable from a *Fusulina*, to say nothing of their specific value. According to Staff's figure of the cross-section supposed to have been taken from Krotow's original slide, the number of chambers for each of the succeeding whorls is 8, 13, 14, 16, 22±. The diameters of these whorls are .35 mm., .57 mm., 1.32 mm., 2.67 mm., and 3.3 mm., respectively. The whorls loosen near the end of the second volution. Staff gives the ratio of the diameter to the length as 1:1.5 to 1:1.34.

There are probably other undescribed species of *Schwagerina* from the Russian deposits, but there is little to be gained by discussing this one further until more is known of the whole fauna.

Locality.—"Upper Bergkalk of the Beresowaja."

SCHWAGERINA YABEI Staff

Plates IV, VII. Figs. 11:4, 5.

Schwagerina yabei Staff, Beiträge zur Kenntniss der Fusuliniden, Neues Jahrb., Beilage Band XXVII, pp. 463–468, Taf. VII, figs. 1–3, 1909. Anatomie u. Physiologie der Fusulinen, Zoologica, XXII, pp. 59, 67, fig. 48, 1910.

Staff's description.—Before us are four specimens. The state of preservation is, as in almost all fossils of the Socio limestones, an excellent one. The white limestone, which fills the chambers, can be made almost transparent in thin sections and permits, therefore, the use of strong magnification under the microscope. The relations of the dimensions are the following:

	Specimen 1	2	3	4
Diameter	8.8 mm.	9.3 mm.	9.2 mm.	8.8mm.
Length	11.2	10.7	12.3	11.3±
Ratio	1:1.27	1:1.15	1:1.34	1:1.29±

In No. 3 the length is most accurate, since in Nos. 1 and 2 the points of the ends (or poles) are slightly broken off. Consequently the value of the ratio in No. 3 is the most accurate, even if possibly this specimen is somewhat more elongated than the others. Nos. 1 and 4 have been used for sectioning since their measurements almost coincided and therefor the two sections are splendidly adapted for comparison. The illustration is based on No. 3 (Tafel VII, fig. 1).

Form.—Almost spherical, with the ends of the axis of the volutions plainly marked. From pole to pole there extend faint furrows which mark the origin of the septa. The width between the furrows in the middle varies from 0.4 to 0.8 mm. Their course is not exactly in a straight line, but very weakly and rather regularly waved. An inrolling toward the poles is occasionally found to a small extent. Occasionally a septal furrow seems to be slightly bent forward in the middle; that is, toward the opening of the last formed chamber.

The cross-section (Tafel VII, fig. 2) shows the picture characteristic of Schwagerinas from the group of *S. princeps*. The initial chamber is (in the two sections at hand) minutely small; likewise the first two or three volutions are coiled extremely tightly. The transition to a more loose winding takes place suddenly. The septa are shown very clearly to be formed by the inturning of the chamber wall. They often reach the base, and in the cases where this does not happen, the distance is a very small one. Their extent is no wise always in a straight line; moreover, the majority of the septa on the inner end, that is, the one turned toward the axis, make a sharp angle toward the front or back, which amounts to about 1/6 to 1/4 of the whole length. Porosity of the septa is not distinguishable. This would be, judging by analogies, very small, corresponding to the extremely thin septa. The chamber walls, likewise, have only a very fine alveolar structure. The thickness of the wall increases greatly toward the outside. In the last, seventh, and eighth volutions, it exceeds the fourth and fifth three-fold. The increase in septal thickness is not quite so great.

On the whole, the cross-section shows three entirely different forms of shell structure, just as the axial sections (Tafel VII, fig. 3). Both are listed side by side for comparison:

Cross-section	*Axial section*
A. Volution, 2½, very closely wound; septa and walls relatively thick; septal folding considerable; septa relatively very numerous.	*A.* Volutions, 1–3, wound very closely; septa and walls relatively thick; septal folding rather important; ratio about 1:3; shape quite fusuliniform.
B. Volutions, 2½–6½; whorls very much inflated; septa very thin; wall thickness small; septal folding exceedingly weak, at most pertaining to the lowest fourth; septa not very numerous.	*B.* Volutions, 3–6; whorls very inflated; septa (distinct at the poles) extremely thin; wall thickness small; septal folding rather weak, only affecting the very lowest part; ratio in the fifth volution only 1:1; form corresponding to the group of *S. princeps*.

C. Volutions, 6½–8; whorls rather closely wound; septa rather thin; wall thickness considerable, septa folding strong and affecting almost the whole height; septa proportionate, not very numerous.

C. Volutions, 7–8; whorls rather closely wound; septal thickness small; wall thickness considerable; septal folding rather strong, at times affecting somewhat more than the lower half, consequently there is at the poles a dense *Fusulina*-like network; ratio in the eighth volution 1:1.3.

A comparison of these statements obtained independently from the two sections shows clearly the excellent agreement of the two sections. A youthful section and a stage with indications of old age can be clearly demarkated from the really typical shell structure. The fact is of interest that old age and earliest youth possess entirely *Fusulina*-like characteristics, and the conclusion seems justified sufficiently that we have in this an indication as to the origin of the Schwagerinas. This assumption that *Schwagerina* has been developed from *Fusulina* has already been made by Schellwien. In *S. fusulinoides* and *S. fusiformis* he has already discovered connecting forms which are somewhat more closely related to *Fusulina*. It is rather hard, as far as *S. fusulinoides* is concerned, to determine which generic name is the right one for it.

The form described here is especially of great interest since it is without question a true *Schwagerina*, exceedingly closely related to *S. princeps*, which has, however, preserved in the earliest volutions of youth, *Fusulina*-like marks which are repeated in the senile condition, even if it seems to extend beyond its group in certain respects. The latter seems to be entirely in accord with its high stratigraphic position.

The relations of *S. yabei* to the group of *S. princeps* are very close. If it is here determined as a new species, this is done nominally because it occupies an intermediate position between the group mentioned and *S. fusulinoides*. The cross-section is almost exactly like the one of *S. princeps*. The section (Fig. 1) reproduced from Mœller from the Kohlenkalk of the Bjelaja (tributary of the Indiga) of the Timan Range is different almost solely in its greater thickness from Plate VII, Fig. 2. The differences of the longitudinal sections are most pronounced. C. Schwager has already separated a variety *glomerosa* from *S. princeps* (Ehr.) s. s., which is said to be distinguished from the type by a more spherical form. With respect to the relation of the length to the diameter, different forms of the group of *S. princeps* can be grouped as follows:

		Ratio, diameter to length
1.	Schwagerina princeps Ehr. glomerosa Schellw.	1:1.05
2.	Schwagerina princeps s. s.	1:1.2 to 1:1.3
3.	Schwagerina yabei	1:1.15 to 1:1.34
4.	Schwagerina fusiformis (External form)	1:1.4 to 1:1.7
5.	Schwagerina fusulinoides	1:1.8 to 1:2.8

The pronounced pointings of the ends in the otherwise pronounced spherical form brings *S. yabei* in relation to Mœller's type of *S. princeps*, from which it is separated by its pronounced size (5.6 as compared with 9.12). The size approaches closest Schellwien's type from the Bombaschgraben; however, the pointing at the poles is missing.

The more important characteristics of the whole group are something like the following: The inclination to extreme microspheric form, the exceedingly close winding of the first two or three volutions which are always elongated *Fusulina*-like, the surprisingly rapid increase of the height of the chambers and in the last volutions also the thickness of walls in connection with decreasing height of the volutions, the rather small number of sparsely folded, very thin, long septa, which in long section often show the characteristic shadow, warrant placing this group with other so-called Schwagerinas.

The group of *Schwagerina (Verbeekina) verbeeki* is distinguished from it above all by the regular development of the much lower and more numerous volutions, as well as by the greater constancy of the (lesser) wall thickness, by the absence of the septal pores and the stronger, exceedingly regular, septal foldings affecting only the lowest part of the septa. A very important characteristic of *Verbeekina verbeeki* is that its initial volutions already approach the same spherical form as the grown animal shows, whereas the group of *S. princeps* always begins with *Fusulina*-like elongated volutions.

The excellent state of preservation permitted the making of thin sections which really deserve this name. The crystalline calcite filling the chambers at most times could be removed almost completely or could be made lighter by a light etching with phosphoric acid.

SCHAWAGERINA UDDENI n. sp.

Plates I, IV, VI. Figs. 1, 2:10:1, 2, 4–7.

Test reaching a fairly large size for species of this genus, sub-spherical with distinctly elongated poles, walls in volutions of the neanic stage closely wound. Chambers increase abruptly in height in the beginning of the ephebic stage in the later part of the second or the beginning of the third convolution. In the outer, gerontic, stage the number of chambers increases and the volution decreases in height. The septa in the neanic stage are relatively numerous, heavy and short, while in the ephebic zone they are very long and thin, as seen in transverse sections. They become shorter, stouter, and more closely spaced in the gerontic stage. They are nearly straight in the last two growth stages, except in the axial zone which is well developed. The septa are perforated with rather frequent, fairly large pores.

STATISTICS OF THE CROSS-SECTION

Whorl	Number of specimens								Average
	1	2	3	4	5	6	7	8	
No. 1	10	13	11	14	12	13	15	13	12½
No. 2	17	17	17	20	17	18	20	18	18
No. 3	14	17	18	18	16	15	18	17	16½
No. 4	20	16	18	21	15	18	16	23	18½
No. 5	32±	29	26	26	....	31	25±	...	29+

Occasionally a specimen is seen in which there is no sag in the curve as plotted by actual successive complete whorls, though they are rare. One, 12, 16, 17, 18, 25.

MEASUREMENT OF SEVEN UNSECTIONED SPECIMENS, SHOWING DIAMETER, LENGTH, AND RATIO

Specimen	Diameter	Length	Ratio	
1	6.5 mm.	12.5 mm.	1:1.92	
2	6.5	8.5	1:1.31	
3	6.	8.	1:1.33	Range 1:1.3 mm.
4	6.5	9.5	1:1.46	1:1.92
5	7.	11.5	1:1.64	Average 1:1.60 to 1.70
6	6.5	10.	1:1.54	
7	6.5	8.5	1:1.92	

Statistics from axial sections follow:

No. 1

Whorl No.	Diameter	Length	Ratio
1	.46 mm.	.6 mm.	1:1.33
2	.8	1.7	1:2.1
3	1.32	2.6	1:1.97
4	2.9	5.4	1:1.77
5	5.	8.	1:1.68
*6	..	10.±	....

*Incomplete.

No. 2

Whorl No.			
1	.8	1.4	1:1.75
2	1.25	2.6	1:2.08
3	2.3	4.8	1:1.46
4	5.3	7.3	1:1.36

No. 3

Whorl No.			
1	.51	.8	1:1.57
2	.8	1.7	1:2.12
3	2.0	3.7	1:1.85
4	4.9	5.33	1:1.09
5	5.3	8.6	1:1.62
*6			

No. 4

Whorl No.			
1	.32	.29	1:0.89
2	.57	1.43	1:2.5
3	1.21	3.11	1:2.57
4	3.25	4.49	1:1.37
5	3.64	7.35	1:2.2
5½	4.71	8.54	1:1.8+

The average data, not including No. 4, which is quite abnormal, are:

Whorl No.			
1	.52 mm.	1. mm.	1:1.92
2	.95	2.	1:2.1
3	1.52	2.96	1:1.95
4	4.1	5.6	1:1.31
5	4.6	6.1	1:1.30 to 1:1.77

The average ratio of width to length in adult forms is about 1:1.6, ranging from about 1:1.3 to 1:1.92.

The diameter of the initial chambers of ten specimens follows:

.14
.144
.17
.128
.255x.29
.231
.195
.423x.346
.18
.29

Dimorphism is clearly shown in the measurements of the initial chambers of this species. The microspheric forms have a diameter of 0.14 mm. to 0.18 mm. and the megalospheric forms from about 0.2 to 0.42 mm.

	Wall thickness of each volution	——Height of chambers in each volution——		
1	.04	.08 mm.	.058 mm.	.12 mm.
2	.06	.12	.135	.19
3	.04	.48	.346–1.38	.52–0.8
4	.14	1.24–1.36	1.31	.77–1.0
5	.16	.84	.54	.46

The thinning of the walls in the gerontic zone of inflation is made plain by these measurements, while the sharp decrease in height recorded in the last whorl shows the characteristics of the ephebic stage of the Schwagerinas.

There are gradational forms between this species and *S. fusulinoides*. However, there is little difficulty in recognizing the species.

This species differs from *S. fusulinoides* Schellwien in its thinner and more distant walls in the ephebic stage, larger initial chamber, more highly inflated form, and the longer and thinner septa. It differs from *S. princeps* (Ehrenberg) Mœller in its more elongate form, especially the elongated tips of the axes, and more complicated structure in the axial zone of the test. It is most closely related to *S. fusiformis* described from Russia.

Horizon and locality.—Section I and the lower part of Section J in the lower Manzano beds as represented in the Hueco Escarpment east and southeast of the Hueco Tanks, El Paso County, Texas; from the basal Wolfcamp formation of the Glass Mountains of the Marathon region, Brewster County, Texas.

SCHWAGERINA KANSASENSIS n. sp.

Plates V:VII:VIII. Figs. 1–5:6:4.

Shell subspherical, of medium size and form for species of this genus; the ends of the axis somewhat extended;

the furrowing of the surface, where the outer plate turns in to form the septum, usually inconspicuous. The initial chamber is minute. The volutions of the neanic stage are very closely wound, quite elongate, with numerous septal chambers. The ephebic stage sets in late, at the beginning of the fourth volution. Its volutions heighten rather gradually and evenly, the walls are thin, the septa quite thin and deeply folded for a *Schwagerina.* The volutions of the gerontic stage are more nearly cyclic, with more massive walls and septa; lower, and more numerous septal chambers. The number of volutions in this species is large. Sections of four specimens are as follows:

Whorl	Chambers per Whorl —Specimen—				
	No. 1	No. 2	No. 3	No. 4	
No. 1	14	12	10±	10	Diameter of initial chamber of No. 1 is 0.05.
No. 2	20	17	13±	14	
No. 3	26	18	18	17	
No. 4	28	23	22	22	Ratio of adult specimen is 1:1.5.
No. 5	22	22	19	16	
No. 6	21	27	21	12	Ratio of third whorl is 1:2.85.
No. 7	26	30±	26	17	
No. 8			31	32	Ratio of fourth whorl is 1:1.79.

Thickness of wall of fifth whorl of No. 3, 0.04; outer whorl, 0.08; of outer plate, 0.01.

Nos. 1 and 2 are from the Neva limestone at Hooser, Kan., and Nos. 3 and 4 are from the Wolfcamp formation near Gaptank, Glass Mountains, Brewster County, Texas.

The species is sharply distinguished from *S. princeps* in the following points: First, in our species, the septa are much more highly folded; second, the volutions of the neanic stage in our species resembled more elongate type of *Fusulina*; third, mature individuals of our species are slightly more elongate; fourth, the ephebic stage of our species is more closely wound throughout.

Its relation to *S. yabei* Staff, is much closer. Our specimens seem to be quite as closely wound and have a more elongate neanic test. The wall of the test in our specimens thickens more regularly from the center outward. The outer whorls are less convergent and the septa are more deeply folded, while the specimens appear to be smaller.

Staff's section, as shown in his illustration, seems to be slightly diagonal instead of truly axial, though this cannot be stated with certainty without the material in hand. If it is a true axial section, the form of the test in the neanic stage would clearly make a distinct species. Otherwise, the two are quite similar.

Horizon and locality.—Neva limestone, Hooser, Kansas; Wolfcamp formation, near Gaptank, Glass Mountains, Brewster County, Texas.

SCHWAGERINA AMADAEI Deprat

Plate IX. Figs. 3. 4.

Schwagerina amadaei Deprat, Etude comparative des Fusulinidés d'Akasaka (Japon) et des Fusulinidés de Chine et d'Indo-Chine; Mém. Sérv. Géol. de l'Indo-Chine, IV, Mém., pp. 8–10, Pl. I, figs. 1, 2, 5. 1915.

Deprat's description.—I have discovered this *Schwagerina* recently in a limestone at Laos, brought back by the commandant, Dussault. At first sight I thought I recognized *Schwagerina princeps* Ehr., and for that reason I abandoned the shell without subjecting it to a more thorough examination. Later. resuming the study, I discovered in the limestones the new species described above under the name *Fusulina crassiseptata* n. sp. In the same preparation, I observed the oblique section of a large *Schwagerina*. It then appeared to me impossible that the latter could be *Schwagerina princeps* Ehr., since it is rigorously characteristic of the Uralien. I then cut oriented sections and was able to convince myself that this form was new and entirely different from *S. princeps* Ehr. This fact was of greater interest, since only *Schwagerina princeps* Ehr. and the little *S. prisca* Deprat were yet known. This showed the absolute necessity of having recourse to sections through the center when one wishes to establish a useful diagnosis.

Schwagerina amadaei n. sp. is completely spherical (fig. 3a). It shows normally 3.5 to 4 mm. in polar diameter, rarely 5 mm. The ratio of the length to the height is, of course, 1:1. The number of whorls is 5 to 6, with a coiling very different from that of *S. princeps* Ehr. The values of the increments are established thus:

Whorl 1	.32 mm.
2	.58
3	1.23
4	2.14
5	2.86
6½	3.12

The last whorl shows senile reduction (Photograph 1, Plate I). The increment is very much more rapid than in *S. princeps* Ehr.; the first whorl is very much higher, according to the following dimensions, more considerable in the embryonic structures, and later the height of the whorls increases, following a more rapid formula. I compare the figures of the two species, thus:

Whorl	*Schwagerina amadaei*	*Schwagerina princeps*
No. 1	.32 mm.	.21 mm.
No. 2	.58	.30
No. 3	1.23	.35
No. 4	2.14	1.07
No. 5	2.86	2.17
No. 6	3.12	3.64
No. 7		4.97

It is *Schwagerina amadaei* which has the advantage. The form of the embryonic structure and the diameters appear wholly different if one compares them with Photograph 1, Plate I, of the present Memoir, and Photograph 3, Plate I, of my Memoir of 1912. In place of the little, almost invisible chamber of *S. princeps* and the numerous crowded whorls which envelop it, the large chamber of *S. amadaei* n. sp. is followed immediately by high whorls. The primary septa are pierced by small, round, closely spaced openings; they are thin and flat (Photograph 2, Plate I) with a tendency to fold and to anastomose somewhat at the poles (photograph taken half-way between the center and the poles; Photograph 3, Plate I). The number of septa is as follows: 10, 15, 15, 15, 15 per whorl. The chambers are a little lower than in *S. princeps* Ehr.

The drawings 3b and 3c show the embryonic structure and the first whorls magnified. My observations suggest to me the following remark: It is in the true Schwagerinas (and this new species confirms this observation) that the first whorls are always more elongated in the axial direction, while in the Verbeekinas they are always flattened following this axis. I shall establish it in the following table:

Forms elongated in youth	*Forms transverse in youth*
Schwagerina fusiformis Krot.	S. verbeekina verbeeki
Schwagerina fusulinoides Schellwien.	S. verbeekina pseudoverbecki
Schwagerina princeps Ehr.	S. verbeekina douvillei
Schwagerina amadaei Depr.	

. . . This *Schwagerina* is Permian, and it is the only one that I know. All the rest show some rudiments of basal ribs in the adult age. (The ribs of the rest are totally distinct; of these, the Doliolinas, as I have shown in my various works.) The true Schwagerinas have continued to exist outside the Uralien during the Permian.

This species is accompanied by *Fusulina crassiseptata* n. sp. in a limestone of Cam-Mon (Laos) with *Neoschwagerina elongata*. (Very free translation.)

Inflation begins in this species at the close of the first whorl. No other species could be confounded with it.

The increase of the septa in this species is of special interest, as is its remarkably simple neanic stage and axial zone. According to Deprat's statement, there is no increase in the number of septa per whorl, after the first whorl. The specimen from which the cross-section was prepared was evidently immature and lacked the gerontic stage. Nevertheless, its features at once separate it from all other species of the genus. It is one of the youngest of the known species of *Schwagerina*.

SCHWAGERINA MUONGTHENSIS (Deprat)

Plate IX. Figs. 5, 6.

Fusulina muongthensis Deprat, Fusulinidés du Japon, de Chine et l'Indo-Chine, et classification des calcaires á Fusulines, Mém. IV.

Les Fusulinides des calcaires carbonifieur du Tonkin et du nord Annam, pp. 5–7, figs. 2 a–d; Pl. II, figs. 1–6, 1915.

Deprat's description.—Species very globose, polar extremities very remarkably twisted; the ordinary dimensions are 5 mm. long by 3.5 mm. wide, with a ratio of (length to diameter) 1.4:1. The number of whorls is five to five and a half; the enlargement is prodigiously rapid.

Whorl	Diameter
1	.39 mm.
2	.62
3	.98
4	1.89
5	2.99
5½	3.48

Such are the normal figures of enlargement from the third to the fourth whorl. I do not know of species with equally accelerated development, but *F. kozui* and *F. globosa* Deprat, Uralien species, similar to *F. muongthensis* n. sp. The following table shows the comparison between these species for the whorls and for the rapid increase:

Whorl	*F. muongthensis*	*F. kozui*	*F. globosa*
No. 1	.39 mm.	.40 mm.	.86 mm.
No. 2	.62	.65	1.14
No. 3	.98	1.50	1.80
No. 4	1.89	2.95	4.20
No. 5	2.99		5.88
No. 6	3.48		7.28
No. 7			8.50

The photographs of Plate II show clearly this rapidity of acceleration. Were a ratio supposedly established from the point of view of proportion between *F. muongthensis* and *F. globosa*, no confusion would exist from the diagnostic point of view, for the dimensions are totally different. So with the septa and the embryonic structure. The last whorl shows sharply senile regression. The thickness of the outer plate and the inner plate is not very considerable.

Whorl	Thickness in mm.
1	.016
2	.026
3	.039
4	.075
5	.104
6	.110

The increase is slight enough from one whorl to the next and this *Fusulina* in section gives mostly an impression of gracefulness, contrasting, for example, with the stout edifice of *F. crassiseptata* n. sp. The poutrelles are fine and crowded. The inner plate only carpets the outer plate, is confined to it, and is not prolonged with the septum.

(Very free and brief translation.) That places the species in our group 1 (Fig. 2 and Photograph 5, Plate II). The initial chamber is small for a *Fusulina*. Its diameter is only 0.15 mm. The septa are long, slender, and formed only by the incurving of the outer plate; they are also straight, feebly fluted, which hinders its confusion with *Fusulina globosa* Deprat; anastomosis not very pronounced, in tangential sections. The septa fix the limits of a tunnel that is low and narrow as seen in longitudinal section.

Septa per whorl:	
No. 1	13
No. 2	25
No. 3	26
No. 4	27
No. 5	28

There is a rapid increase in the number of septa of the first and second whorls. Following them, the septa are spaced without much further increase in number per whorl. This fact completely throws out *Fusulinae* of the *F. globosa* Deprat type, in which the septa number thirty in the first whorl and sixty in the fifth whorl.

At first sight, upon an examination of the exterior appearance, it can be confounded with *F. globosa* Deprat, but as soon as one examines a longitudinal or transverse section, this impression immediately vanishes. I invite the reader to compare for his convenience the photographs Nos. 5–16 of Plate VI, and No. 1 on Plate VII of my first memoir on the Fusilinas, where I have represented *Fusulina globosa*. The number of septa, their very feeble folds, the smallness of the initial chamber, increment of the whorls of the spire, their smaller number, the dimensions of the shell, much larger in *F. globosa*, the equatorial elevation of this latter, separate them completely. *Fusulina muongthensis* can be further compared in longitudinal section with *Fusulina kozui* Deprat; it presents an increment almost similar in value to the height of the whorls in the spire; the same small initial chamber; the same restricted number of whorls; the same regularly restricted ovoid form of the shell; but the transverse section of *Fusulina kozui* Deprat shows in the median region the meridional septa much more straight, but one is able to convince himself in comparison with Photograph 4, Plate III of my third Memoir on the Fusulinidae.

This very peautiful species has been collected by me in the Uralien[12] limestone from the ridge of Cham-Chit, near the col of Muong-Thé,

[12]Deprat uses the term *Uralien* throughout his work for Indo-Chinese and Asiatic beds which he correlated with the Uralian of eastern Russia.

map of Yan-Yen (Tonkin). It accompanies *F. cayeuxi* Deprat, *F. alpina* Schellwien, and *F. kozui* Deprat.

It is interesting to note that the points by which Deprat distinguishes *Fusulina muongthensis* Deprat from *Fusulina globosa*, with the exception of the size of the test, are points in which the former agrees with *Schwagerina* s. s., to which it appears to belong. From his photograph which is reproduced on Plate IX, it should be classed with *Schwagerina*. The inflation begins at the end of the third whorl, according to his cross-section. On the whole, the walls are somewhat thicker in the gerontic stage than is the case with most of the species of *Schwagerina*. (In this connection, it should be remarked that thick tests, or excessive test secretions in the enlargement of the test, development of secondary septa, and accessory skeletal elements, are characteristic of the *Fusulininae* of the whole southern Asiatic region.) This character, taken in connection with the fact that inflation begins at the end of the third whorl, places it close to the Fusulinas, but not within them. The form of the axial region and the clearly defined four stages of development are likewise characteristic of the true Schwagerinas. These characters of the walls and the late inflation of the whorls, together with the size and form of the test, separate this species from the Schwagerinas already described.

The specimens were collected at Muong-Thé.

SCHWAGERINA OLDHAMI Noetling

Schwagerina oldhami Noetling. Carboniferous fossils from Tenasserinn, India Geol. Survey Records, XXVI, Pt. 3, pp. 97–98, Pl. III, figs. 1–1b, 1893.

The specimens described and figured here by Noetling do not have the internal characters preserved, but they are not *Schwagerina* s. s.

Hayden published an article in 1909 on the Fusulinidae from Afghanistan, dealing with *Schwagerina*, which has not come to hand, and its contents are unknown to us aside from remarks upon it made by Staff[13]

EVOLUTION OF THE HIGHER FUSULININAE

The Fusulininae make their appearance promptly with the beginning of the Pennsylvanian deposits, or possibly even earlier. They occur as three genera, *Fusulinella* Schwager, *Girtyina* Staff, and *Fusulina* Fischer.

It is uncertain which of these genera first appear in America, but *Girtyina* is more prominent in the early Pennsylvanian rocks than is *Fusulina*. *Girtyina* is unknown above the lowermost beds of the Missourian, or Upper Coal Measures, in the western Mississippi Valley. The species of *Fusulina* rarely become conspicuous until rocks of the Kansas City stage are passed, when they form the chief part of many thick limestone beds and fill some marl beds.

They continue as small fusiform species until the horizon of the Emporia limestone of Kansas and the Foraker limestone of Oklahoma are reached. A few of these forms continue into the lower Permian beds. In Texas they are found up to the top of the Cisco formation of north Texas, the lower Wolfcamp formation of the Marathon region, and into the base of the Wichita stage (=Manzano) in the Hueco Mountains in West Texas. The American species have not received the discriminating treatment in print necessary to differentiate the various species and to determine their limiting horizons. The succession of the *Fusulinae* in northern Texas has not yet been worked out in detail, but it is, in a general way, parallel with the Kansas-Oklahoma succession, until the top of the Cisco stage is reached, beyond which they are at present unknown.

At the upper limiting horizon mentioned in Kansas and Oklahoma, these obese forms set in. Among the first of these more obese forms is *Fusulina ventricosa* Meek, and following it is *F. obesa* Beede. One or both of these forms

[13]Monograph der Fusulinen, Teil. III die Fusulinen Nordamerikas. Palaeontographica LIX, p. 190, 1912.

occurs in northern Texas, from the Marathon region, and from the rocks of the Wichita stage in the Hueco Mountains east of El Paso, Texas. In these horizons another type of *Fusulina* appears, which is quite elongated. One of these forms is *F. longissimoidea* Beede, from Kansas and Oklahoma, and similar forms from West Texas. These species are not only more elongated, but the septa are also very much more highly fluted, and some of them show a tendency to fill the axial zone with secondary test material.

Returning to the Kansas-Oklahoma section, we find in the Neva limestone, about 150 feet above the lowest beds previously mentioned, a species of *Schwagerina*. Another species occurs in the Florence flint, 300 feet above the Neva limestone. Similar species occur in the Wolfcamp beds of the Glass Mountains and in the Hueco Mountains of West Texas. In the last region they are distributed through about 600 feet of strata. In this West Texas region, the Schwagerinas are accompanied by slender Fusulinas similar to the elongate forms found in lower horizons, and also associated with *Schwagerina* in Kansas. In fact, wherever species of *Schwagerina* occur, these elongated *Fusulinae* are found. In California, *F. gracilis* Meek, and *F. extensa californica* Staff are found. In the eastern Alps (Carnic Alps and the Karawanken), we find *Fusulina regularis* Schellw. (robust type), *F. multiseptata* Schellw. and *F. tenuissima* Schellw. (elongated forms) preceding the Schwagerina beds of the Bombaschgraben, the last species occurring in them.

In the Uralian, according to Tschernyschew,[14] the same and similar species occur in the Schwagerina horizon of the Urals and the Donez basin regions. In the Asiatic beds the fauna is abundant and varied. According to Deprat, the following species precede *Schwagerina: Doliolina aliciae* Depr., *Fusulina tchengkiangensis* Depr., *F. kattaensis* Waag., *F. regularis* Schellw., *F. multiseptata* Schellw., *F. tenuissima* Schellw., and *F. globosa* Depr. In the beds carrying the true *Schwagerina*, we find *S. fusulinoides* Schellw., *S. princeps* Ehr., and *Fusulina alpina* Schellw.

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[14]Die Obercarbonische Brachiopoden Fauna, etc., p. 671, 1902.

Some of the species are doubtless identical throughout the Northern Hemisphere, and are constantly associated with the Schwagerina fauna. Thus we find the same tendency toward differentiation of *Fusulina* into two groups, both of which start near, or even below, the base of the Schwagerina zone. Through *Fusulina regularis* Schellw., *Schwagerina*, perhaps followed by *Verbeekina*, is at the end of one branch. As another branch, the main stem of *Fusulina* persists much higher into the Permian rocks and is of gigantic size. These forms are typified by *F. elongata* Shum. Some of these species reach a length of about 60 mm. and have a diameter of 5 mm. These are apparently closely akin to those reported from eastern Siberia by Tschernyschew[15] when he speaks of "abundant *Fusulina* characterized by unusual length and number of volutions (17, 18, even 20)."

Some of our specimens from West Texas appear to have as many volutions as those from Siberia, though they have not all been counted. The axial zone is filled with secondary deposit so that the number of whorls cannot be counted except in axial section.

The only other region aside from West Texas where the *Fusulinae* occur above the Schwagerina horizon is in Asia. Here we find the following species in beds succeeding the Schwagerina zone, as listed by Deprat: *Fusulina mansuyi* Depr., *F. richthofeni* Schwag., *F. lateno:si* Depr., *F. exilis* Schellw., *F. margheritti* Depr.

Another branch of the Fusulinas was given off in southeastern Asia. This succession is very different from either of those just treated, and comprises the most highly differentiated of Paleozoic foraminifera. This succession is: *Doliolina, Neoschwagerina*, and *Sumatrina* extending to the top of the marine Permian beds. Many of these forms also occur in Japan and the Indian Archipelago.

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[15]Die Obercarbonische Brachiopoden Fauna des Urals und des Timan, etc., p. 731, 1902.

DISTRIBUTION

The Verbeekinas are generically distinct from *Schwagerina*, as has been pointed out in the earlier pages of this paper. The same statement applies to *Fusulina deprati* n. n. (=*Schwagerina prisca* Deprat).

Number 13 of Deprat's Yun-Nan section evidently represents the main *Schwagerina* horizon of the Urals, America, and Europe. It is impossible to pass Deprat's work in critical review here without the material for actual comparison and study. The presence of the true Schwagerina horizon is well demonstrated, but the succession from the lower beds of the Moscovian and lower Uralian is extremely different from the succession of Europe and America. Here is a separate and different succession of the Fusulininae giving rise to the peculiar phylum of southeastern Asia, Asia Minor, and the Indian Archipelago.

It is likewise interesting to note that the cosmopolitan *Schwagerina* is present in this southeastern Asiatic region, though it has not been reported from Japan, where an otherwise similar fauna occurs, and especially the fact that none of the higher forms of the Fusulininae discussed by Deprat from South China, Indo-China, and the Indian Archipelago ever found their way out of Asia, since at the present time not a species of *Verbeekina, Doliolina, Neoschwagerina* or *Sumatrina* is known from America, Europe, or even Siberia. Staff has expressed the thought that they may yet appear in northwest America, and the present writer has likewise held a similar opinion; but their apparent absence from the California-Nevada and Idaho regions, taken in connection with the fact that the Russian geologists did not pick them up in their Siberian reconnaissances while getting a variety of other fossil foraminifera, including Fusulinas, from eastern Siberia, makes it probable that they never reached the Atlantic nor crossed the Pacific. Moreover, they are at present unknown in northern Korea.

The fact that the percentage of shell substance in these forms is very much greater than that of the lighter Fusulinas, and especially the true Schwagerinas, may account for the isolation of this abundant and varied fauna since the weight of the test may have retarded migration. But it is much more likely that there is an absence of these deposits from the region to the northeastward in China or southern Siberia that has much more to do with the absence of the Neoschwagerinas from the Pacific Slope of the United States. Why *Doliolina* and *Neoschwagerina* are present in the extreme west end of Asia Minor and absent in Europe and Sicily, is another interesting question to which there is at present no satisfactory answer. It would seem that this Asiatic basin was to a considerable extent isolated from the rest of the seas of the time. One more or less reasonable postulate that could be suggested at present would be that the westward spread of the more highly specialized foraminiferal fauna of southern Asia was stopped by currents of the peculiarly branched, rather narrow geosynclinal seas connecting regions of great differences of latitude and longitude and of water temperature. The hardier forms of organisms from the Foraminifera—including *Fusulina* and *Schwagerina*—to the Ammonoids, passed these rather feeble barriers. Similar conditions appear to have existed in the Japanese geosynclinal sea at this time. However, our knowledge of Asia Minor and northeastern Asia is still too hazy to permit of very reasonable speculation concerning it.

At the present time, species of *Schwagerina* s. s. are known from Shasta County, California; El Paso and Brewster counties, Texas; Cowley County, Kansas; Osage County, Oklahoma; Socio Valley, Sicily; the Carnic Alps, Crimea; Donez and Okla-Kljasma basins of south-central Russia; Ural-Timan region of Russia; Spitzbergen; Balia Maaden in Asia Minor; Persia; Tian Shan, South China, and Indo-China.

From the remarkable distribution of the few species of this genus, two conclusions suggest themselves: First, that

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page

these animals were marine pelagic forms; and, second, that they spread very freely throughout the connected geosynclinal basins then existing. The following map, modified after Haug, shows the distribution of the Schwagerinas.

CHARACTERISTICS AND RELATIONSHIPS OF THE FAUNA AND FLORA OF THE SCHWAGERINA ZONE

KANSAS-OKLAHOMA

It has been pointed out that the differentiation of the fauna began at a horizon quite as low as the base of the Schwagerina zone. As early as the beginning of Schwagerina time, the conditions which gave rise to the Permian fauna and flora had been sufficiently established to eliminate the great majority of the Pennsylvanian species which had existed in the older beds so that the remaining fauna is to be regarded as residual. In the lower Schwagerina beds of Kansas and northern Oklahoma, fully 40 per cent of the species found are either characteristic of the horizon or contribute to the fauna of higher beds. Something like 50 per cent of the fauna of the zone as a whole are unknown in the older rocks. Moreover, this change of fauna seems to occur with relatively little introduction of foreign forms, since only a few species are known which may have come from the West Texas region, or from other regions. These species are: *Schwagerina kansasensis* n. sp., *Meekella mexicana* Girty, *Allorisma capax* Newb.?, *Omphalotrochus?* sp., and a species or two of Nautiloids. The remainder of the new fauna is represented by such species as *Fusulina emaciata* Beede, *Schwagerina* sp., *Nodosaria postcarbonica* Spand., *Meekechinus elegans* Jackson, *Coral* sp., *Deltocrinus?* sp., *Ophiuroid, Deltopecten nebraskansis* Beede, *Myalina bialata* Beede, *Aviculopina knightii* Beede, *Pteria* sp., *Allorisma* sp., *Chaenomya barbouri* Beede, *C.* sp., *Nucula* cf. *beyrichi* Schau., *Euconospira* sp., *Phymatifer* cf. *pernodisus* Meek, and other gastropoda and Nautiloids. It is to be regretted that so large a part of the faunas of the American region remains to be described.

Dr. E. H. Sellards has kindly prepared the following paragraph on the fossil insects of the Kansas Pennsylvanian and Permian beds:

> The insect life of the Permian, as indicated by that of the Wellington shales in Kansas, presents notable differences from that of the Pennsylvanian. These differences, among other things, include a very high percentage of new forms. Of greater significance than new forms, however, is the radical change in the relative preponderance of the different groups. In the Pennsylvanian formations from which insects have been obtained, the cockroaches, as a rule, preponderate. In the Permian sediments, on the contrary, insects of this group make up but a small percentage of the whole, by far the greater number of forms belonging to other groups. A further important difference in the insect life of the Wellington shales of Kansas as compared to that of the Pennsylvanian formations is in the average small size of the insects of the Permian. While the Coal Measures contain a relatively high percentage of large forms, including the large dragon flies and cockroaches, the Wellington shales have yielded only a few dragonflies of moderate size, the fauna as a whole having a preponderance of small insects.

So far we have discussed the evolution of only the marine invertebrate animal life in relation to the geologic position of the Schwagerina fauna. However, the evidence of the position of the zone of transition from Pennsylvanian to Permian faunas is excellently exhibited by the fossil air-breathing vertebrates. Only one region will be selected as typical—the eastern half of North America; though similar conditions are met with elsewhere.

This region is regarded as very critical, since the vertebrate fossils found there are interstratified with fossil plants and fossil invertebrates. In order to make clear the relation of these formations and faunas, a table showing the succession of formations is introduced.

LOWER PERMIAN AND PENNSYLVANIAN FORMATIONS

Texas	Kansas-N. Oklahoma	Pennsylvanian-W. Va. Ohio
*Clear Fork Vertebrates throughout		
*Wichita Vertebrates throughout Walchia—gigantopteris flora	Wellington stage *Vertebrates, Okla.	
	Marion stage Vertebrates in Okla.?	
	Chase stage Winfield limestone Doyle shales Ft. Riley limestone Florence flint *(Schwagerina)* Matfield shales Wreford limestone *(Walchia flora)*	?
	Council Grove stage Neosho formation (S. Kansas vertebrates) Florena shales Cottonwood limestones Eskridge shale Neva limestone *(Schwagerina)*	Dunkard *Pa. vertebrates
?		?

Lower Permian and Pennsylvanian Formations (Continued)

Texas	Kansas-N. Oklahoma	Pennsylvanian-W. Va. Ohio
Cisco	Wabaunsee stage Elmdale formation (Onaga plants) *Louisville labyrinthodont) Armenius limestone Admiren shales Emporia limestone Willard shales Tarkio limestone Scranton shales	Monongahela
		?
	Shawnee stage	
	Douglas stage	*V. Va.-Pa. vertebrates
	Lansing stage	Danville, Ill.?? vertebrates
?		
	Kansas City stage	Conemaugh
	Pleasanton stage	*Linton, O., and Nova Scotia? vertebrates
	Henrietta stage	Allegheny
	Cherokee stage	Mazon Creek, Ill. vertebrates *
		Pottsville.

In this chart only those formations are given in detail which are of special importance, since they are the beds from which vertebrates or critical flora were collected. Owing to its central position and facility in correlation, the necessary parts of the Kansas section are detailed for comparison with the other two regions. The position of the asterisks (*) shows the correlated position in the Kansas section of the vertebrate horizons of the eastern region, which are used in compiling the following table. The data of this latter table were compiled from Case's paper on the "Permo-Carboniferous redbed and their vertebrate fauna"[16] and Moodie's "Coal Measures Amphibia of North America."[17] It illustrates in a very general way the constitution of the Pennsylvanian and Permian vertebrate faunas.

Permian

Genera and species of Amphibia			Genera and species of Reptilia			Locality and horizon
Genera		Species	Genera		Species	
17		26	27		41	Texas Clear Fork
11		15	23		35	Okla.-Texas Wichita
—		—	—		—	
28	Total	41	50	Total	76	
			Pennsylvanian			
1		1	1?		1?	Kansas. Louisville. Base Elmdale?
4		6	3		3	Ill. Danville. Conemaugh?
1		1	2		2	W. Va.-Penn. Conemaugh
23		51	1		1	Linton, O. Top Allegheny
10		17	0		0	Nova Scotia. Top Allegheny?
8		10	0		0	Mazon Creek, Ill. Base Allegheny?
—		—	—		—	
47	Total	86	7	Total	7	

[16]Carnegie Institution, Washington, publication No. 107, 1915.
[17]Carnegie Institution, Washington, publication No. 238, 1916.

Of the genera of Pennsylvanian Amphibia, four continue into the Permian, as do three of the seven genera of Reptilia.

The line used to separate the two systems is the base of the Neva limestone, though none of the fossils referred to in the table occurs within 100 feet of this horizon.

An inspection of this table shows a sharp distinction between the Pennsylvanian and Permian faunas. In the Pennsylvanian beds there is a total of 47 genera and 86 species of amphibia, while there are but 7 genera and 7 species of reptiles known from the same succession of rocks. On the other hand, passing into the lower Permian section, we are presented with a total of 50 genera of reptiles represented by 76 species, and have but 28 genera of amphibia represented by only 41 species. Thus there is a strong amphibian fauna represented by a great variety of genera and species in the Pennsylvanian, followed by the reverse condition in the basal Permian, which is characterized by a strong reptilian fauna and a relatively much weaker amphibian fauna, the latter being represented by fewer genera and species than in the underlying Pennsylvanian beds. However, viewed from another angle, this difference assumes a vastly greater importance than is shown even by the supremacy of the reptiles in the lower Permian, for the earliest reptile, *Eosauravus* Williston, was a small archaic form, while those of the Permian are relatively large and extremely, not to say grotesquely, specialized; as, for instance, *Dimetrodon* and *Clepsydrops*.

Moreover, we see a relatively constant increase in numbers of the reptilia from their inception to the top of the Clear Fork beds; slow at first, but very rapid after the initiation of Permian conditions; while, if they show anything, the amphibia show a decline in their later history so far as numbers are concerned, but still a high degree of progressive specialization and increase in size. Attention should also be called to the fact that much of the development of the reptiles occurred very early, in the very base of the Wichita beds. This significant fact tends to confirm the evidence already shown by the invertebrates, and it will now be interesting to check out the evidence of the vertebrates and invertebrates with the fossil plants. Much of this work has been done by David White and E. H. Sellards. Sellards' important work was summarized in the reports of the Kansas Survey, Vol. IX, where he also described the insect fauna of the Pennsylvanian and lower Permian beds, as well as the fossil plants from the same horizons. Since Sellards' work was completed, David White has added to it and given a valuable summary of the floras and their range and distribution.

Fossil plants.—In the central part of the United States, the evidence of the fossil plants is more intimate and direct regarding the age of the marine deposits than in the Uralian region. The same is true, so far as our present information goes, in South China and Indo-China. Thus, alternate bedding of marine and terrestial plant-bearing beds in America furnishes the closest check upon the evolution of these two types of life. In the coal basins of France the paleobotanic evidence is present but the marine faunas are wanting; and in the Ural region, the rocks under critical analysis, the Upper Uralian, lack the evidence of the fossil plants. In Bohemia, the fossil terrestrial vertebrates and the fossil flora are both preserved but marine invertebrates are lacking. However, the plant successions in the two continents are very similar, and likewise the successions of marine life, so that a comparison is possible, though the two types are separated.

If we start with one of the best known plant successions, the Stephanean, we may use the words of David White:

> The Stephanean is marked by the great development of *Pecopteris*, *Callipteridium*, and *Odontopteris* of the true type. It witnessed the nearly complete disappearance of *Alethopteris*, *Sigillaria*, and *Lepidodendron*. *Neuropteris* of the long pinnuled forms, enters its period of decadence. Before its close appear the first representatives of *Callipteris*, *Walchia*, *Taeniopteris* of the simple type, *Pterophyllum*, *Zamites*, and *Plagiozamites*; all characteristic of the Permian of later periods.[18]

[18]Journ. Geol., XVII, p. 331, 1909.

Regarding the American flora of similar age, he says:

> The relatively few species characteristic of the European Permian which occur in the Dunkard, and which were not able to conquer the older flora under conditions then existing, are clearly migrants from western Europe. It must be noted, though, that both West Virginia and Kansas exhibit new generic types, the products of local conditions, that have not been found outside of these regions. On the other hand, *Walchia*, which is present in Kansas and New Mexico, has not yet been discovered in the Appalachian trough, though it is present in the Nova Scotian basin, which seems to have been in closer touch with Europe at that time.[19]

A bed of fossil plants was found somewhat above the middle of the Schwagerina beds, in the shale parting of the Wreford limestone of Kansas, from which David White identified the following species: *Callipteris jutieri*, *C. goepperti*, *Walchia pinniformis*, *W.* cf. *filiciformis*, and *Schuetzia? anomala;* while the Pennsylvanian species are: *Cordaites principalis*, and *Rhabdocarpos* n. sp.[20] This clearly places the middle of the Schwagerina horizon in the state of Kansas in the zone of *Walchia*, *Callipteris*, etc. Further light is thrown on the relationship of the beds below of the Schwagerina zone by the fossil plants found in the shales of the Elmdale formation which underlie the Neva limestone which latter forms the base of the Schwagerina zone. The following species are listed from the Elmdale formation from Onaga, Kan.: *Pecopteris newberryana* F. and I. C. W., *Pecopteris hemitelioides* Brongn., *P. oreopteridia* (Schloth.) Brongn., *Odontopteris beardii* Brongn., *O. moorii* Brongn., *Neuropteris plicata* Sternb., *N. auriculata* Brongn.?, *N. scheuchzeri* Hoffm., *Daubreeia* sp., *Asterophyllites equisetiformis* (Schloth.) Brongn., *Annularia stella* (Schloth.) Wood, and *Radicites capillaceus* (L. and H.) Pot.

Concerning this flora, White states:

> No species in any way characteristic of the Lower Coal Measures or Allegheny formation remains. On the other hand,

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[19]Op. cit.

[20]White, David, Proc. U. S. Nat. Museum, XLI, pp. 489–516, 1912.

the ferns, either as individual species or as phases of species having wide range, are clearly indicative of a stage at least very high in the Upper Carboniferous (Pennsylvanian). Nearly all the species have been reported from the Permian of Europe or the Dunkard formation of the United States, though, with the possible exception of *Pecopteris newberryana*, none is distinctly characteristic of the Permian. . . .

The evidence presented by this small Onaga flora may, therefore, be construed, so far as it represents the plants of its horizon, as indicating a stage probably within the Monongahela formation of the Appalachian region, or possibly as high as the lowest part of the Dunkard formation, although, with the exception of *Pecopteris newberryana*, the collection in hand does not contain any species characteristic of the Permian of the Old World, and does not signify a Permian age for the Onaga (Elmdale) beds.[21]

However, in northern Texas a flora similar to the Wreford limestone flora mentioned, but containing *Gigantopteris*, is found in beds probably somewhat above the Schwagerina horizon and the same fossil plants occur in similar horizons in Oklahoma, together with other Permian species. Regarding the origin of these plants, White makes some interesting observations which include the plants of somewhat higher beds. He points out that "*Gigantopteris*, the peculiar *Annularia*, and a *Taeniopteris* form, to which should possibly be added the representatives of *Araucarites* and *Neuropteridium*," probably together with *Walchia* and other forms from the Urals, were "unmistakably derived from eastern Asia," probably "by way of the north Pacific,"[22] which accounts for their absence in beds of the Dunkard formation of Pennsylvania and West Virginia.

While, as stated above, no fossil plants have been found in West Texas, it stands to reason that should they be found in beds contemporaneous with the Schwagerina zone, they would be of lower Permian age as are those of Kansas, and with a somewhat stronger Asiatic affinity. The migration routes of the land plants by the northern Pacific

[21]U. S. Geol. Surv., Bull. 211, pp. 115. 116, 1903.

[22]White, David, The Characters of the fossil plant *Gigantopteris* Schenck, and its occurrence in North America. Proc. U. S. Nat. Mus., XLI, pp. 508–512, 1912.

connection are of interest in connection with the previous remarks concerning the very peculiar distribution of the species of *Schwagerina.*

As for the age of this transition flora, the same ground is taken here as in the case of the transition fauna: That it is to be classed with the new order which it introduces. Many eminent paleobotanists regard the upper Stephanean as clearly of Permian age, and there is reason to think that many others in referring to the whole Stephanean as "Carboniferous" do so with the mental reservation that the upper part is at least quite as closely related to the Permian flora as to the Pennsylvanian.

From the point of view of the flora associated with the Schwagerina horizon in America, it is apparent that the transition from Pennsylvanian to Permian conditions began at almost identically the same level, and, as has already been pointed out, the same thing is approximately true for the whole vertebrate and invertebrate faunas.

It will be seen that species peculiar to Pennsylvanian beds have been eliminated from this small flora, leaving only the species which pass over into the basal Permian deposits elsewhere. As has already been pointed out, the well developed basal Permian flora occurs in the middle of the Schwagerina zone in Kansas, while this hold-over flora occurs but a short distance below its base.

Hence the introduction of the Schwagerina fauna in the Neva limestone, with *Schwagerina kansasensis* n. sp., at the top of the Elmdale formation, may well be regarded as the base of the Permian beds of this region.

In the next region where species of *Schwagerina* occur, no fossil plants have been brought to light, either in the Marathon region or in the Hueco Mountain beds of El Paso County, Texas.

TEXAS

Leaving the southern Kansas and northern Oklahoma basin for the north-central Texas basin, we discover other and very interesting conditions and phases of faunas of this zone. In the Colorado River section and north of it in central Texas, no specimens of *Schwagerina* have been found. However, they are rather difficult to discover unless they happen to be very abundant, and that part of the section most likely to contain them has not been carefully collected with the object of discovering them in mind. There is evidence of disconformity near the horizon where they would be supposed to be found, at Baird, Texas. The obese forms which immediately precede the Schwagerina horizon have been found at the surface near Baird, near the west line of Kimble County, and from well samples in Nolan County. But no specimen belonging to a species of the genus *Schwagerina* has been seen, though, unless they have been removed by erosion, they probably occur in the strata now covered by later deposits in Central and West Texas.

The rocks of both the Kansas-Oklahoma and the Central Texas regions consist of limestones and shales, but there is a slightly different facies of sedimentation in the two regions which may account for the absence of *Schwagerina* from the rocks exposed in the Central Texas region. But, what seems likely, it may be that the beds of the Schwagerina zone were not deposited in Central Texas. It should be noted here that no Fusulinas have been seen in the surface rocks above this horizon, while in West Texas they occur at horizons several thousand feet higher than the Schwagerina zone. There also await solution other peculiarities of the Central Texas basin that cannot be discussed here, which, if understood, might throw much light on the problem in hand.

Perhaps because of an elision of the formations under discussion, the fauna succeeding the rocks which should be expected to contain *Schwagerina* contain an interesting fauna, much of which is new. The characteristic species are confined to relatively narrow zones in which they are usually very abundant. Since it is possible that had conditions been favorable, Schwagerinas might have ranged well up in these beds, the characteristics of the fauna are mentioned. We find a great abundance of reef-building worms, and reef-building Bryzoa, myriads of peculiar foraminifera, a camarated *Aviculopinna* nearly three feet long, *Meekella mexicana* Girty, a peculiar *Composita*, a large, peculiar species of *Productus*, at least two genera of very large gastropods and a large number of small and minute species. There are also a number of nautiloids described by Hyatt and referred to the "Carboniferous," including *Phacoceras dumblei* Hyatt. It is apparent from this mere sketch of the fauna that the new conditions initiated in the Schwagerina zone had a marked effect upon faunal developments in Central Texas.

As we pass on farther to the southwest where the rock succession is more favorable, still more interesting faunas are encountered. Thus, in the Hueco Mountains we find two species of *Schwagerina* in rocks resting unconformably upon Pennsylvanian beds. The species are *Schwagerina uddeni* n. sp. and *S. fusulinoides* Schellw., *Fusulinae* and other foraminifera. These fossils are found through about 600 feet of limestones which contain some thin shale beds. They are associated with two species of *Omphalotrochus*, species of *Enteletes*, and other brachipods characteristic of the Schwagerina horizon elsewhere, but so far no Ammonoids have been found in these beds.

However, it is farther east in the Marathon Basin that the conditions demonstrate the real age of the Schwagerina beds by their associated fauna quite as well as elsewhere in America.

The lowest horizon in which *Schwagerina* occurs is the basal Wolfcamp formation, which rests on the Pennsylvanian. The species as described are *S. uddeni* n. sp. and *S. kansasensis* n. sp. There are associated with them the following species of fossils: *Meekopora?* sp., *Enteletes oelerti* Gemm. (Sicilian), *Geyerella?* sp., *Meekella* sp., *Productus guadalupensis comancheanus* Girty, etc., including very many species characteristic of the Pennsylvanian rocks. In the next higher horizon of the Wolfcamp, we find species of *Schwagerina* associated with *Cladopora* sp?, *Leptodus?* sp., *Aulosteges* aff. *guadalupensis* Girty, etc., together with *Darelites texanus* Boese, *Uddenites schucherti* Boese, *U. minor* Boese, *Gastrioceras modestum* Boese, *Paralegoceras* *incertum* Boese, *Agathiceras frechi* Boese, *Marathonites vidriensis* Boese, *M. smithi* Boese, *Vidrioceras uddeni* Boese, and *V. irregulare* Boese, which give it a basal Permian fauna. Some of these ammonoids are older than any known European forms, but younger than the typical Pennsylvanian forms. The brachipods mentioned fall into the same category, though a considerable percentage of Pennsylvanian hold-overs are present.

CALIFORNIA

In California the relation of the Pennsylvanian and Permian section is still uncertain because of the meagerness of the data available due to the physical conditon of the deposits. However, the association of *Schwagerina robusta* Meek and *S.* sp., shown on some of our slides, together with *Fusulina gracilis* Meek, *Fusulina "cylindrica"* and *F. "extensa"* var. *californica* Staff, is a normal association which may be expected and is usually found in the regular Schwagerina horizons of other regions. *F. gracilis* Meek has the elongated form and the highly fluted septa characteristic of many *Fusulinae* of the Schwagerina horizons the world over, and which are unknown in deposits much below these beds in Europe or America.

In the Trans-Pecos region of Texas, species of *Omphalotrochus* are associated with *Schwagerina* and elongated *Fusulinae,* but the *Schwagerina* and the *Omphalotrochus* are different species from those of California. A single poorly preserved specimen of *Omphalotrochus* has been found in the Florena shale of Kansas, within the Schwagerina horizon.

This occurrence of *Omphalotrochus* and *Schwagerina* in the same horizon in America is somewhat confusing to some on account of the former fossil being absent from the Schwagerina formation in Russia, and characteristic of a much lower horizon named the Omphalotrochus beds. But it may be borne in mind that the genus was first described by Meek from California from the rocks containing

Schwagerina. Since then species have been referred to this genus in rocks as old as the Silurian, and Eastman's translation of Zittel's "Textbook of Paleontology" states that species of the genus are "especially abundant in the Silurian." Consequently in naming a horizon the "Omphalotrochus horizon," as was done in Russia, a certain species or related group of species of the genus must be inferred. In the case of the Russian Pennsylvanian, the group name is based on "*Omphalotrochus whitneyi Meek*." Whether Tschernyschew had specimens from California for comparison with the Russian fossils is not known here. The very different horizons from which the fossils are derived in the two countries would certainly seem to imply that the species might be distinct. In the central part of the United States species of this genus are known only from the lower Permian deposits, as at Shafter, in the Glass Mountains; Diablo Plateau and Wylie Mountains, in Trans-Pecos, Texas; in the Wichita stage (mainly in the Talpa beds) of Central Texas; and the Florena shale in Kansas. All, or nearly all, of these species are apparently distinct from *O. whitneyi* Meek, of California.

As the matter stands, the age of the California Schwagerina beds is not as definitely known as is to be desired, but the balance of evidence seems to be that the beds are referable to the base of the Permian in the sense in which the American basal Permian beds are treated in this paper.

SICILY

Taking up next in order the Mediterranean region, we find one of the two most striking occurrences of species of *Schwagerina* known. It is in the Fusulina limestone of the Socio Valley, near Palermo, in Sicily.

Gemmellaro described two limestone horizons, a lower one which he referred to as a compact gray limestone, and an upper one which he refers to as a coarse white limestone. Both are clearly of Permian age, but one would hardly expect to find *Schwagerina* in both of them, though *Fusulinae* are reported from each of them. Staff did not state from which bed his specimens of Schwagerina came, and there seems to be little use of speculation regarding the matter. However, a study of the distribution of the Ammonoid, Nautiloid, Brachipod, Gastropod, and Pelecypod faunas is of interest.

Ammonoids are found in each bed (both of which are limestone). There are 66 species of these fossils reported by Gemmellaro, 65 of which are found in the lower beds and 5 in the upper, while 1 is peculiar to the upper beds. This species is *Paralecanites* sp. The other four species are *Stacheoceras karpinskyi* Gemm., *Medlicottia verneulli* Gemm., *Parapronorites konincki* Gemm., *Sicanites mojsisovicsi* Gemm., and *Agathiceras suessii* Gemm. Two of the genera are known from the Pennsylvanian and the Permian deposits. Both these forms are regarded as usually older than Waagenoceras or Hyattoceras, neither of which occurs in the upper beds. The other forms might be expected in either of the formations. The lower beds contain the most highly specialized forms, but this may be due to a slight difference in the phase of deposition, else it could not be explained except through a local overturned fold in the beds which reversed their order.

An analysis of the remainder of the published fauna gives the following results:

Compact beds	Coarse beds	Total species	In common	Peculiar to compact beds	Peculiar to coarse beds
		Brachipoda			
29	69	84	15	14	55
		Pelecypoda			
7	45	48	4	3	41
		Gastropoda			
20	63	79	4	16	59
		Nautiloidea			
17	2	18	1	16	1
		Ammonoidea			
68	6	69	5	66	1

The effect of the somewhat different facies upon the fauna of the two beds is here strongly in evidence. The compact beds contain an unusually rich Cephalopod fauna, and the coarse beds an impoverished one; while precisely the reverse is true of the Brachiopod and the remainder of the molluscan fauna. The total fauna worked out by Gemmellaro in the works at hand consisted of 298 species.

A comparison of the relative antiquity of the species of any class within themselves in the two beds, leads to no decisive results regarding the relative age of the beds.

One cannot assume from the general aspect of the fauna of the two beds that the uppermost shows on the whole less traces of greater age than does the lower one.

In any case, Boese's discussion of the age of the rocks based upon their Ammonoid fauna[23] shows them to be much the youngest of known rocks containing a Schwagerina fauna, except the South China region; and the remaining invertebrate fauna is not inconsistent with this view, which makes *S. yabei* Staff perhaps the youngest of the *Schwagerinae.*

CARNIC ALPS

The next region to this one where *Schwagerina* is well developed is in the Carnic Alps northeast of Italy. Here the Auernig beds—bed "*s*" of Schellwien[24]—contain the highest Pennsylvanian Fusulina deposits of the Carnic or eastern Alps. It is a black Fusulina limestone which harbors a fauna of the "Cora" horizon of the Uralian, and contains the large Fusulinas which commonly precede *Schwagerina.* While species of the latter genus occur in the higher beds as represented in the Bombachsgraben in dark gray limestones, *Schwagerina princeps* and *S. fusulinoides* also characterize the lighter colored limestones of the Trogkofel beds of the Karawanken.

The differentiation of the Brachipoda is initiated in the base of the Trogkofel beds, and we find that the following brachiopoda with Permian affinities, or characteristics, are

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[23]Permo-carboniferous Ammonoids of the Glass Mountains, Univ. of Texas Bull. 1762, pp. 24, 32, January, 1919.

[24]Schellwien, Fauna des Karnischen Fusulinenkalks, Palaeontographica, XXXIX, p. 16, 1892.

represented by such forms as *Enteletes carnicus* Schellw., *E. suessii* Schellw., *Streptorhynchus* aff. *operculatus* Waag., *Meekella irregularis* Schellw., *M. evanescens* Schelllw., *M. procera* Schellw., *Geyerella distorta* Schellw., all the species of *Sacchinella* Gemm., *Tegulifera deformis* Schellw., *Productus curvirostris,* Schellw., *P. incisus* Schellw., *P. gratiosus* Waag., *P. cancriniformis* Tschern., *Marginifera pusillus* Schellw., *Keyserlingiana facilis* Tschern., *Spirifer wynnii* Waag., *S. tibetanus occidentalis* Schellw., *S. subtriangulatus* Schellw., *S.* aff. *battus* Gemm., *S. quadriradiatus* M. V. K., *S.(?) bistritzae* Schellw., *Reticularia stachei* Schellw., *Martinia macilentus* Schellw., *Uncinulus velifer* Gemm., *Rhynchonella confinensis* Schellw., *Camarophoria sella* Kut., *C. globula* Phill., two species of *Notothyris*, and the figured species of *Hemiptychina* show clearly a sharp advance over the Pennsylvanian faunas, both in the specialization of species and the introduction of new types with Mesozoic affinities.

The Ammonoids are very rare in the Trogkofel beds, but *Thalassoceras* and *Popanoceras* were found in these beds in the Karawanken, which shows the Permian age of the formation.

WESTERN ASIA MINOR

Enderle[25] described a fauna from northwestern Asia Minor, Balia Maaden, which comes, in part, from the Schwagerina zone. The Foraminifera were submitted to Schellwien who reported *Schwagerina princeps* Ehr., *Fusulina,* cf. *japonica, F. tenuissima* Schellw., *Doliolina lepida* Schwag., *Neoschwagerina craticulifera* Schwager. This occurrence is of special importance in two respects: First, it shows the westward extension of the southeastern Asiatic Fusulina fauna, to northwest Asia Minor, while it is absent from the Carnic Alps, the Karawanken, and in the Uralian

[25] Ueber eine Anthracolithische Fauna von Balia Maaden in Kleinasien. Beit. z. Palaeont. Oesterreich-Ungarns, XIII, pp. 49–109, Pls. IV–VIII, 1911.

and south-central Russian region. In the light of this occurrence, it would seem impossible that *Fusulina* cf. *japonica*, *Doliolina lepida* and *Neoschwagerina* could have occurred in the same beds with *Fusulina tenuissima* Schellw., and *Schwagerina princeps* Ehr., without the former having spread over Europe with these latter species, unless currents in the seas then existing were such as to prevent it, as has already been mentioned.

It seems that *Doliolina* only of this fauna is associated in individual beds containing the true *Schwagerina* in southeastern Asia.

RUSSIA

As mentioned elsewhere, Tschernyschew has pointed out the relationship of this occurrence to that of the Donez and Oka-Kljasma basins and the Ural-Timan region; thus connecting the Ural and Mediterranean regions as well as the southeastern Asiatic region. The discussion of the Mediterranean-Asia Minor region now brings us to the most interesting and critical part of the broader phase of this study, the Russian Uralian section. The remarks regarding the Schwagerina zone of the Uralian section apply with nearly the same force to the fauna of the same formation in the Donez and Oka-Kljasma basins of Little Russia.

Since the publication of Tschernyschew's great work on "Die Obercarbonischen Brachiopoden des Urals und des Timan,"[26] it seems that paleontologists have taken his conclusions regarding the age of the Upper Uralian fauna without question; in spite of the fact that many have had to differ radically with his correlation of the faunas of other regions, such as those of the Salt Range, Sicily, Trogkofel Beds, etc., which were based upon his Ural-Timan fauna.

It was the study of the American faunas containing species of *Schwagerina* s. s. and their relation to the Pennsylvanian and Permian faunas that led to a close analysis

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[26]Mém. du Com. Géol. St. Petersbourg, XVI, No. 2, et dernier, 1902.

of the entire fauna of the Uralian section, so far as it was possible.

The Brachiopod fauna of the Schwagerina formation of northeastern European Russia is made up of three distinct elements: One consisting of hold-over species from the older formations; another composed of new species, genera and sub-families which characterize later formations; and a third characterized by fossils confined to the Schwagerina limestones, and which are unknown in the higher or lower formations. Tschernyschew's list of the brachiopods for the whole "Upper Carboniferous" of the Ural-Timan region contains the names of 213 species, so divided among the three formations concerned that the lowest, "Omphalotrochus beds," has 30 species, the middle or "Cora" horizon has 67, and the highest or "Schwagerina limestone" has 194 species. Of this 194 species known from the Schwagerina beds, 80 go over into the Artinsk deposits, while 60 of them are found in lower horizons; that is, approximately 69 per cent of the entire Brachiopod fauna was introduced in the Schwagerina beds and only 31 per cent came from lower horizons; while 80 species or 41 per cent go over into the Artinsk or equivalent deposits, or into other beds higher than the Artinsk. This does not take into account any extended comparison with the fauna of the Sicilian deposits from Socio Valley, or that from the more lately discovered American Permian, which might increase the percentage continuing into, or known from, other Permian deposits. Thirty-one species occurring in the rocks below the Schwagerina beds go over into the Artinsk or other formations higher than the Schwagerina limestones.

The fact that 31 per cent of the Brachiopod fauna of the Schwagerina horizon of eastern Russia is composed of common Pennsylvanian fossils is freely admitted, and the following discussion is intended to bring clearly to mind the character and significance of the remaining 69 per cent. The same condition holds for the discussion of the Pelecypod and other faunas of these rocks.

Thus it appears from mere numbers alone that the fauna of the Schwagerina limestone is more closely bound to the younger than to the older formations and that it is faunally very sharply separated from the lower beds.

However, the percentage of introduced species is of lesser importance than its faunal character, which far outweighs its numerical relationships.

Tschernyschew's review,[27] which constitutes an elaborate and extended discussion of the fauna and its relationships, cannot be repeated here, but it is of such weight that it is necessary to go into it in considerable detail, following him very closely. Some of its important features will be brought out, putting the main emphasis upon the new and salient forms which tend to distinguish the Schwagerina limestone fauna from that of the two underlying formations.

Beginning with the Terebratulidae, the Dielasmas are characterized by gigantic forms—a feature common to many Permian organisms. *D. supracarbonicum* Tschern., *D. giganteum* Tschern., *D. curvatum* Tschern., *D. plica* Kut., *D. dubium* Tschern., and *D. juresanensis* Tschern. fall into the group of specialized forms differing from those of the upper Pennsylvanian. According to Tschernyschew, five of these species occur in the Salt Range, and only two are known below the Schwagerina beds. Regarding the Dielasmas, he states: "The diversity of their types, their abundance of individuals, and the dimensions which they attain reach their flourishing point in comparison with older deposits, especially of the Ural and the Timan, where the genus *Dielasma* is characterized quantatively as well as in number of species by a dearth of forms. In the same abundance and diversity, we again find the *Dielasma* forms in the Artinsk deposits." *Notothyris* has its nearest relative in *Juvenella* Bittner, and *Nucleatula* Bittner, from the Triassic. It ranges from the Schwagerina limestone to the Artinsk, and the Salt Range. It is the oldest representative of this group. Three species are described from the

[27]Die Obercarbonischen Brachiopoden des Urals und des Timan, Mém. de Comité Géoligique, XVI, No. 2, pp. 656–673, 1902.

Schwagerina beds. "In higher degree our representatives of the genus *Aulacothyris* show Mesozoic characteristics." Two of the species range from the Cora horizon into the Artinsk. *Keyserlingiana facilis* Keys., is found in the Schwagerina and the Trogkofel beds, and *K. schelldieni* Tschern. is confined to the Schwagerina formation. The species of this genus are distinctly of Permian type. *Terebratuloidea*, represented by two species, is a Permian genus heretofore known only from India. Of *Pugnax* there are two species, one of which is large, inflated and ribless, differing from Pennsylvanian forms. In the genus *Camarophoria*, the species *C. mutabilis* Tschern., *C. biblicata* Stuck., *C. globasa* Tschern., *C. karpinskyi* Tschern., *C. aplanata* Tschern., *C. plicata* Kut., *C. superstes* Vern., and others, show distinct divergence from the Pennsylvanian species, while such species as *C. pentameroides* Tschern., of the Schwagerina horizon, may be regarded as a typical end product of one branch of the species of the genus. With a single exception, all these species start in the Schwagerina horizon and two of them continue into the Artinsk.

Among the species of *Spiriferina* there are three divergent types: *a*, short-hinged, rounded forms, *S. ornatus* Waag., *S. panderi Moell.*, and *S. holzapfeli* Tschern.; *b*, extremely elongate hinge, *S. expansa* Tschern.; *c*, high-hinged, pyramidal types, *S. pyramidata* Tschern., and *S. sterlitamakensis* Tschern.

Spiriferella is a specialized branch of *Spiriferina*. Four species are known from the Schwagerina beds, one occurs below these beds, and three of them range into the Artinsk, while one is confined to the Schwagerina horizon.

Compared to those of lower horizons, the species of the genus *Spirifer* contain many specialized forms. They are characterized by *S. ravenna* Diener, and *S. dieneri* Tschern., with long hinge and regular striae. Another type is represented by *S. tastubensis* Tschern., with high, conical, pedicle valve, and nearly flat brachial valve, while a third type is represented by *S. tibetanus* Diener, as figured and described by Tschernyschew from Russian specimens, *S. lyra* Kut. and *S. interplicatus* Rothpl. var. *nikitini* Tschern. These are very short-hinged, inflated shells, of which *S. mexicanus* Shum., from the American Permian, is a representative. Still another branch is represented by *S.* cf. *fritschi* Schellw., *S. enderlei* Tschern., *S. panduriformis* Kut., and those with nearly plane surfaces as *S. slokovi* Tschern., and *S. supracarbonicus* Tschern.

Among the Martinias deserving special mention with respect to their form, are *M. gemmellaroi* Tschern., *M. uralica* Tschern., and *M. triquetra* Gemm.

Streptorhynchus halli Derby., *Meekella uralica* Tschern., and *Schizophoria juresanensis* Tschern., represented by the Russian specimens as figured, fall into the same category as the fossils discussed above.

Likewise there are similar specialized forms in the Productidae falling into different groups, as *Productus transversalis* Tschern., *P. tastubensis* Tschern., *P. mexicanus* White, *P. pustulatus* Keys., *P. iriginae* Stuck., *P. camariniformis* Tschern., *P. pseudomedusa* Tschern., P. *porrectus,* Kut., *Marginifera clarkei* Tschern., *M. juresanensis* Tschern., *Tegulifera? uralica* Tschern.

Aside from all these, Tschernyschew finds the genera *Aulacothyris,* and *Magellanea (Waldheimia=Magellenia)* whose species have heretofore been known only from Mesozoic deposits.

The following genera and sub-genera which occur in the Schwagerina horizon are otherwise restricted to the Permian deposits: *Notothyris, Aulacothyris, Keyserlingiana, Terebratucoidea, Spiriferella, Martinopsis, Aulosteges* and *Proboscidella.*

Tschernyschew's conclusion regarding the affinities of the Brachiopod fauna was stated as follows:

> From a biological point of view there can hardly be a question that the Upper Carboniferous Brachiopod fauna is of a younger type than the Permian, and in its whole extent it shows a more clearly pronounced Mesozoic aspect than the younger Permian, which, in comparison with the former, shows an atavistic trend. (Page 663.)

Yet he referred the Schwagerina fauna (in which nearly all the species referred to in the above discussion occur) to the "Carboniferous."

The use of the term "Carboniferous" should be noted here, since most of the Brachiopoda of younger affinities belong to the Schwagerina zone and not to the Omphalotrochus and Cora beds.

In a similar manner, Tschernyschew discusses the Pelecypoda of the Ural-Timan region.

In the introduction to the discussion of the Pelecypod fauna (page 666) Tschernyschew states that it has not been treated monographically, that the main contributors have been de Verneuil, Keyserling, Eichwald, Krotow, and Stuckenberg; and that "at present there is in my hands extensive material which embraces over sixty specific forms and puts us in position to call attention . . . . to some interesting peculiarities of this fauna."

A very brief review of Tschernyschew's extended discussion is necessarily introduced, and is followed in the same manner as was the treatment of the Brachipoda.

In this discussion he mentions ten species which occur in the Cora beds and twenty-seven from the Schwagerina limestones, so far as it is possible to tie the species mentioned to the formations from which they came. There are twenty-seven species in all, out of the sixty; since five of them are common to both the formations, leaving twenty-two species introduced in the Schwagerina beds. In other words, the number of pelecypod species mentioned in the Schwagerina beds is 2.2 times the number discussed from the Cora beds. These figures cannot be used with accuracy since it is only a partial discussion of the pelecypod fauna; but here again, we find the nature of the introduced fauna is quite as important as the numerical ratio.

Aside from the common Carboniferous species present in the Schwagerina horizon, there are among the Limidae, *L. timanica, L. krotowi, L. laticostata* Tschern., "and also *Mytilus*-like, greatly disarranged forms with the ligament pushed backwards, reduced anterior wing and widened hinder portion of the hinge line, for which Salomon has proposed the name *Mysidiopteria*. To this genus, of which Bittner has described numerous representatives from the Alpine Trias, belong *M. krotowi* Stuck., and *M. duplicostata* Stuck., from the Schwagerina limestone." There are also large, coarsely-ribbed forms like species of *Ctenostreon* from the Jurassic and Cretaceous. Among the Pectinidae may be mentioned especially *Pecten keyserlingi* Stuck., and one perhaps identical with *P. prototextorious* Waag., with Triassic affinities. The species of *Euchondria* are closely related to those from the Salt Range, as is the case with several of the *Streblopteriae*, some closely resembling Permian species. Some of the *Aviculae* strongly resemble *A. chidruensis* Waag., form the Upper Productus limestone, while others resemble European Permian forms. The species of *Parallelodon (=Macrodon)* in part belong to Pennsylvanian forms, while others resemble or are identical with Indian forms. There is also a greatly elongated *Pseudomonotis*, apparently identical with *P. gigantea* Waag., from the Salt Range, along with *P. pseudoradialis* Tschern., which is very similar to *P. radialis* Phill., from the Permian of Russia and England, and is more closely related to *P. radialis* Waag. (non Phill.) from the Upper Productus limestone. *Modiola simplicissimus* Tschern., is very close to *Lithodomus atavus* from the Cephalopod layers of the Chideru beds. Some *Myophoria* are very closely related to *M. praecox* Waag., of the "uppermost of the Upper Productus limestone" of the Salt Range, and there are species that resemble *Pholadomya*, grouped under *Goniomya*, which reached their greatest development in the Mesozoic.

In summing up the data furnished by the Pelecypods, Tschernyschew states:

> Our fauna has its greatest resemblance to the Coal Measures of North America. In a smaller measure, with the Productus limestone of the Salt Range. The latter can be easily comprehended, for the horizon of the Productus limestone, which I regard as homotaxial with the Upper Carboniferous division, is on the whole poor in pelecypod remains. However, it is to be noted that in an analysis of the fauna from a biological point of

view, we can in no wise reach the conclusion that it represents an older type when compared with the Zechstein of Russia and western Europe. . . . Therefore, if we were to follow Waagen and be led only by its biological characters, we have to assign it to a higher position than is yielded by undeniable stratigraphic data, and would thereby commit a great mistake, which is in opposition to what can be actually noticed in nature.

More light is thrown upon the relationship of this fauna to that of the overlying beds in his remarks regarding other groups of fossils. Thus the discussion of the fauna of the Schwagerina horizon has shown that a large part of its fauna is common to the Artinsk horizon. In addition to this community of fauna already alluded to, the fact should be mentioned that *Schwagerina princeps* Ehr. is common to both stages.

In a similar manner, in his discussion of the Cephalopod faunas, Tschernyschew points out the fact that three Ammonoids, two species, and a variety, are specifically and varietally held in common in the two formations. These species are: *Pronorites postcarbonicum* Karp., *Pronorites cyclolobus uralensis* Karp., and *Agathiceras uralicum* Karp. It should also be remembered that these three species constitute the known Ammonoid fauna of the Schwagerina horizon.

This fact is of special interest in the light of Boese's discussion of the relation of the American ammonoids to those of the Russian Permian, where he remarks: "Our fauna (Wolfcamp, zone of *Uddenites;* contains *Schwagerina*) would thus range between the Uralian and the Artinsk; or, as we take this latter expression as the name of a stage, we might say that our fauna belongs to the Artinsk but is older than the Cephalopod-bearing sandstones of this age."[28]

It follows from the very close relationship of the Schwagerina and Artinsk horizons already pointed out, including the occurrence of identical species of Ammonoids

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[28]Permo-carboniferous Ammonoids of the Glass Mountains, etc. Univ. of Tex. Bull. 1762, p. 37, 1919.

and even a variety of species of them, together with the fact that, locally, no unconformity is known between the two formations, that if one were to look for beds "older than the Cephalopod-bearing sandstones of the Artinsk," it would seem necessary to look for them in the Schwagerina zone.

It will be remembered that Tschernyschew positively places the Brachipod and Pelecypod fauna of the Schwagerina zone biologically far in advance of the Pennsylvanian fauna below it; but, paradoxically, refers them to the same stage as the underlying fauna. This advanced fauna of the Schwagerina horizon only occupies a maximum of 60 meters of rocks in the Timan region and hence is not a thick formation compared to the same horizon in West Texas, which is twice that thickness; or to some of the other formations of that region.

The close faunal relationship of the Schwagerina zone and the Artinsk, and the broken faunal relation of the former with the underlying Cora and Omphalotrochus beds, leaves but one logical conclusion—that the Schwagerina beds and the Artinsk both belong to the same system, the Permian, within which their closest faunal affinities are found. Consequently, Tschernyschew correlates the Schwagerina fauna with nearly all the basal Permian faunas of the Northern Hemisphere, and, because the two lower formations of his "Upper Carboniferous group" were unmistakably older than the Permian, he was inclined to put all these faunas—the Salt Range, the Trogkofel, and the Socio beds—partially or questionably in the Carboniferous. Since then they have all come to be regarded as of Permian age.

The main difficulty with this correlation was Tschernyschew's attitude toward the age of the Schwagerina beds, regarding them as an integral part of the whole Upper Carboniferous of the Ural-Timan region and elsewhere; so that when he was discussing the Mesozoic characters of the fauna he was unconsciously dealing largely with the fauna of the Schwagerina horizon to the exclusion of the fauna of the lower beds. However, it must be stated that the earliest suggestion of the higher fauna is the appearance some of the species in the Cora horizon. Likewise, when he discussed the Carboniferous facies of the fauna, he had largely in mind the fauna of the Omphalotrochus and Cora horizons and the ubiquitous hold-overs found in the Schwagerina zone.

Had he clearly separated the distinctive characters of the Brachiopod and Pelecypod faunas of each of the three horizons in his mind, it would seem that he would have appreciated more clearly the distinction between them in spite of the lithologic similarity of the beds.

As it stood, the Brachiopod fauna of two of the three members was clearly of Pennsylvanian age, and 31 per cent of the third Brachipod fauna of the third member was also Pennsylvanian, while the remaining 69 per cent of it was introduced. Yet, since he insisted on treating the three formations as a unit, he was forced to concede that the whole should be classed with the Pennsylvanian.

Had he tabulated his faunas in three successive groups instead of mixing them indiscriminately, these factors would have stood out. As it was, they did not so stand out. Not infrequently this loose method of tabulation of charts of fossil faunas fails to reveal the faunal characters of the individual formations; but on the contrary, tends to obscure them and may lead to confusion.

Another point that may have added to the tendency to separate the Schwagerina zone from the Artinsk is the difference of lithologic facies of the two deposits. Thus, from the very composition of the beds of the two formations, with few exceptions, taken from the occurrence of the faunae of the other known basal Permian regions, one would expect to find Ammonoids in the Artinsk rather than in the Schwagerina limestone. This could readily be argued from the Texas Permian beds, and also calls to mind the relation between the so-called Albany and Wichita beds, the latter carrying the Ammonoids which occur in the more sandy phases of the rocks. Thus, sediments of the Artinsk stage are composed of sandy limestones, dolomites, sandstones, clays and marls, while the Schwagerina beds are composed of limestone.

The parallelism between the difference of lithologic facies of the Schwagerina beds and the Artinsk deposits with the difference of facies of the Albany-Wichita beds of Texas, is sufficiently striking to warrant the review of the latter conditions.

Originally the Wichita stage of northern Texas was described as Permian (Artinskian) red beds, since they carried an ammonoid fauna resembling that of the Artinsk beds; and the Albany beds of limestones and shales carried a fauna resembling the Pennsylvanian fauna in which the Ammonoids were largely wanting, and were described as Pennsylvanian and older than the Wichita beds. These beds were also supposed to lie stratigraphically above the Albany beds, since lithologically similar formations rested on the Albany strata.

However, Cummins, who had previously described both formations,[29] traced a limestone near the top of the Albany beds northward into and through the Wichita beds and found that the same limestone also lay near the top of the Wichita formation, and since both the Wichita and the Albany formations were found to rest upon the same Cisco beds of the Pennsylvanian, they proved to be different facies of the same formation.[30] Other limestones of the Albany beds may be traced into the Wichita strata and be seen to gradually fade out into typical Wichita beds, and the term "Albany" has been dropped as a formation name in Texas. Similar conditions obtain in the region of southern Kansas and northern Oklahoma[31] in beds of the same age. In terms of eastern European geology, these beds would be the Schwagerina and Artinsk deposits.

In view of the fact that the American beds and those of the Ural region are of so nearly the same age, and physical

[29]Texas Geol. Surv., 1st Ann. Rept., pp. 187–188, 1890.

[30]Cummins, Texas Acad. Sci., II, p. 97, 1897.

[31]Beede, Bull. 21, Oklahoma Geol. Surv., pp. 24–32, 1914.

composition, and that the faunae of the two Uralian formations have so much in common, it may not be impossible that they too may be, in part, different facies of deposits of the same age. A similar idea has been applied by some geologists in explaining the Gschel beds of the Russian Carboniferous. Thus it may possibly be found that the lower Artinsk was locally in part equivalent to the upper part of the Schwagerina beds.

To take this interpretaion and place the Schwagerina limestone as the base of the Permian, or as forming the base of the Artinskian stage instead of the top of the Pennsylvanian, eliminates the incongruities of the fauna of the Uralic section.

CHINA AND INDO-CHINA

With these ideas in mind, it is interesting to note that in southern Asia there is a marine section differing greatly in detail from the sections and faunas previously discussed, and containing a widely different and more complex foraminiferal fauna, though still preserving the true Schwagerina fauna within it.

Recently Deprat has completed a lengthy and very valuable study of the Pennsylvanian and Permian Fusulininae and shown how closely the various forms are confined to definite horizons. His studies included a bed by bed collection from the sections of South China and Indo-China and were printed in four Mémoirs of the Sérvice Géologique de l'Indo-Chine.[32]

In his correlation, the entire Stephanean is classed in the "Carboniferous." Frech uses a different classification in which part of the Upper Stephanean is placed in the Permian. The following tabulation is so arranged as to show the interpretation of both Deprat and Frech.[33]

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[32]Etude des Fusulinides du Japon, de Chine, et l'Indo-Chine, et classification des calcaires á Fusulines. Hannoi, 1912–1915.

[33]Richthofen's China, V. pp. 99, 199, 1911.

Deprat's classification	*Frech's classification*
Upper Permian	Upper Dyas

21. Thick beds of sandstone, marl beds, gypsum and salt. Yun-Nan-Tschwan.
20. Enormous mass of conglomerate of the basin of Tié-Tschen-Ho. (Yun-Nan).
19. Limestone with *Neoschwagerina (Sumatrina) multiseptata* Deprat, from Fong-Wu-Chan.
18. Limestone with *N. (Sumatrina) annae* var. *stricta* Depr., *N. globosa* Yabe, *Doliolina pseudolepida* Depr., *Schwagerina* (not *Schwagerina* s. s.) *douvillei* Depr., *Fusulina exilis* Schellw., *F. margheritii* Depr., *F. granum-avennae* Roem., (rare).

Middle Dyas—Upper zone

17. Limestone with *Schwagerina verbeeki* Gein. (not *Schwagerina* in true sense), *Doliolina lepida* Schwag., both very abundant; *Fusulina mansuyi* Depr., *F. richthofeni* Schwag., *F. latenoisi* Depr.

Lower Permian	Middle Dyas—Lower zone

16. Very thick horizon with Brachipods, but without *Fusulininae: Spirifer blasii* de Vern., *Spiriferella grandis* Waag., *Martinopsis inflata* Waag., *Productus striatus* Fisch.

Upper Uralian	Lower Dyas

15. Limestone horizon with *Neoschwagerina multicircumvoluta* Depr. *N. craticulifera* var. *grandis* Depr., *Schwagerina verbeeki* Gein., very rare.
14. Limestone horizon with *Neoschwagerina craticulifera* var. *tenuis* Depr., *Lingulina nankingensis* Lor., *Climacammina communis* Mœll.
13. Yellow limestone horizon with *Schwagerina princeps* Ehr., *S. fusulinoides* Schellw., *Fusulina alpina* Schellw.
12. Limestone horizon with *Fusulina incisa* Schellw., *Reticularia lineata* Mart., *Spirifer trigonalis* Schellw.
11. Limestone horizon with *Doliolina aliciae* Depr., *Fusulina globosa* Depr., *F. tenuissima* Schellw., *F. multiseptata* Schellw.
10. Horizon with *Productus subcostatus* Waag.
9. Limestone horizon with *Doliolina claudinae* Depr., *Fusulinellae.*
8. Horizon with *Fusulina kattaenis* Waag.

Lower Uralian — True Upper Carboniferous

7. Horizon with *Fusulina tchengkiangensis* Depr., *F. regularis* Schellw.
6. Horizon with *Fusulina regularis* Schellw., *F. dussaulti* Depr., *F. brevicula* Schwag.
5. Horizon of gastropods of Lo-A-Tien and of Chouéi-Tang.
3. Coal beds. (Transition of Moscovian to Uralian. Frech.)

Muscovian — Muscovian

2. Horizon of *Spirifer mosquensis*, rare; *Fusulina regularis* Schellw. *Fusulina cylindrica* Auct., *Schwagerina* (not *Schwagerina* s. s.) *prisca* Depr., *Fusulinella struvii* Mœll., *F. loczyi* Lor., *Tetraxis concha* Ehr., *Spirilina subanqulata* Mœll., etc.
1. Stage of sandstones (300 to 500 m.) with limestone intercalations with *Schwagerina* (not S. s. s.) *prisca* Depr., *Fusulinella struvii* Mœll., *Endothyra parva* Mœll., *Endothyra bowmani* Phill., *E. crassa* Brady, *Crib. panderi* Mœll., *Tetraxis conica* Ehr., *Spirillines*, etc.

JAPAN

After this succession had been worked out, Deprat visited the locality at Akasaka, Island of Honshu, studied by Richthofen, from whence came the material described by Schwager. Later studies by Yabe formed a part of the ground work for Deprat's Fusulina study.[34] As in the case of Indo-China, Deprat used the more careful methods by which he obtained his good results in southern China and Indo-China, and found the following section:[35]

Upper Permian

8. Rocks of *N. (Sumatrina) multiseptata*, with *S. (Verbeekina) douvillei* and *F. grammavenae*.
7. *Neoschwagerina (Yabeina) inouyi* limestone with *N. globosa*, *S. douvillei*, *F. grammavenae*, Roem.

[34]Yabe, H. A Contribution to the Genus Fusulina, with notes on the Fusulina limestones from Korea. Jor. Coll. Sci., Imp. Univ. Tokyo, XXI, 5, 1908.

[35]Etude comparative des Fusulinidés d'Akasaka (Japon) et des Fusulinidés de Chine et d'Indo-Chine, pp. 3–6, 1914.

6. Black or gray-smoky limestone with *F. ambigina* Depr., *F. exelis*, *F. margheritii*, *N. globosa*.

Middle and Lower Permian

5. Limestone with *S. (V.) verbeekii*, *N. margaritae*, *D. lepida*, *F. margheritii*, *N. globosa*.
4. Various limestones with *F. japonica* and var. *constricta*, *D. lepida*, *S. (V.) verbeekii*, *N. craticulifera* var.
3. Limestone carrying *F. japonica*, *F. propinqua* n. sp., *F. japonica akasakensis* n. v., *D. lepida S. (V.) verbeckii*, *N. craticulifera rotunda*.

Uralian

2. Limestone with *N. multicircumvoluta*, *S. (V.) verbeekii*, rare; limestone with *N. craticulifera*.
1. Limestone with *F. tenuissima*, *F. annamitica*, *F. multiseptata*, *F. cayeuxi*, *F. complicata*.

"All of this series, therefore, which I have shown to the end of this work, is absolutely parallel with the series described elsewhere from the extreme orient.

Aside from the Akasaka locality, Fusulina limestones rae reported from the two large islands forming the southern end of the main Japanese islands, Shikoku and Kinshu, though little seems to be known about the fauna.

From Korea, Yabe reports the presence of Fusulina from near Phyong-Yang. The species are compared with *F. richthofeni* Schwager. No figures are given of the sections made, since the material was very poorly preserved. Much of the surrounding country is said to be composed of crystalline schists.[36]

In the lowest beds of the Akasaka section, containing *Fusulina complicata* Schellw., *F. tenuissima* Schellw., *F. anamitica* Depr., *F. multiseptata* Schellw., and *F. cayeuxi* Depr., Deprat recognizes the Schwagerina zone.

Regarding the fauna of this bed, he states:

[36]Yabe, op. cit., pp. 28, 29.

> The first three are three forms characteristic of the Carnic Alps. The last two species which I described in Indo-China and which are associates of the preceding species and *Schwagerina princeps* Ehr. . . . We have shown that this horizon is Uralian.

It will be seen that Deprat correlates No. 1 of the Akasaka section with No. 13 of the South China-Indo-China section, the latter containing *Schwagerina,* and places them in the Upper Uralian; while Frech placed the same bed in the basal Permian or Dyas, with the statement in a footnote to the effect that the Uralian as used by the French contained some basal Permian beds and the Dyas as used by the Germans contained some of the topmost Carboniferous sediments. According to Frech's table, it would seem that the Schwagerina zone in Yun-Nan should be regarded as belonging to the basal Permian (Dyas above the Carboniferous).

If we accept Deprat's correlation of the base of the Akasaka section, which seems reasonable, we are presented with a distribution of *Schwagerina* in Southern Asia extending from the Straits of the Bosphorus to eastern Indo-China and wanting in Japan. On the other hand, we have the Doliolina-Neoschwagerina fauna extending from Japan to the Straits, but otherwise absent in Eurasia.

CORRELATION

From the data so far reviewed, it is evident that the changes which occurred during the Permian period had their inception in the rocks of the Schwagerina zone or their equivalent. In terrestial deposits the beds were marked by the introduction of fossil plants belonging to "*Callipteris, Walchia, Taeniopteris* of the simple type, *Zamites and Plagiozamites,*"[37] *Gigantopteris* and other genera, in rocks of upper Stephanean age.

In these same horizons, as correlated by their fauna and flora, the terrestial animal life is marked by the introduc-

[37]White, David, Jour. Geol., XVII, p. 331, 1909.

tion in America of a rich and highly specialized reptilian fauna and the larger amphibia. In Bohemia it is marked by such forms as *Palaeosirus, Branchiosaurus,* and many other forms described by Fritsch,[38] which carry *Walchia* amid an otherwise "Carboniferous" flora,[39] which places the age of the Bohemian gas coal at, or possibly slightly below, the level of the Neva limestone of Kansas.

With perhaps an exception, *Eryops* and a Cricotus-like form, the Bohemian and general European vertebrate fauna is quite different from the Permian fauna of the American region, which carries in its lower part the amphibian genera *Eryops, Trimerorhachis, Apsidosaurus, Cricotus;* among the reptiles, *Diadectes* and *Dimetrodon.*

The invertebrate marine fauna of the basal Permian as here defined includes *Schwagerina fusulinoides, S. princeps, S. kansasensis, S. bakeri; Meekechinus, Keyserlingiana, Aulosteges, Strophalosia, Proboscidella, Geyerella, Sacchinella, Tegulifera* (Carnic type), *Spiriferella, Notothyris, Aulacothyris, Magellenia, Martinopsis,* and many other Brachiopod genera, depending upon the region.

Among the Ammonites are *Uddenites, Darelites, Paralegoceras, Agathiceras, Marathonites, Vidrioceras, Pronorites,* and others, probably including most of the Artinsk species of the Urals.

The remaining classes have not been sufficiently described to be reliably available, or as is the case with the Pelecypoda, the specialization is much slower than in many other classes of animals, the species are distinct, as has been pointed out in the cases of Russia and India, but new-introduced genera are less frequent in the basal beds which are under consideration.

It is to be held in mind that the first evidences of the great change are sometimes reflected in fossil marine life, where the full marine succession is uninterrupted, some time before the new forms appear. For instance, the

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[38]Fauna der Gaskohle und der Kalksteine der Pennformation Boehmens, Prag., 1881.

[39]Fiestemantel. Geol. Mag., Decade II, IV, p. 109, 1877.

Kansas fauna was marked by a great reduction of species of invertebrates during the whole Wabaunsee stage and even the Shawnee stage. Second, new forms began to appear on top of the Americus limestone. In a similar manner the approach to the basal Permian beds showing a large percentage of new forms is marked by the great reduction of species of fossil plants characterizing lower horizons, as is exemplified in the Onaga flora. In the case of both the invertebrates and the plants, it was the hardy and persistent elements that continued to exist until the new fauna and flora were established.

Whether or not all the localities and beds at the base of the Schwagerina zone are approximately contemporaneous, they may be considered as homotaxial equivalents within the usual meaning of that term, without doing violence to any considerable mass of known data.

Furthermore, the fact that the transitions, both pelagic and subaerial, happen to be preserved and exposed on study in no way vitiates the necessity of drawing the line between the Pennsylvanian and the Permian, or Dyas, at the point where these changes actually set in, since these new forms gained a permanent foothold, were never displaced, and soon dominated the fauna and flora of the world. The changed conditions were responsible for changed faunas and floras, and likewise these forms are the expression of the already changed conditions.

This specialization of forms initiated in Schwagerina time marks the beginning of the greatest episode in geologic history from Cambrian time to the close of the Cretaceous Period—the transition from the Paleozoic to the Mesozoic. The very fortunate fact that it so happens that this whole transition is preserved for our study in outcropping rocks of various types, does not lessen its great importance, nor remove the necessity of limiting its boundaries precisely where these changes were initiated.

From this standpoint, one may consider the base of the true Schwagerina zone and its equivalents throughout hte Northern Hemisphere, as the base of the Permian system, or the Dyas, or by whatever term may be applied to it. None of those now in use is satisfactory, and it is hoped that a better designation may be found when our knowledge of the whole succession of rocks with its fauna and flora is known, so that it may be applied to the specific boundaries of the system.

SUMMARY

1. *Schwagerina* s. s. is a well-defined genus whose species are distributed over much of the Northern Hemisphere.
2. They were pelagic organisms of widest and nearly contemporaneous distribution over the seas of that time.
3. Schwagerinas occur near the level at which the simpler Fusulinas broke up into diverse forms.
4. At or near the base of this horizon, the older faunas and floras were greatly reduced and newly developed species and genera appear which come to dominate the later fauna and flora.
5. Some species of *Schwagerina* persist well up into the Permian rocks, as is the case in the Sicilian and the southern Chinese regions.
6. *Schwagerina* forms a good index fossil and its earlier occurrences may safely be taken as the base of the Permian deposits.
7. This interpretation (No. 6) is not seriously out of harmony with similar correlation lines laid down on the basis of other organic remains.

PLATES

Explanation of lettering used in plates:

o.	Outer plate	t.	Tunnel
a.	Inner plate	c.	Chamber
i.	Initial chamber	az.	Axial zone
s.	Septum	p.	Pseudopores in inner plate (Poutrelles)
n.	Neanic stage	w.	Wall of chamber
e.	Ephebic stage	as.	Accessory skeleton
g.	Gerontic stage.	ca.	Communication apertures
b.	Basal skeleton		

PLATE I

Figures 1, 2. *Schwagerina uddeni* n. sp. Hueco Mountains, West Texas.

1. Cross- section, initial chamber of microspheric form. Neanic stage, *n;* ephebic stage, *e;* gerontic stage, *g;* septum, *s;* chamber, *c;* wall, *w*. Enlarged.
2. Same species showing the same details as seen in axial section. Enlarged.

Figure 3. *Fusulina ventricosa* Meek, sectioned and enlarged as above, showing typical Fusulina characters. ×38.

Figcre 4. *Schwagerina fusulinoides* Schellw., from the Hueco Mountains, West Texas; greatly enlarged to show initial chamber, septa, outer and inner plate. Note especially that the inner plate does not extend down the septum, but that the latter appears to be solid and composed of a single layer.

Figures 5–8. *Schwagerina princeps* (Ehr.) Mœller, after Schellwien.

5. Part of shell shown in cross-section, greatly magnified to show nature of inner plate. Note that the dark lines (pseudopores) are much coarser in the lower than in the upper part of the plate.

7, 8. Two sections taken through this inner plate; Fig. 7 in the upper part (x), and Fig. 8 in the lower part (y). The dark lines in Fig. 5 are the light spots in Fig. 8; both equally magnified.

6. Part of axial section highly enlarged. Shows part of septum with many small pores through it.

Figure 9. *Fusulina obesa* Beede, type. Axial section. Shows three growth stages and basal skeleton, and tunnel. ×7.

Figure 10. *Fusulina longissimoidea* Beede, type. Elongated form of *Fusulina* preceding and accompanying *Schwagerina* in the Kansas beds. ×7+.

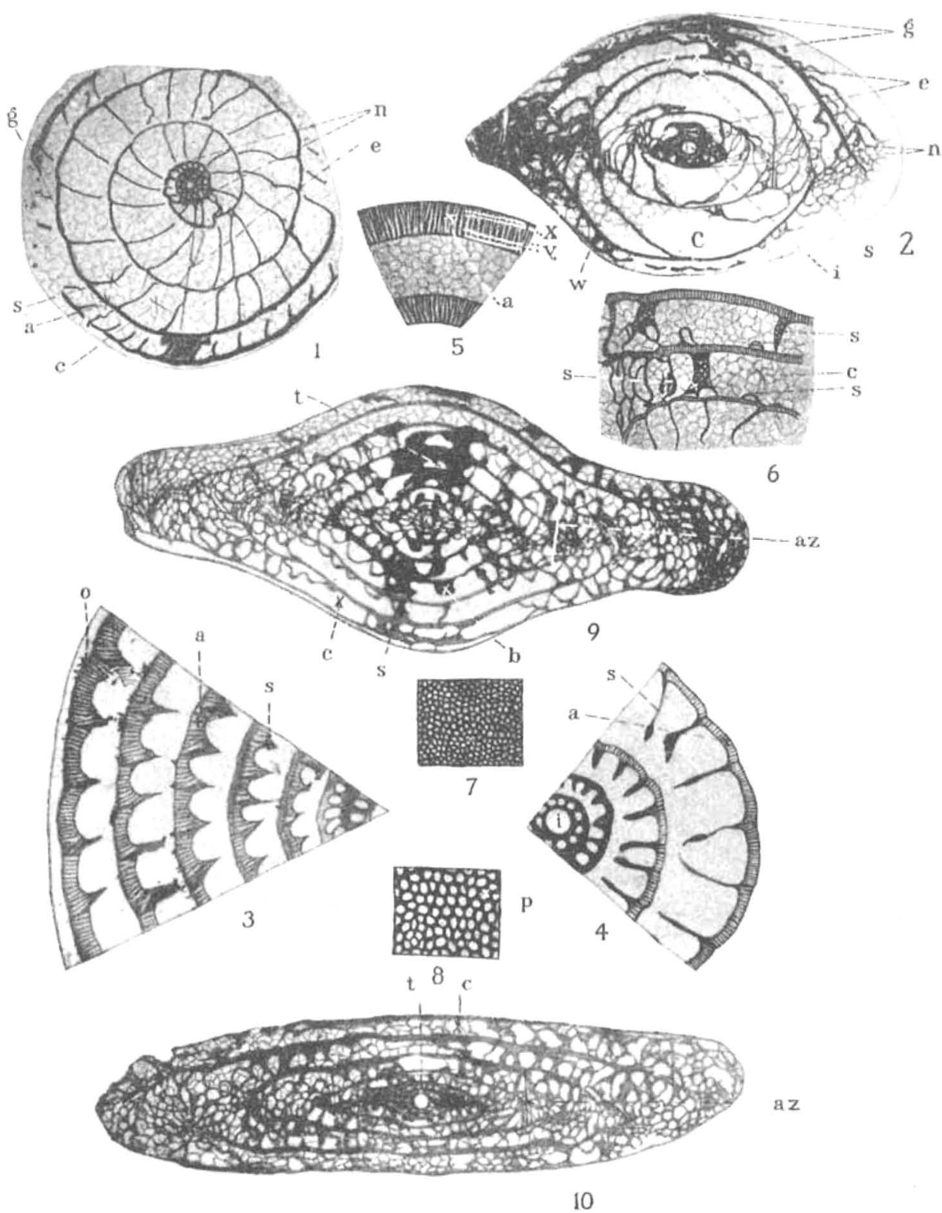
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PLATE II

Figures 1, 2. *Verbeekina verbeeki* (Schwager). After Deprat.

1. Axial section not quite through the center. Shows axially compressed neanic stage, the very simple axial zone with straight septa, the regularly increasing height of all the whorls outside the neanic zone. ×12.5.
2. Slightly excentric cross-section showing these features as they appear in cross-sections. ×12.5.

Figures 3–5. *Doliolina*. After Deprat.

3. *D. termieri* Depr. Diagrammatic section of portion of axial section showing two chambers with the ribs of the accessory skeleton. Enlarged.
4. Cross-section of *D. claudiae* Depr. Shows large initial chamber and regular increase of growth like that of *Veerbeekina.* ×12.5
5. *D. Major* Depr. Deep tangential section showing accessory skeleton. ×8.5.

Figures 6, 7. *Neoschwagerina*. After Deprat. Yun Nan.

6. Shows projections from inner plate to form curtain-like secondary septa as seen in cross-section, and communication apertures (ca) from one part of the chamber to the other. The heavy black line at the base of the lower chamber is a revolving rib of the accessory skeleton. This diagram shows the revolving projection of the lower plate uniting with this rib to form a revolving septum formed by the combination of the lower plate and the accessory rib. Deprat's figure.
7. Diagrammatic drawing of part of axial section showing ribs of accessory skeleton and projections of the inner plate joining them. Greatly enlarged. After Deprat.

Figure 8. *Neoschwagerina (Yabeina) inouyi* Depr. Tangential section. Note accessory skeleton and projections above. Greatly enlarged.

Figure 9. *Sumatrina*. After Deprat. Diagrammatic interpretation by Deprat. Shows accessory skeletal ribs growing up to the enlarged pseudopores and finally to the top of the chambers, forming revolving septa composed of the accessory ribs. Greatly enlarged.

Figure 10. *Sumatrina*. Same as above. Cross-section made between the accessory ribs, shows enlarged septa and poutrelles. Deprat's interpretation. Greatly enlarged.


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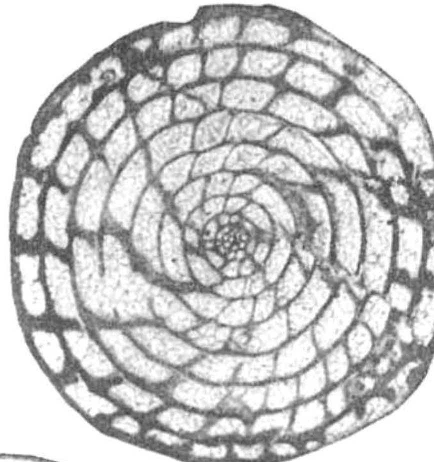
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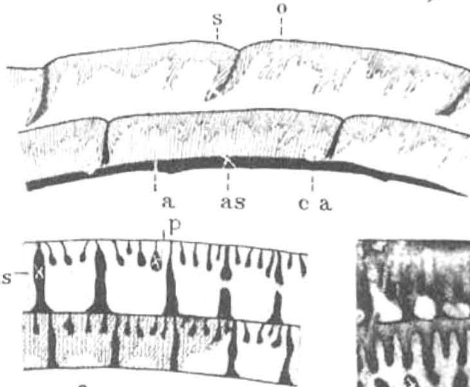

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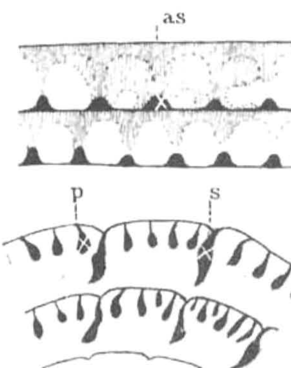

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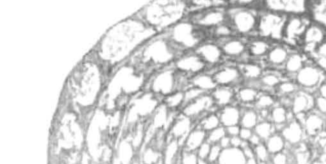

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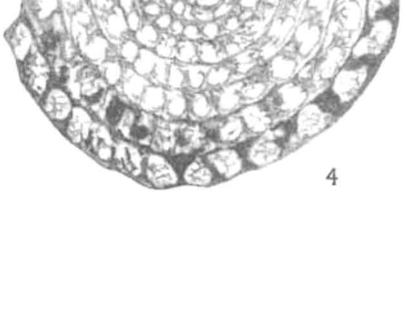
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PLATE III

Figures 1–4, 8. *Schwagerina fusulinoides* Schellwien. Types. From Carnic Alps. After Schellwien.

1. Complete specimen, natural size.

1a. Same, enlarged. ×6.

2. Cross-section. ×18.

3. Enlargement of etched specimen in axial section. ×9.

4. Axial thin section showing initial chamber, axial zone, fluting of lower part of septa, etc. ×9.

8. Axial section of immature specimen. ×9.

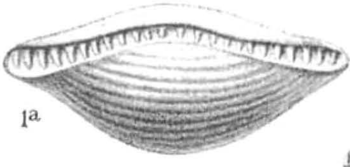
Figures 5–7, 9. *Schwagerina princeps* (Ehrenberg) Mœller. Carnic Alps. After Schellwien.

5, 6. Specimens. Natural size.

5a, 6a. Same, enlarged 9 diamaters.

7. Cross-section. ×9.

9. Axial section showing axial zone and unfluted septa in the plane of the section. ×9.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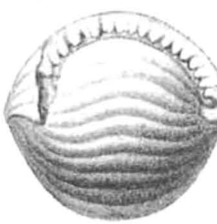
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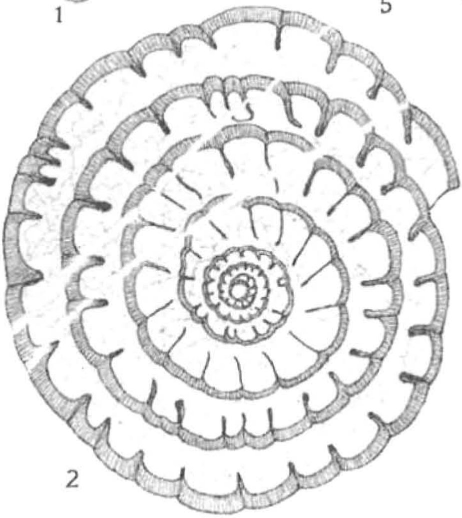
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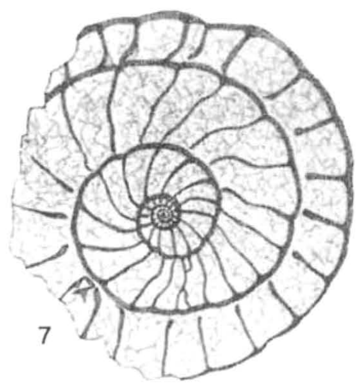
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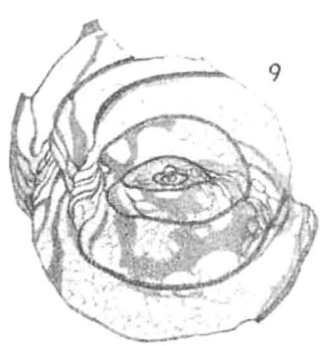
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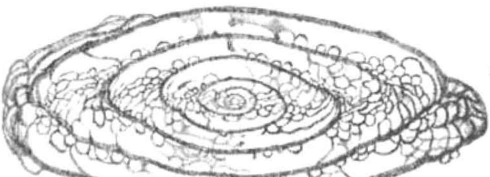
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PLATE IV

Figures 1–5. *Schwagerina robusta* (Meek) Mœller. Bass Ranch, California.

1. Diagonal section. Shows initial chamber, and, in a vertical direction, the relative height of each chamber. Other features shown of little critical value. ×7.
2. Crushed specimen more nearly axial, showing megaspheric form. ×7.5.
3. Diagonal cross-section after Staff. ×13.
4. Cross-section of specimen. The section parted on the slide. Shows all the characteristics of the typical *Schwagerina*. ×8.5.
5. Complete specimen, after Meek. Enlarged.

Figures 6–9. *Fusulina deprati* n. n. (*Schwagerina prisca* Deprat.)

6. Axial section, showing basal skeleton well developed, large well-defined tunnel, heavy walls, etc. ×19.
9. Less enlarged section showing some of these features more clearly. ×6.5.
7. Tangential section showing heavy basal skeleton. ×6.5.
8. Cross-section showing heavy walls and septa, which are straight, and the absence of the inflated ephebic stage. ×19.5. After Deprat.

Figure 10. *Schwagerina uddeni* n. sp., Section B, Hueco Mountains, West Texas. Cross-section for comparison with the other forms, especially Fig. 8. ×8.

Figure 11. *Schwagerina yabei* Staff. Fusulina limestone, Socio Valley, Sicily. Axial section showing fairly well-folded septa, which are closely folded in basal part, and the very broad axial zone near the poles. (Cross-section on Pl. VII, Fig. 4.) ×13. After Staff.

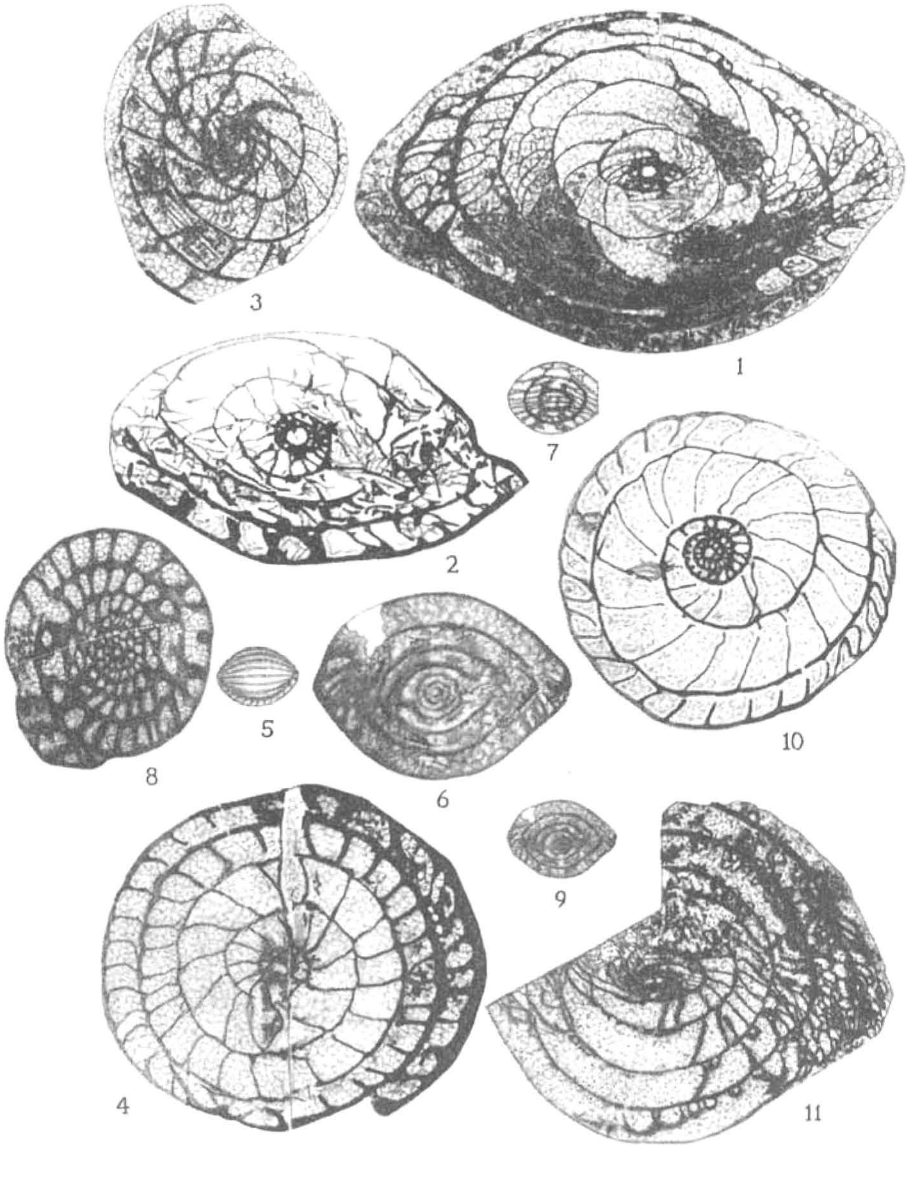
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PLATE V

Figures 1–5. *Schwagerina kansasensis* n. sp. Neva limestone, Cowley County, Kansas.

1. Axial section, type of species. Shows evenly and deeply-folded septa, minute initial chamber, and broad axial zone. ×15.
2. Slightly excentric section. ×12.15. (The initial chamber of this species is so minute and the first volutions so closely wound that it is very difficult to get a true axial section.)
3. Slightly excentric section of specimen from the Wolfcamp formation, Brewster County, Texas. ×12.5. (These specimens are heavily impregnated with iron.)
4. Axial section of specimen from same locality. ×11.
5. Part of axial section showing exceptionally well the very thin folded septa of the axial region. The septa of this species are nearly devoid of pores. One or two are shown in this figure. Neva limestone.

Figure 6. *Schwagerina princeps* (Ehrenberg) Mœller? Deprat's diagrammatic interpretation of the relation of the walls and septa of this genus. Note that the inner plate is shown as extending the whole length of the septum. Compare with Pl. 1, Fig. 4; Pl. III, Fig. 2, except last whorl; Figs. 2, 3, of this plate; Fig. 3 of Pl. VIII. Greatly enlarged.

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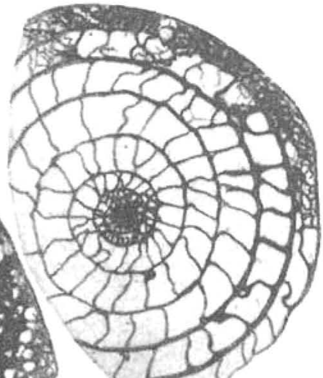

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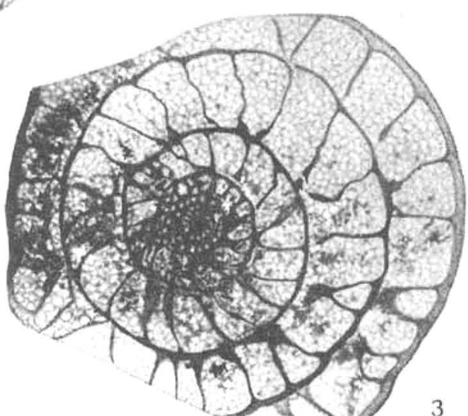

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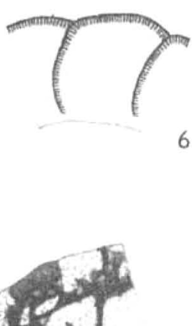

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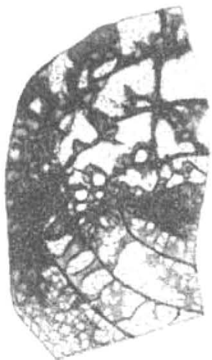

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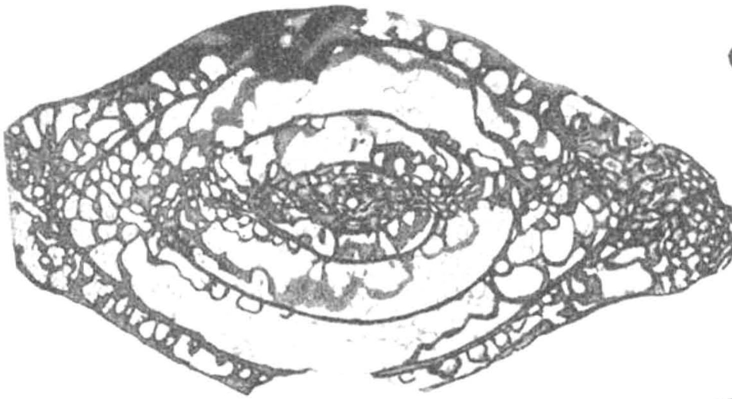
PLATE VI

Figures 1–6. *Schwagerina uddeni* n. sp. Hueco Mountains, West Texas.

1. Axial section of microspheric form. Shows septal pores in wide part of septum in lower third of figure. $\times 10$.
2. Specimen of similar form to that sectioned in Fig. 1. Enlarged.
3. *Schwagerina* sp. Florence Flint, Marysville, Kansas. Somewhat diagonal excentric section of specimen in chert. $\times 8\pm$.
4. Specimen of similar form to section shown in Fig. 3. Enlarged.
5. Cross-section of megaspheric form, somewhat compressed. $\times 10$. Section J.
6. Cross-section of microspheric form. The size of the initial chamber of this species is very variable. $\times 10$.

Figure 7. Axial section of megaspheric form, ends slightly incomplete. $\times 10$.



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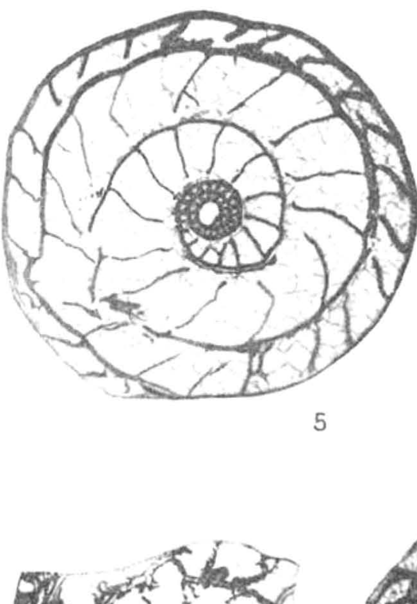

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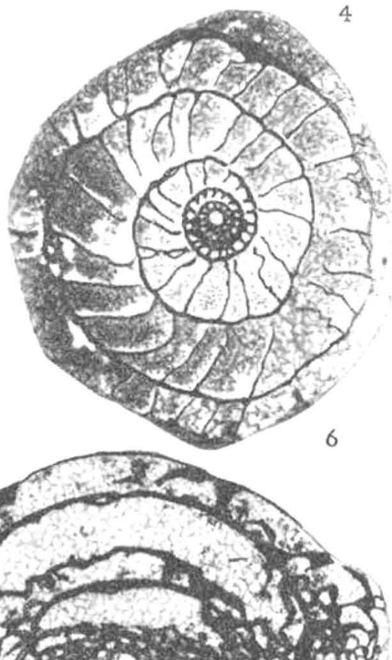

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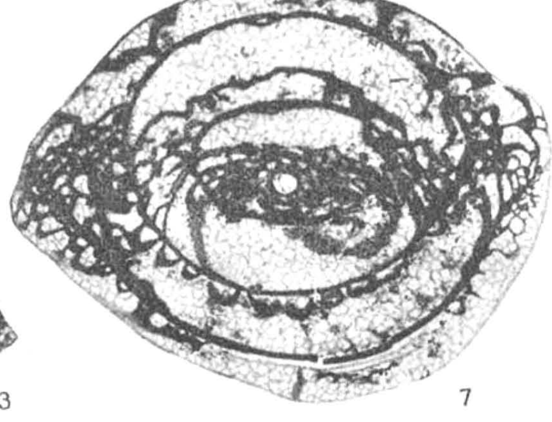

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PLATE VII

Figures 1–3. *Schwagerina fusulinoides* Schellwien. Hueco Mountains, West Texas.

1. Axial section, microspheric form. $\times 10$.
2. Axial section, megaspheric form. This form has stronger Schwagerina characteristics than Fig. 1. $\times 10$.
3. Cross-section. $\times 14$.

Figures 4, 5. *Schwagerina yabei* Staff. Fusulina limestone, Sicily.

4. Cross-section, after Staff. $\times 13.5$. See Pl. IV, Fig. 11.
5. Complete specimen. $\times 2+$.

Figure 6. *Schwagerina kansasensis?* n. sp.? Bass Ranch, California. Specimen on slide from same piece as that containing *S. robusta*. Diagonal section, almost axial. $\times 9.3$.

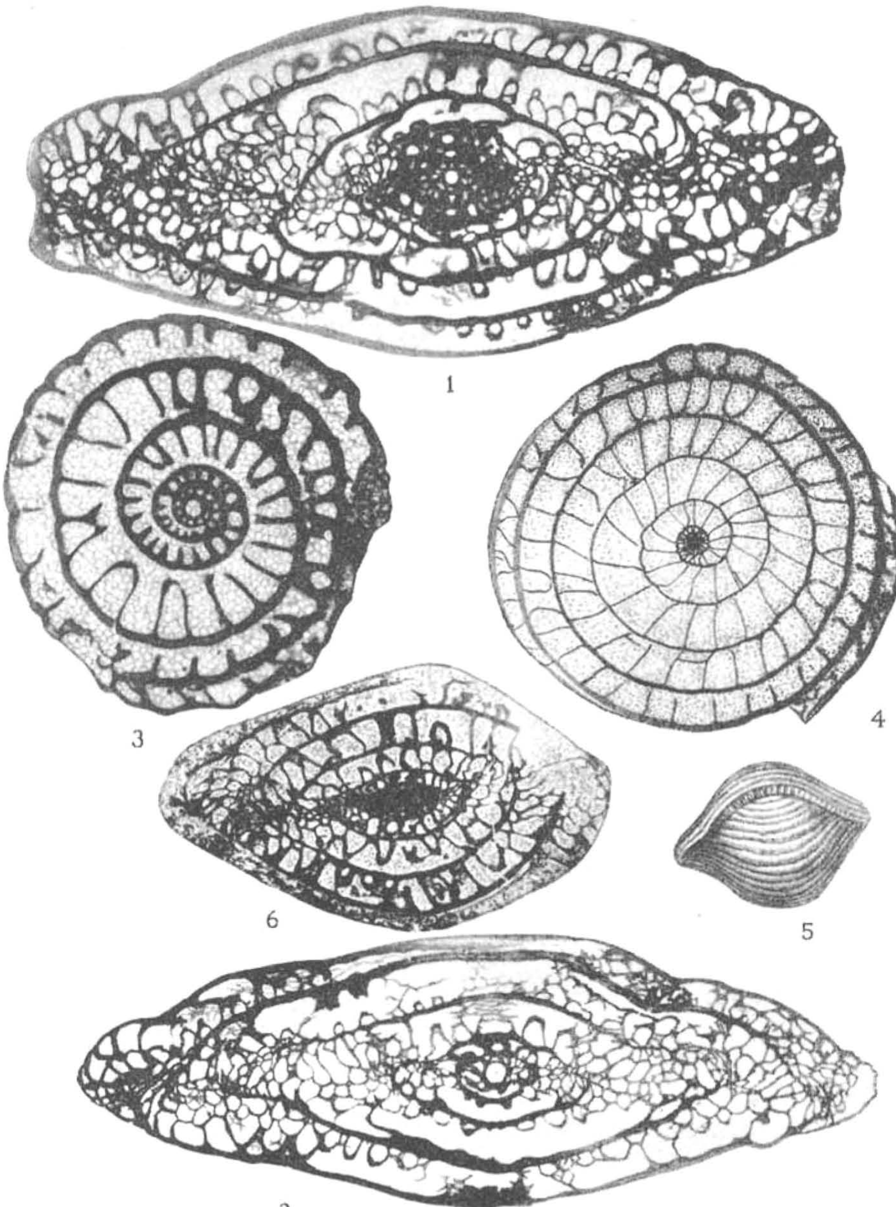
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PLATE VIII

Figure 1. *Schwagerina fusiformis* Krotow, after Staff. Russia. Cross-section after Staff, showing enlarged ends of septa, large initial chamber and great inflation of ephebic stage. ×13.

Figure 2. *Schwagerina robusta* (Meek) Mœller. Cross-section of a specimen from California, showing similar characters. ×6.

Figure 3. *Schwagerina fusulinoides* Schellw. For comparison with Fig. 1.

Figure 4. *Schwagerina kansasensis* n. sp. Deep tangential section to show intense fluting of septa in neanci stage. ×6. Only the black lines of this figure belong to the specimen. The more faint meshwork is not present in the specimen, and is somehow a result of engraving.

Figures 5–8. *Schwagerina fusiformis* Krotow, Krotow's figures. Russia.

5, 6. Complete form, two views. Enlarged.

7. Cross-section. ×2.

8. Section near axis. ×2.

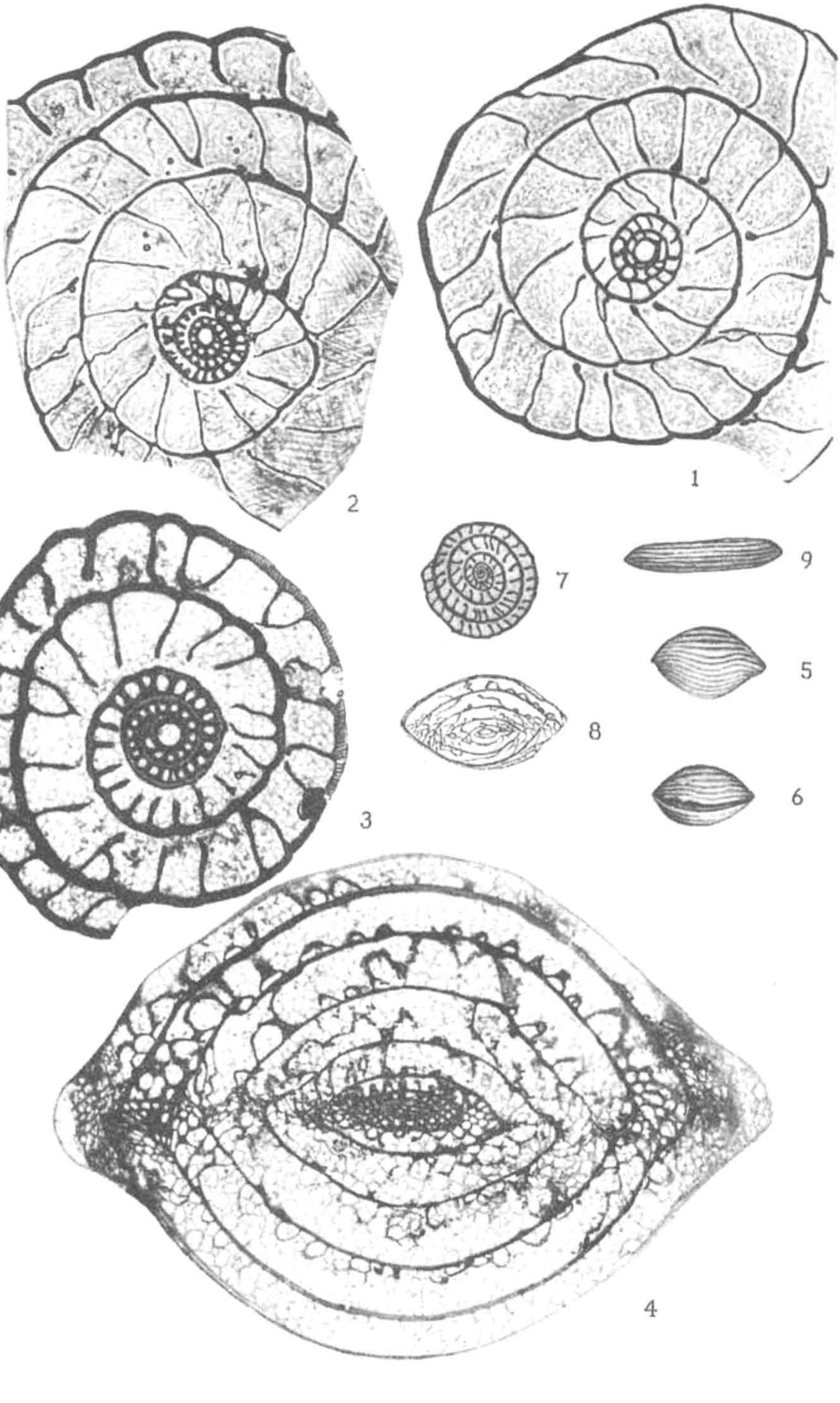
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PLATE IX

Figures 1, 2. *Schwagerina princeps* (Ehrenberg) Mœller. After Deprat. Tshu Mo, Mi-Leu, South China.

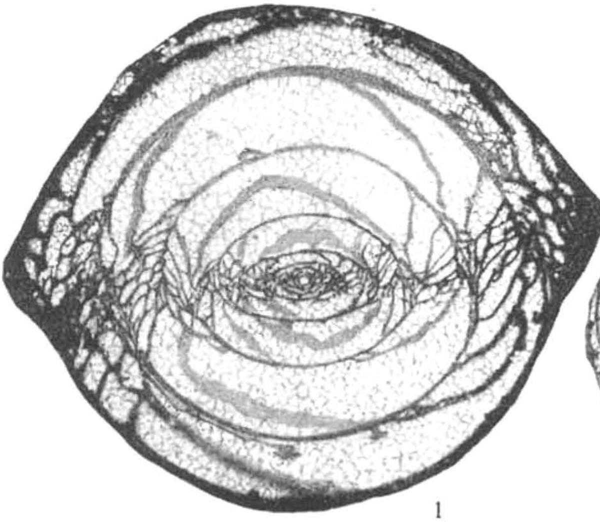
1. Axial section. ×12.5.
2. Excentric section. ×12.5. Compare these figures with those of Pl. III, Figs. 5, 6, 7, 9 from the Carnic Alps.

Figures 3, 4. *Schwagerina amadaei* Deprat. Yun Nan, South China. After Deprat.

3. Axial section. ×12.5.
4. Cross-section. ×12.5.

Figures 5, 6. *Schwagerina (=Fusulina) muongthensis* Deprat. After Deprat.

5. Cross-section. ×12.5. Compare with Fig. 2, above.
6. Axial section. ×12.5. Compare with Fig. 1, above, and other Schwagerinas, and with the figures of *Fusulina* on Pl. I. ×12.5.



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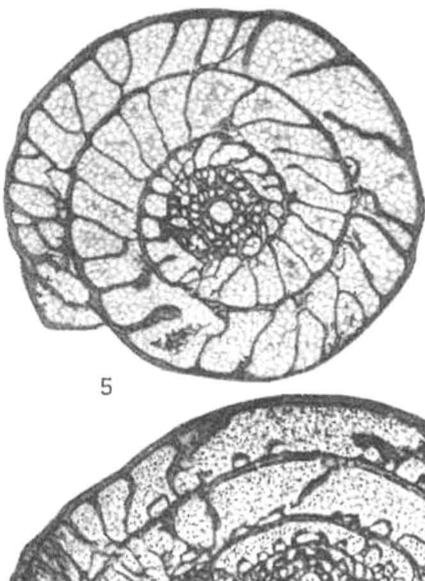

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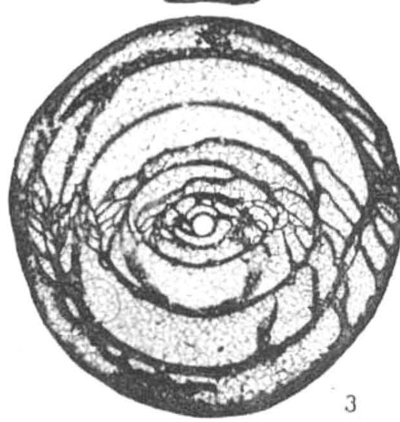

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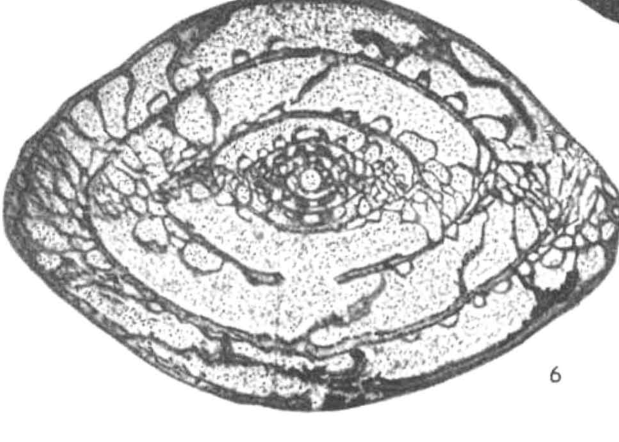

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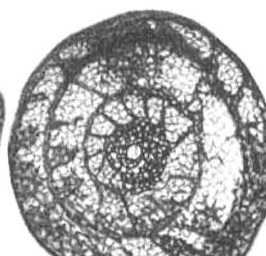

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