



CHAPTER IV

EVOLUTION AND DESCRIPTION OF FUSULINACEAN FAUNAS

Fusulinacean faunas first appeared in the late Viséan, diversified remarkably during the Middle and Upper Carboniferous and Permian times, and became extinct a little before the end of Permian (Kanmera and others, 1975). They are very useful for biostratigraphic zonation and correlation. They occurred in most areas of marine environments during the times mentioned above. The phylogenetic relations among species, genera and families are demonstrated by morphological changes with certain oneway evolutionary trends in the main characteristics, and the ontogenetic development exhibited in individual shells from a proloculus to a mature stage.

The fusulinacean faunas found in the study areas can be grouped into 5 families viz. Ozawainellidae, Schwagerinidae, Verbeekinidae, Schubertellidae and Staffellidae. Kanmera and others (1975) summarized that the Ozawainellidae had undergone generic expansion in the Middle Carboniferous and displayed some diversity in a long-ranging genus in the Middle to Late Permian. The most important groups in Permian were the Schwagerinidae and Verbeekinidae ; the former displayed the greatest generic and specific diversity in the Early Permian, and the latter in the Middle Permian, and both became extinct before the Late Permian. The Schubertellidae showed little change in Carboniferous times, but underwent marked expansion in Middle Permian. The Staffellidae, whose walls are always replaced by secondary mineralization, underwent a fairly remarkable genetic diversity in early Middle Permian and persisted into Late Permian with little modification.

Evolutionary patterns of fusulinacean families

Various theories have been presented regarding the phylogeny of any or all the families of the fusulinaceans which are concluded by Kanmera and others (1975). The view on the phylogeny at the generic level of the fusulinaceans is shown in figure 45, although some uncertainty is still attached to several genera regarding their phylogenetic positions or ages of appearance and extinction.

1. Evolutionary pattern of the Verbeekinidae

The earliest genus of the Verbeekinidae, *Pamirina* Leven, is the simplest and smaller in shell size (less than 1 mm) in the family. It has characteristics common to the genera of the Ozawainellidae and has transient characteristics common to the Verbeekinidae. In addition to Darvas, *Pamirina* has been known from northern Thailand (Sakagami and Iwai, 1974, described as *Staffella* ?) and Japan (Sakagami, 1956, described as *Pseudostaffella* ?). These are all from the upper Lower Permian and are representatives of the *Pamirina*-phase, the earliest stage in the phylogenetical development of the Verbeekinidae. Leven (1970) precisely described the complete morphological transition from *P. darvasica* to *Misellina dyrenfurthi* (Doutdevitch) in a 10-15 m interval of the continuous section in the Darvas Range, and pointed out that the appearance and establishment of new characteristics distinguishing *Misellina* species from their ancestors occurred in a very short period of time. Thus the *Pamirina*-phase is represented by as short a duration as the range of a species.

Pamirina is succeeded by *Misellina*, which has parachomata even in inner volutions and a shell slightly larger than *Pamirina*. *Misellina* has a wide range in the shell form (subspherical with a short axis of coiling to subcylindrical), height of

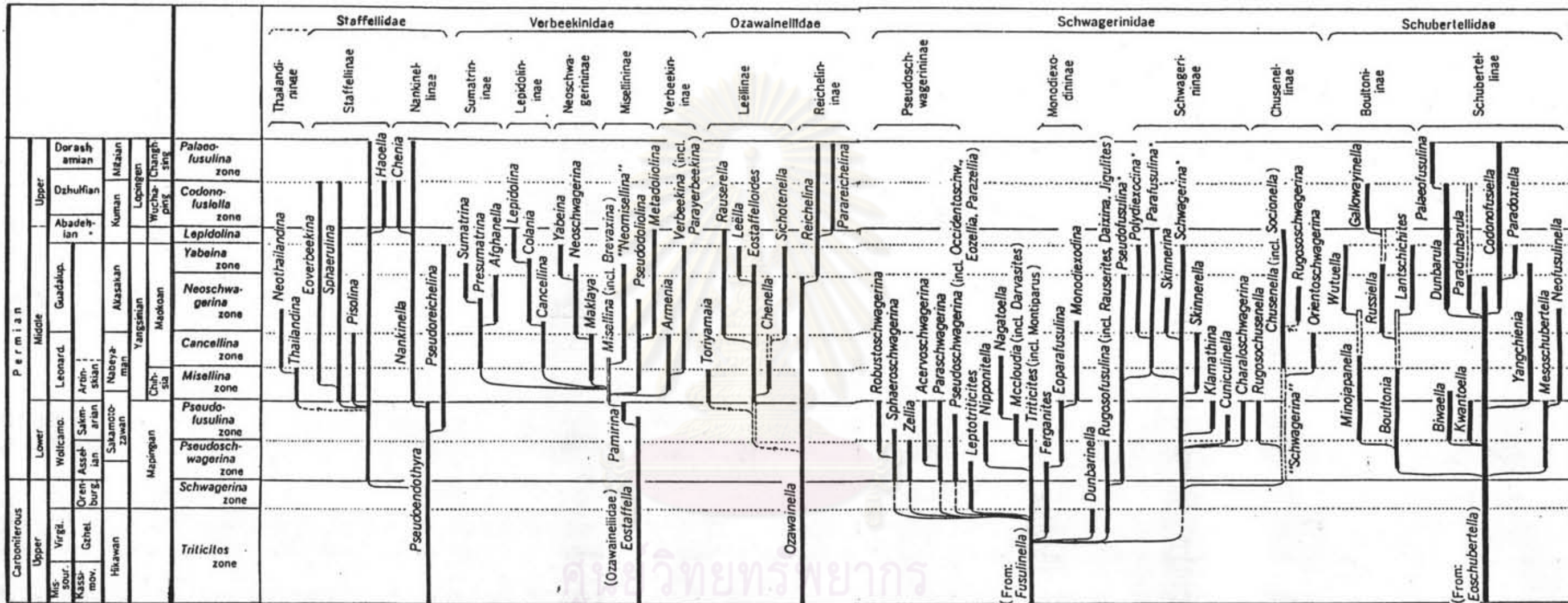


Figure 45 Inferred phylogeny and known range of fusulinacean faunas down to generic level. (Kanmera and others, 1975)

volution, shape and size of parachomata, thickness of spirotheca and septa, and so on. Based on the difference of these characteristics several distinct species-groups are distinguished. In these species-groups septula have not yet developed. This evolutionary stage is the *Misellina*-phase, in which cladogenetic branching of main lineages of the Verbeekinidae was achieved (Kanmera and Toriyama, 1968; Ozawa, 1970). Namely, antecedent species-groups of *Cancellina*, *Maklaya*, *Pre-summatrina*, *Armenia* and *Pseudodoliolina* can be distinguished in *Misellina*. Those of *Armenia* and *Pseudodoliolina* are distinct especially owing to their particular shell shapes.

In the *Maklaya*-phase that followed the *Misellina*-phase, at least the above-mentioned five genera are clearly distinguished, and their assignments to the Sumatrininae, Lepidolininae, Neoschwagerininae, or Verbeekininae become clearer. The former two subfamilies in this phase are characterized by the embryonic development of septula, and the last one is easily distinguishable by shell shape and mode of coiling.

At the higher horizons (*Neoschwagerina* zone, *Yabeina-Lepidolina* zone), the verbeekinid subfamilies comprise some or several phyletic lineages that exhibit continuous and rapid evolutionary development or progressive morphological changes with some one-way trends. Morphological changes of some characters are common to all the subfamilies, and some others are diagnostic within each subfamily. In particular, the Neoschwagerininae, Lepidolininae, and Sumatrininae showed remarkable morphological changes that were represented by the increase of shell size, relative elongation of the shell towards the axis of coiling, increase in number of volution, development of the primary and secondary transverse septula, axial septula and parachomata, relative thinning of spirotheca, septa and septula in reciprocal proportion to the increase of shell size, and so on.

2. Evolutionary pattern of the Schwagerinidae

The Schwagerinidae began with *Triticites*, which was derived directly from *Fusulinella* of the Fusulinidae in Late Moscovian time. The earliest representatives of *Triticites* have a four-layered spirotheca identical to that of the Fusulinidae in inner volutions but two-layered schwagerinid spirotheca in outer ones. Other shell structures are very similar to *Fusulinella*.

Triticites of the Upper Carboniferous time has a wide range in the shell shape (subcylindrical, fusiform, elongate fusiform), proloculus size, mode of coiling, shape of chomata, thickness of spirotheca, and so on. A number of species-groups are discriminated on the basis of the combination of these characters. The Early Permian Schwagerinidae can be differentiated into at least 15 genera, diagnostic characteristics of which can be traced back into those of any of the species-groups of the *Triticites*-phase in Late Carboniferous. As stratigraphically going upwards from the Upper Carboniferous, the main characters of respective species-groups became more distinct and radiated, and the shells became large and relatively more elongated.

Ancestors of the genera *Pseudoschwagerina*, *Paraschwagerina*, *Sphaeroschwagerina*, and *Zellia* have not yet been confirmed in the Upper Carboniferous *Triticites* zone. These genera are known to have appeared suddenly in the Lower Permian. Their large and highly vaulted shells suggest that they have not branched from any of the other Lower Permian genera. It is assumed that their ancestors appeared in Late Carboniferous times, and some species-groups, having a shell characterized by tightly coiled inner volutions and highly vaulted outer volutions, would be found in the *Schwagerina* zone and the *Triticites* zone.

Among various characteristics, the most distinct morphological change is in the septal fluting, which began the first at the polar ends of the shell and then extended to the central part of the shell and from the lower part to the upper part of the septa. The septal fluting became stronger progressively from the *Triticites*-phase in the Upper Carboniferous, through the *Schwagerina*-phase in the Lower Permian, to the *Parafusulina*-phase in the Middle Permian.

The septal fluting occurred in the Schwagerinidae, Fusulinidae, and Schubertellidae that have a fusiform to elongate shell with a long axis of coiling and pointed polar ends. In contrast, no septal fluting occurred in the other three families, the Staffellidae, Ozawainellidae, and Verbeekinidae, which have a discoidal to subspherical shell with a short axis of coiling and umbilicate or broadly convex polar ends throughout growth or at least in the juvenile stage. Thus, the presence or absence of the septal fluting seems to have primarily related to the difference of the shell shape at the phyletically juvenile stage each of the families.

Septal fluting became very intense in genera and species of the *Parafusulina*-phase, which commonly assumed a large elongate shell (usually 8-20 mm long), since the septa were folded in the way that their folded salients stood against those of the neighboring septa and their lower margins were coalesced with each other so as to transversely divide a chamber into a number of chamberlets. Then their conjoined or overlapped lower margins were later absorbed to develop continuous tunnels called cuniculi. Cuniculi have been regarded as a diagnostic feature of the genus *Parafusulina*, but they are well developed not only in elongate forms such as *Parafusulina* but also in almost all shell forms including a short fusiform or vaulted form such as *Pseudofusulina vulgaris* and species of *Cuniculinella* (Skinner and Wilde, 1965) and so on. Thus, cuniculi cannot be regarded as a criterion to distinguish

Parafusulina from other genera, but represent a structure of a stage in the direct evolution of septal fluting. And the genus "*Parafusulina*" implies the horizontal grouping of parallel grades.

The genera *Pseudoschwagerina*, *Paraschwagerina* and *Acervoschwagerina*, which were short-ranged and became extinct before they reached the *Parafusulina*-phase.

3. Evolutionary pattern of the Schubertellidae

The Schubertellidae is characterized by a fusiform shell and septal fluting, although they are different in spirothecal structure from the Schwagerinidae. It shows an evolutionary pattern similar to that of the Schwagerinidae, ending with genera at the stage in which cuniculi developed, as in the Schwagerinidae. In the Boultoniinae of the Schubertellidae some of latest genera have uncoiled or aberrant outer volutions besides cuniculi.

4. Evolutionary pattern of the Ozawainellidae

The Ozawainellidae, characterized by a discoidal shell with a short axis of coiling and plane septa, was rather conservative throughout its history except for early Middle Carboniferous time. It did not undergo such remarkable morphological changes as three families mentioned above, but the latest genera, *Reichelina* and *Parareichelina*, have an abnormally flanged outermost volution with very closely spaced septa.

5. Evolutionary pattern of the Staffellidae

The Staffellidae have an entirely different wall structure from other fusulinacean families, that is, their shells were always secondarily replaced. Various form appeared in Middle Permian, but most of them, except the Thailandininae, persisted with little morphological change into Late Permian. Their evolutionary pattern and lineages are still not completely known, because of their infrequent occurrence and poor preservation, but it is apparent that there were no genera and species that attained very complex or aberrant structures as seen in other families.

Description of fusulinacean faunas

As mentioned before, the investigated limestones are composed of fusulinids in 5 families and 13 genera. In the amount of genera, 12 genera are identified by author and 1 genus (*Chalaroschwagerina* sp., Figure 93) has been suggested by Dr. K. Ueno.

Daixina sp. in the samples are not in axial section and *Sphaerulina* sp. is recrystallized, so they are difficult to identify and explain in more detail. The author is indebted to Mrs. R. Ingavat-Helmcke and Dr. K. Ueno who suggested her to identify these genera.

The identification of fusulinacean faunas in the study areas is only in genera categories. Because the references of fusulinids are not enough to study in species categories and the biostratigraphic zonation of fusulinids can be studied in genera categories. Twelve fusulinacean genera are described as follows :

Order Foraminiferida Eichwald, 1830

Suborder Fusulinina Wedekind, 1937

Superfamily Fusulinacea von Moller, 1878

Family Schwagerinidae Dunbar and Henbest, 1930

Subfamily Schwagerininae Dunbar and Henbest, 1930

Genus *Triticites* Girty, 1904

Triticites sp.

Figures 46-52

Description : Shell is small to medium, fusiform, elongate fusiform in shape. Shell is composed of 5-10 volutions, 3-10 mm long and 2-5 mm wide. Proloculus is spherical and small. Shell expanded slowly. In axial section, septal fluting limited to axial regions. Chomata developed strongly. Tunnel single. In sagittal section, the septa are short and rather straight. Wall structure consists of tectum and keriotheca in outer volutions but inner volutions are not clear to observe.

Materials : TCM 94-1, TCM 94-2, TCM 94-3-1, TCM 94-3-5 and TCM 94-4-3.

Genus *Daixina* Rozovskaya, 1949

Daixina sp.

Figures 53-62

Description : The specimens are in sagittal and parallel sections. Shell is approximately 2-4 mm wide and contains 5-6 volutions. Proloculus is rather small compared with size of shell, spherical in shape. Spirotheca is composed of tectum and keriotheca with alveoli. Inner two volutions tightly coiled. Outer volutions rapidly increase in their length.

Remarks : The genus *Daixina* was established by Rozovskaya (1949). Originally, Rozovskaya treated this as a generic rank. Later, Ross and Dunbar (1962) transferred this genus to the genus *Pseudofusulina*, and treated it as a subgenus of the later as *Pseudofusulina (Daixina)*. Most fusulinacean workers consider *Daixina* as a valid genus and independent of the genus *Pseudofusulina*.

Materials : TCM 94-3, TCM 94-4-3 and TCM 94-8.

Genus *Jigulites* Rozovskaya, 1948

Jigulites sp.

Figure 63

Description : Shell large, fusiform to elongate fusiform shell. Septa moderately fluted with increasing their intensity toward polar regions. The specimen have 6 to 7 volutions, 6-8 mm long and 2-3 mm wide. Proloculus spherical in outside diameter. Spirotheca thin and composed of tectum and keriotheca. Chomata narrow.

Remarks : Diagnosis of *Jigulites* have a well developed massive chomata but the present specimens have narrow chomata.

Materials : TCM 94-4-4 and TCM 94-8

Genus *Pseudoschwagerina* Dunbar and Skinner, 1936

Pseudoschwagerina sp.

Figures 64-68

Description : Shell is medium to large, subspherical to spherical in shape. Shell is composed of 6-8 volutions, 8-15 mm long and 6-14 mm wide. Proloculus is small and spherical. The inner 2 or 3 volutions coiled tightly and the adjacent outer volutions expanded rapidly. In the axial section, septa fluted weakly in axial regions. Chomata

distinct only in inner volutions. In the sagittal section, the septa are almost plain. Spirotheca consists of tectum and keriotheca with fine alveoli. The spirotheca of 2 outer volutions are thicker than inner volutions.

Materials : TCM 94-3-6, TCM 94-4-1 and TCM 94-4-3 to TCM 94-4-8

Genus *Darvasites* Miklukho-Maklay, 1959

Darvasites sp.

Figures 69

Description : Ellipsoidal shell. Proloculus large and spherical. Spirotheca composed of a tectum and a lower structureless layer in inner few volutions, but of tectum and keriotheca in outer ones. Septa moderately and regularly fluted throughout length of shell except for central part. Chomata low narrow and developed in all volutions except for the last one.

Remarks : *Darvasites* sp. is dimorphism in megalospheric and microspheric forms. The specimens show megalospheric form.

Material : TCM 94-8

Genus *Pseudofusulina* Dunbar and Skinner, 1931

Pseudofusulina sp.

Figures 70-82

Description : Shell moderate to large, fusiform, elongate fusiform to subcylindrical. Proloculus large and spherical. The spiral wall consists of tectum and keriotheca. Shell coiled rather loosely. Septa strongly and regularly fluted throughout the length of shell. Chomata high narrow. Phrenotheca usually present.

Materials : TCM 94-9-13, TCM 94-9-30, TCM 94-10 (lower and upper parts) and TCM 94-11-15.

Genus *Parafusulina* Dunbar and Skinner, 1931

Parafusulina sp.

Figures 83-92

Description : Shell very large, elongate fusiform to subcylindrical. Proloculus medium to large. Spirotheca thin and composed of tectum and keriotheca. Shell coiled rather tightly. Septa highly and narrowly fluted throughout whole length of shell or partially. Cuniculi present. Chomata absent. Tunnel singular.

Materials : TCM 94-9-16, TCM 94-9-17, TCM 94-9-22, TCM 94-9-30 and TCM 94-10 (lower and upper parts).

Family Schubertellidae Skinner, 1931

Subfamily Schubertellinae Skinner, 1931

Genus *Schubertella* Staff and Wedekind, 1910

Schubertella sp.

Figure 20

Description : Shell small and fusiform with bluntly pointed polar ends and slightly convex lateral slopes. Shell consists of 4 volutions. Inner 1 to 2 volutions skew coiled. Shell expands gradually beyond the third volution. Proloculus small and spherical. Spirotheca thin and composed of a tectum and lower, less dense layer. Septa unfluted and almost plane. Chomata high narrow developed in 3rd-4th outer volutions.

Materials : TCM 94-4-2, TCM 94-11-7 and TCM 94-11-10.

Genus *Yangchienia**Yangchienia* sp.

Figure 96

Description : Shell small, inflated rhomboidal with pointed poles and straight lateral slope. Shell consists of 8 volutions. All volutions compactly coiled. Proloculus small. Spirotheca thin, composed of a tectum and a lower transparent layer, the diaphanotheca. Septa unfluted. Chomata extremely massive developed in all volutions. Tunnel singular.

Materials : TCM 94-9-15, TCM 94-9-16, TCM 94-9-17, TCM 94-9-19 and TCM 94-9-22

Family Ozawainellidae Thompson and Foster, 1937

Subfamily Ozawainellinae Thompson and Foster, 1937

Genus *Pamirina* Leven, 1970 emend. Kobayashi, 1977

Pamirina sp.

Figures 97 and 98

Description : Shell small, subspherical in shape with broadly rounded poles. Shell having 3 to 5 volutions. Proloculus small to large and spherical. Spirotheca thin. The structure of spirotheca in specimens are not clear. Septa straight and plane. Chomata low broad developed in outer volutions.

Materials : TCM 94-11-1, TCM 94-11-2, TCM 94-11-6, TCM 94-11-7, TCM 94-11-9, TCM 94-11-10 and TCM 94-11-14

Family Staffellidae Miklukho-Maklay, 1949

Genus *Sphaerulina* Lee, 1933

Sphaerulina sp.

Figure 99

Description : Test almost globose with slightly umbilicated axial regions and broadly expanded poles. Number of whorls 8-9.

Remarks : Globula shape of the present specimen indicates that it is included in the genus *Sphaerulina*, although it is recrystallized. Its internal structure can not be explained in more detailed.

Materials : TCM 94-9-14

Family Verbeekinidae Staff and Wedekind, 1910

Subfamily Verbeekininae Staff and Wedekind, 1910

Genus *Verbeekina* Staff, 1909

Verbeekina sp.

Figures 94-95

Description : Shell large and almost spherical. The specimens are not in good sections. Proloculus and inner few volutions are not presented. Outer volutions uniformly expanded. Spirotheca thin and composed of a tectum and keriotheca. Septa plane closely spaced. Parachomata numerous. Foramen small and numerous.

Remarks : Diagnostic for this genus, Form ratio about 1:1. Inner three to four volutions tightly coiled. Outer volutions expanded rapidly.

Materials : TCM 94-9-21

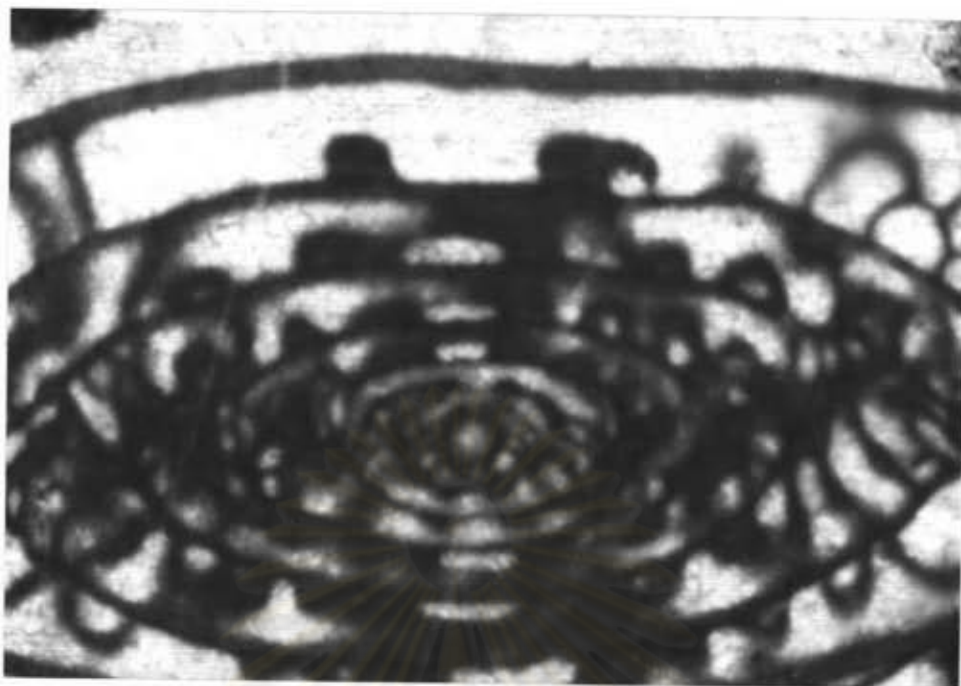
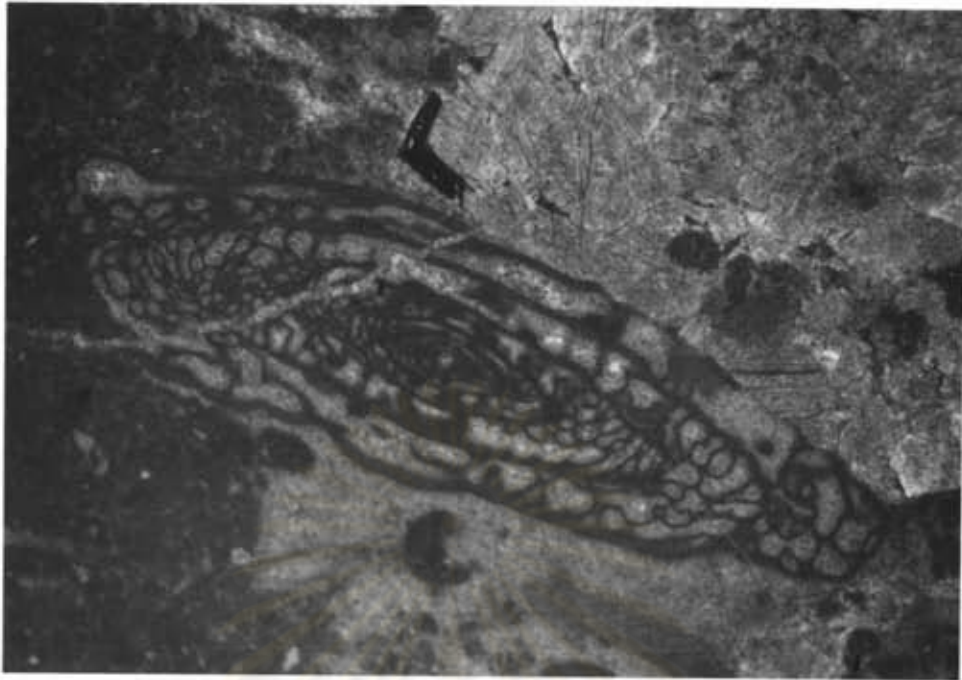


Figure 46 An axial section of *Triticites* sp. showing chomata and tunnel.

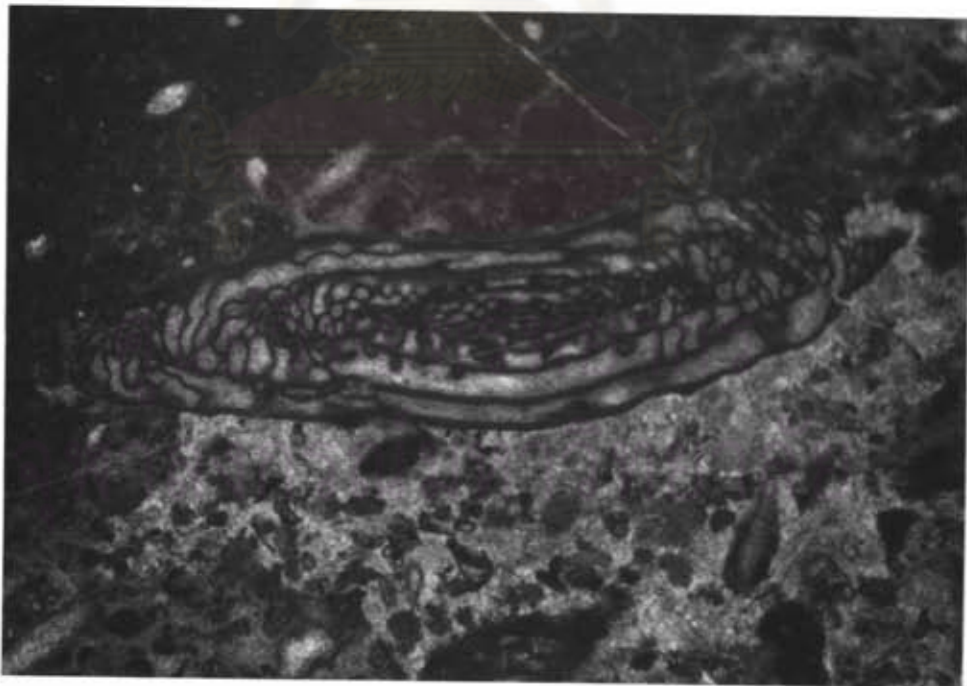


Figure 47 A parallel section of *Triticites* sp. showing septa.



1 mm

Figure 48 An axial section of *Triticites* sp. Location TCM 94-1 (Pha Mo).



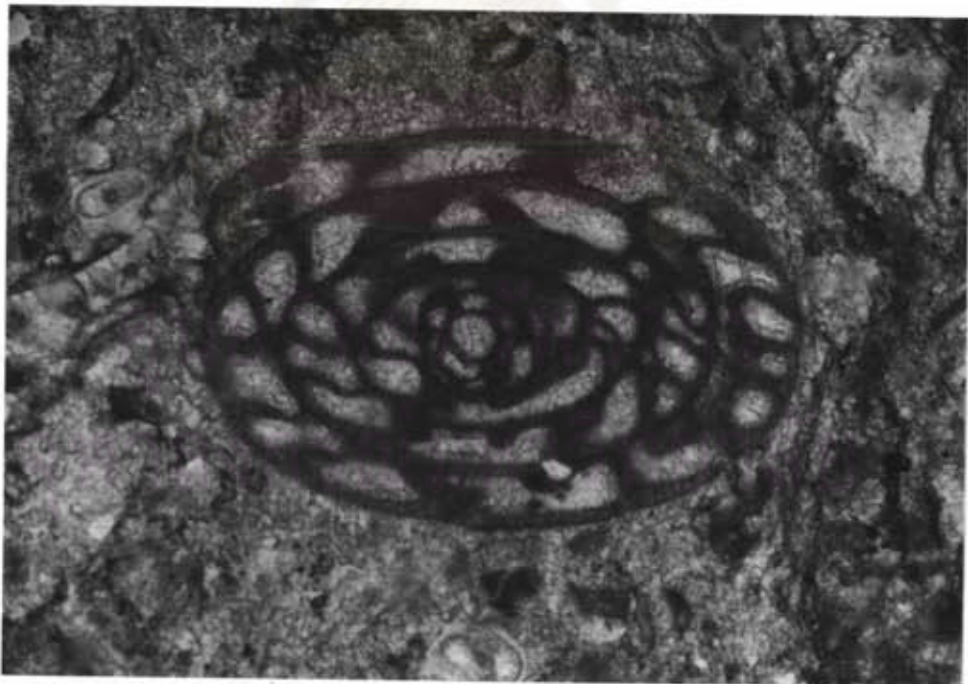
1 mm

Figure 49 A tangential section of *Triticites* sp. Location TCM 94-1 (Pha Mo).



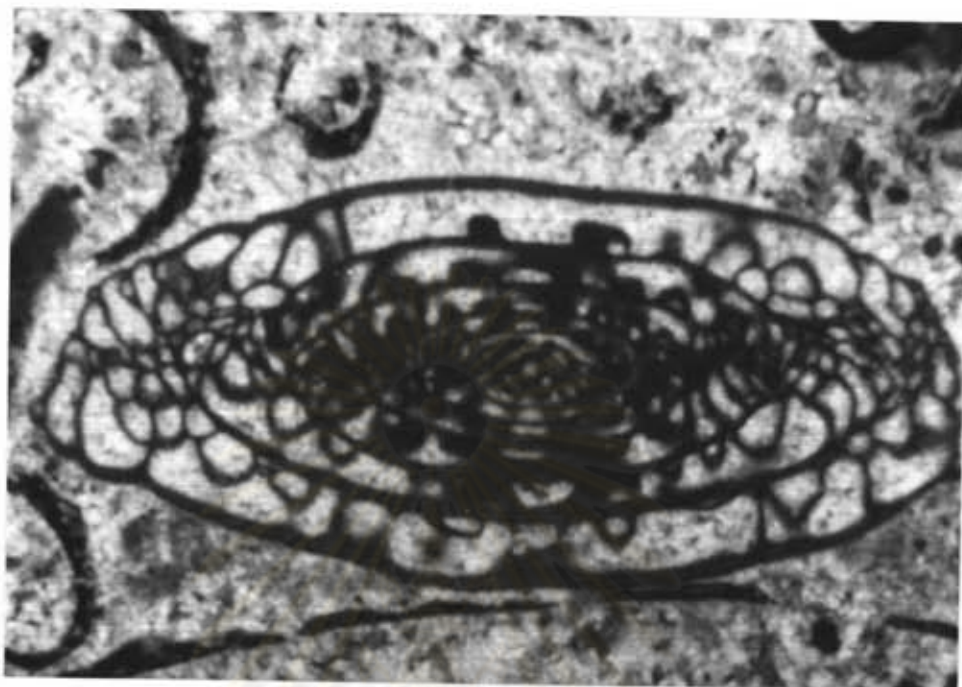
0.5 mm

Figure 50 A tangential section of *Triticites* sp. showing chomata, tunnel and wall structure. Sample no. TCM 94-3-5.



1 mm

Figure 51 An axial section of *Triticites* sp. Sample no. TCM 94-3-5.



1 mm

Figure 52 Axial sections of *Triticites* sp. Sample no. TCM 94-4-3.

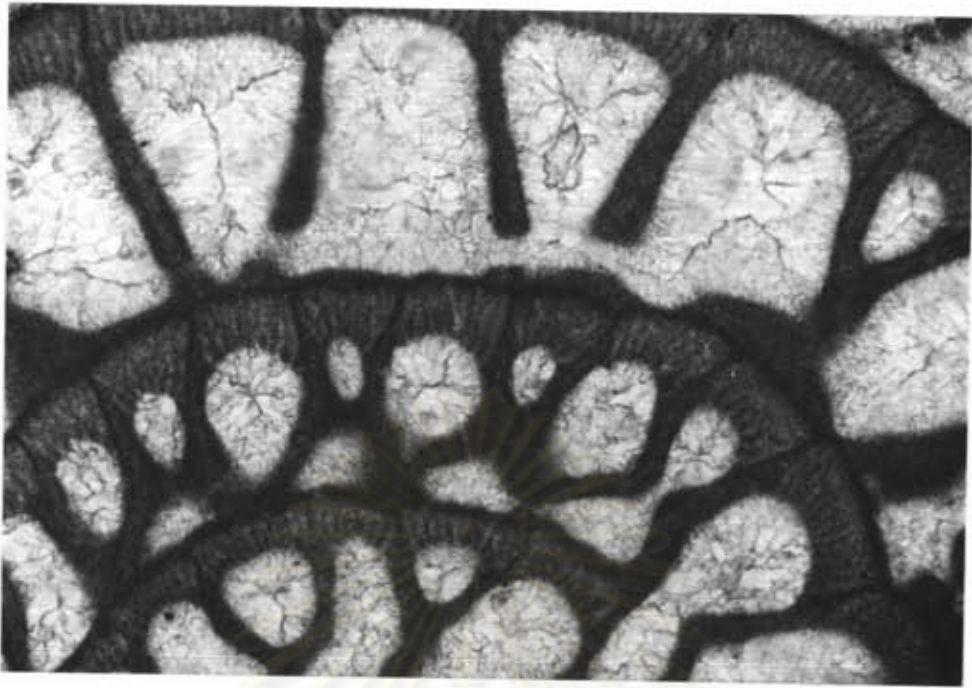


Figure 53 *Daixina* sp. showing parachomata, septa, tectum and keriotheca.



Figure 54 *Daixina* sp. showing wall structure of schwagerinid type.

It contains tectum, keriotheca and alveoli.

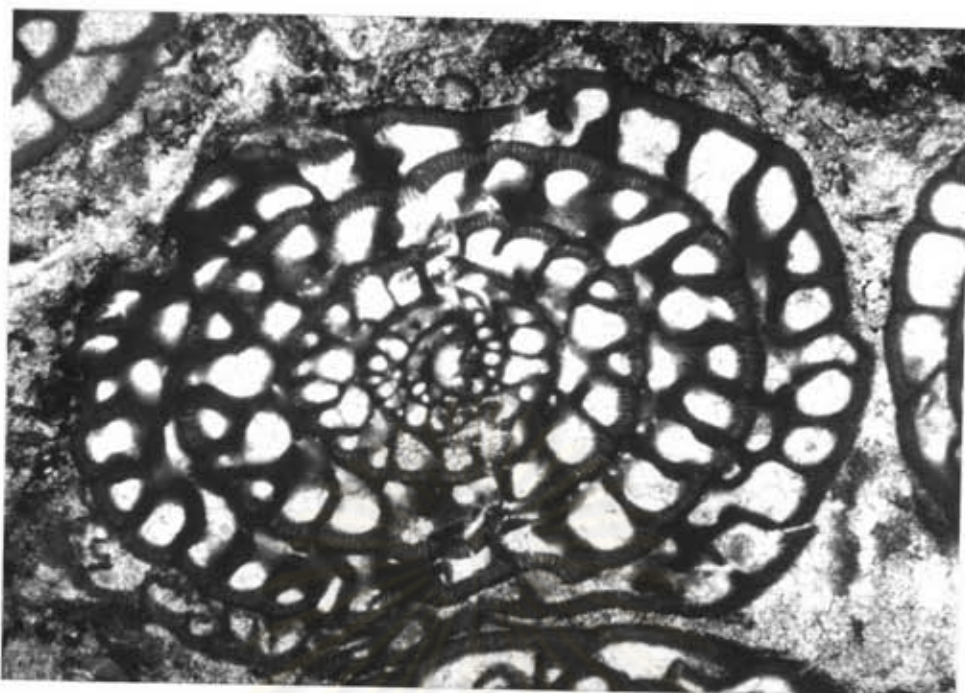


Figure 55 A sagittal section of *Daixina* sp. Sample no. TCM 94-3-1.

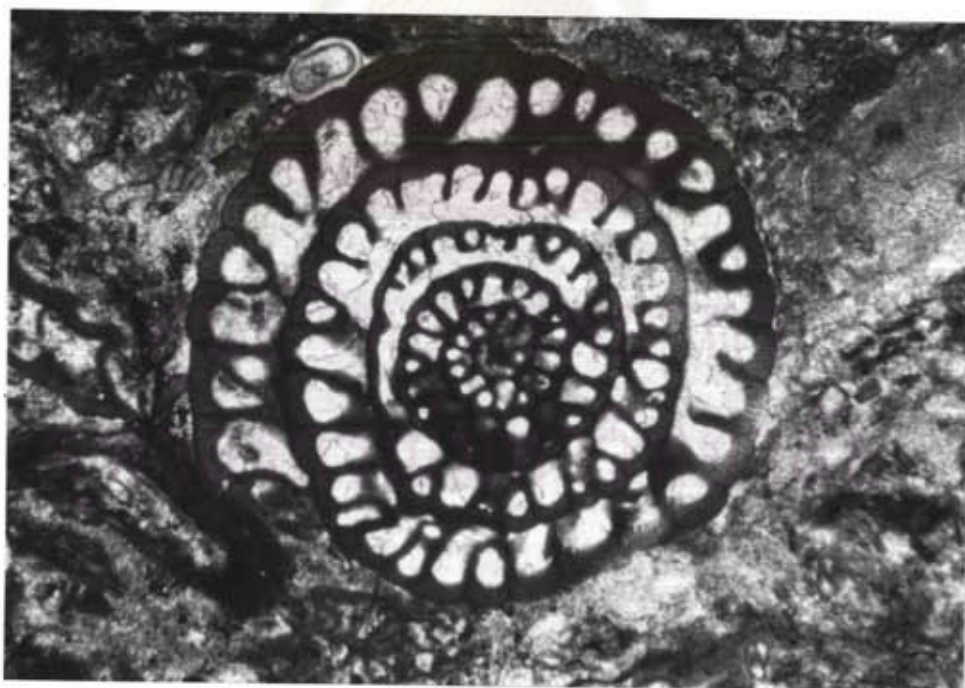


Figure 56 A parallel section of *Daixina* sp. Sample no. TCM 94-3-1.

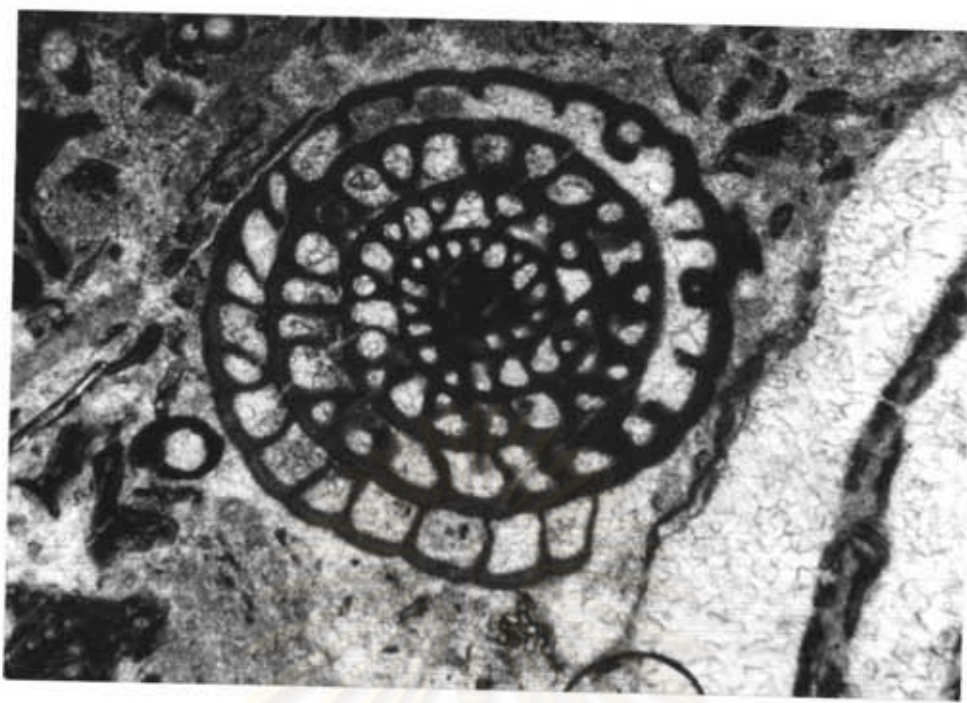


Figure 57 A parallel section of *Daixina* sp. Sample no. TCM 94-4-3.

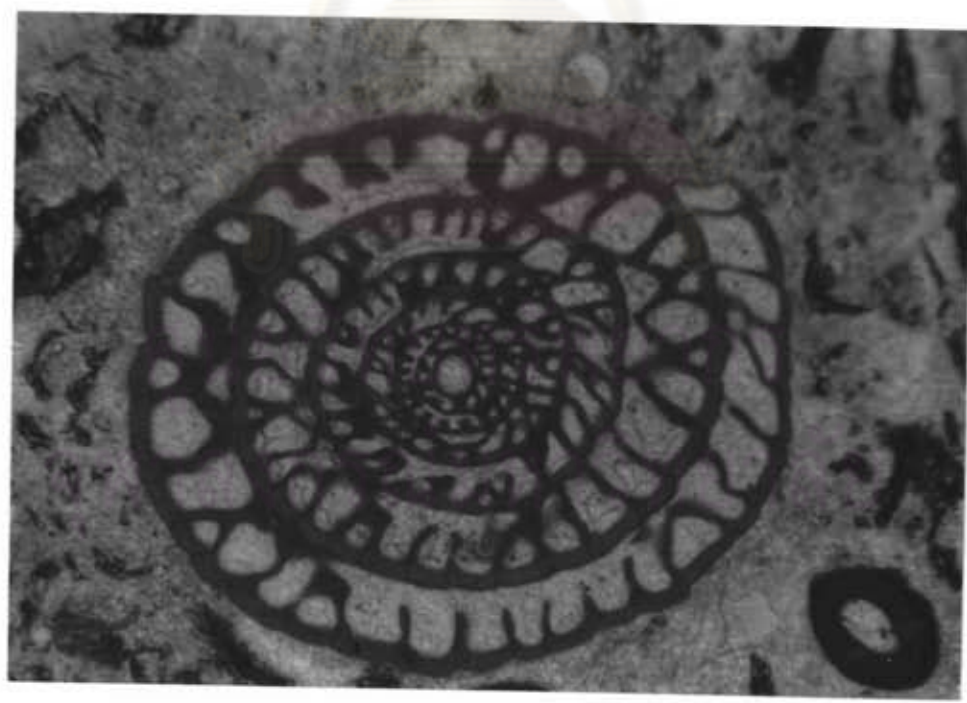


Figure 58 A sagittal section of *Daixina* sp. Sample no. TCM 94-4-3.

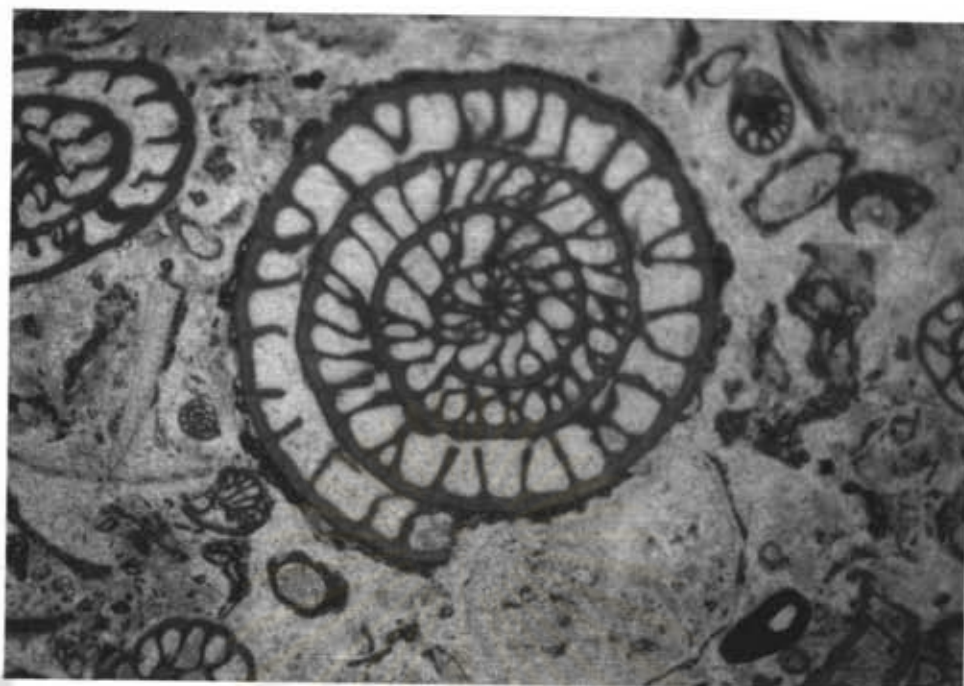


Figure 59 A parallel section of *Daixina* sp. Sample no. TCM 94-4-3.

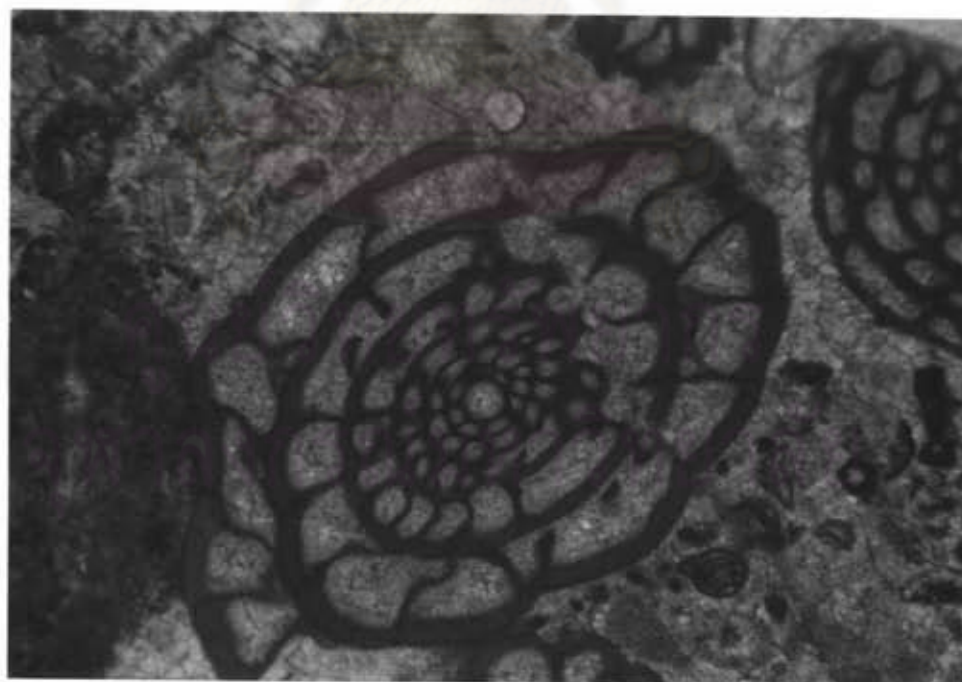


Figure 60 A sagittal section of *Daixina* sp. Location TCM 94-8.

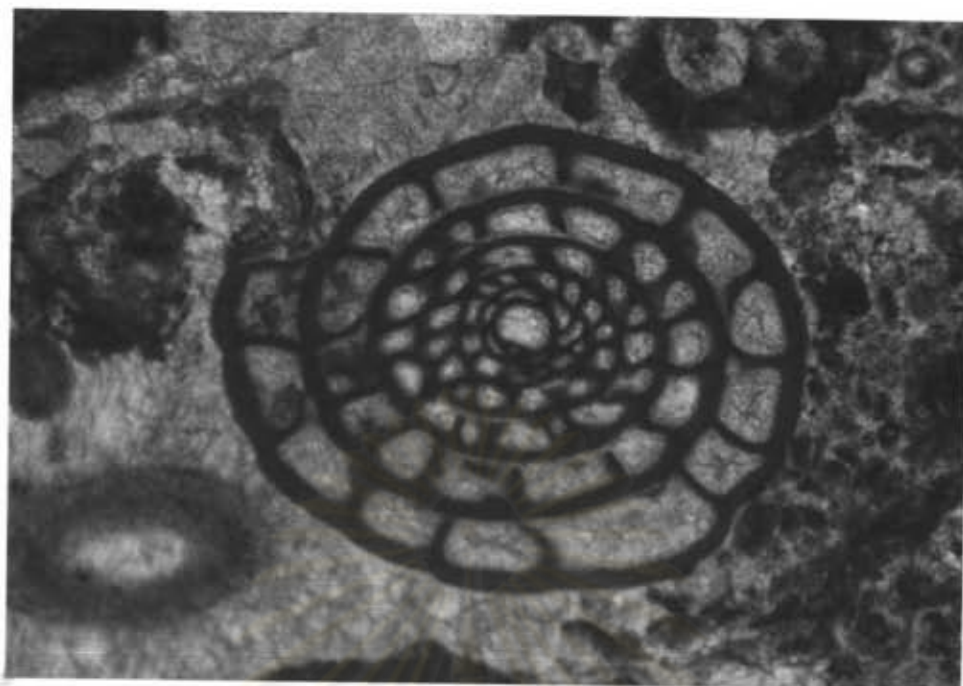


Figure 61 A sagittal section of *Daixina* sp. Location TCM 94-8.



Figure 62 A sagittal section of *Daixina* sp. Tectum and keriotheca are clearly observed. Location TCM 94-8.

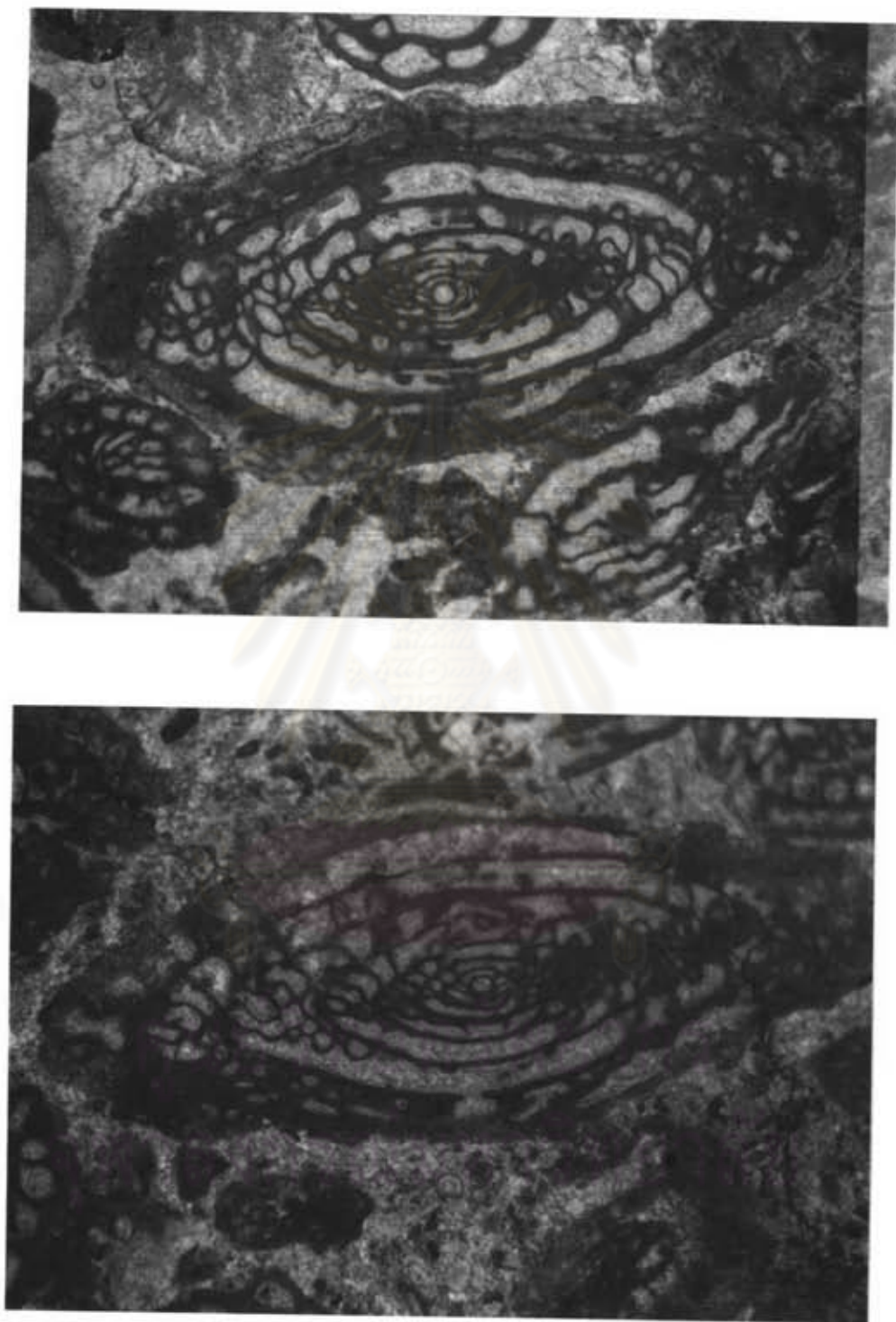
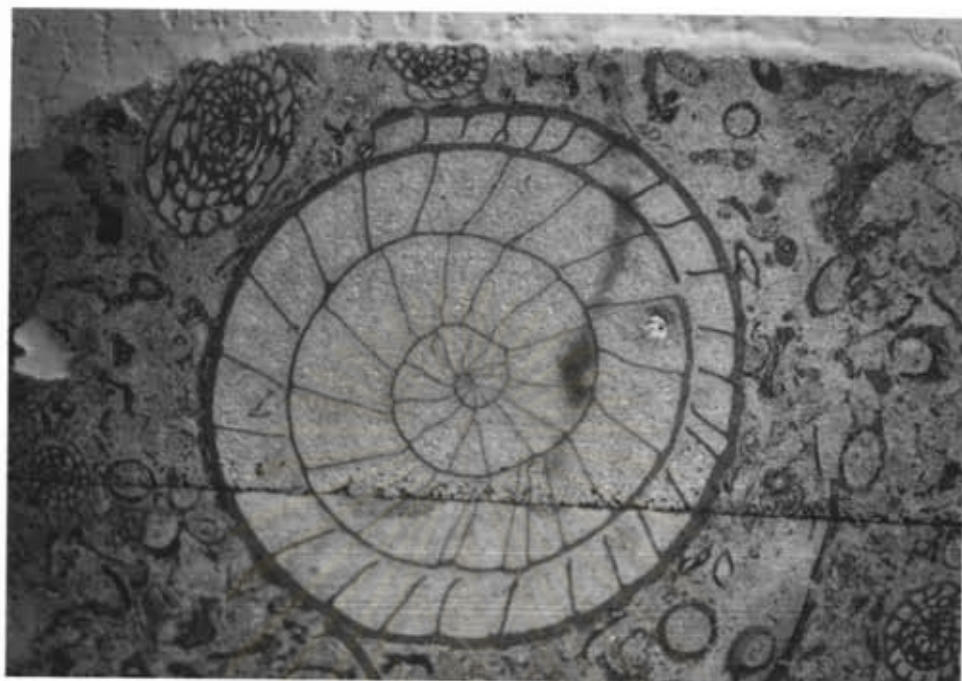


Figure 63 Axial sections of *Jigulites* sp. Location TCM 94-8.



1 mm

Figure 64 Parallel sections of *Pseudoschwagerina* sp. Sample no. TCM 94-4-3.

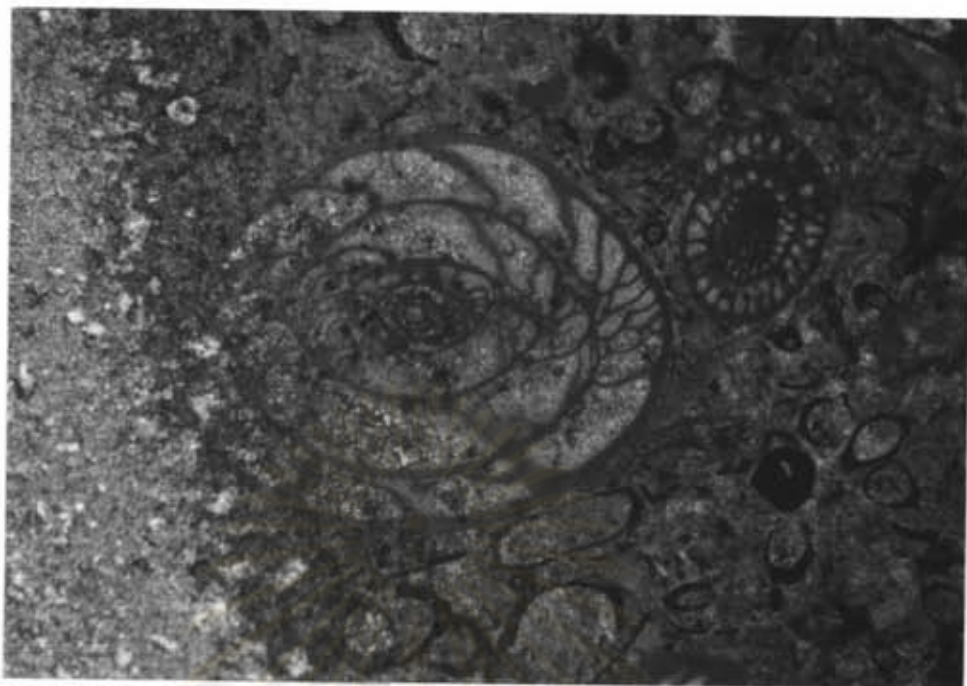


Figure 65 An axial section of *Pseudoschwagerina* sp. Sample no. TCM 94-4-6.



Figure 66A parallel section of *Pseudoschwagerina* sp. Sample no. TCM 94-4-7.



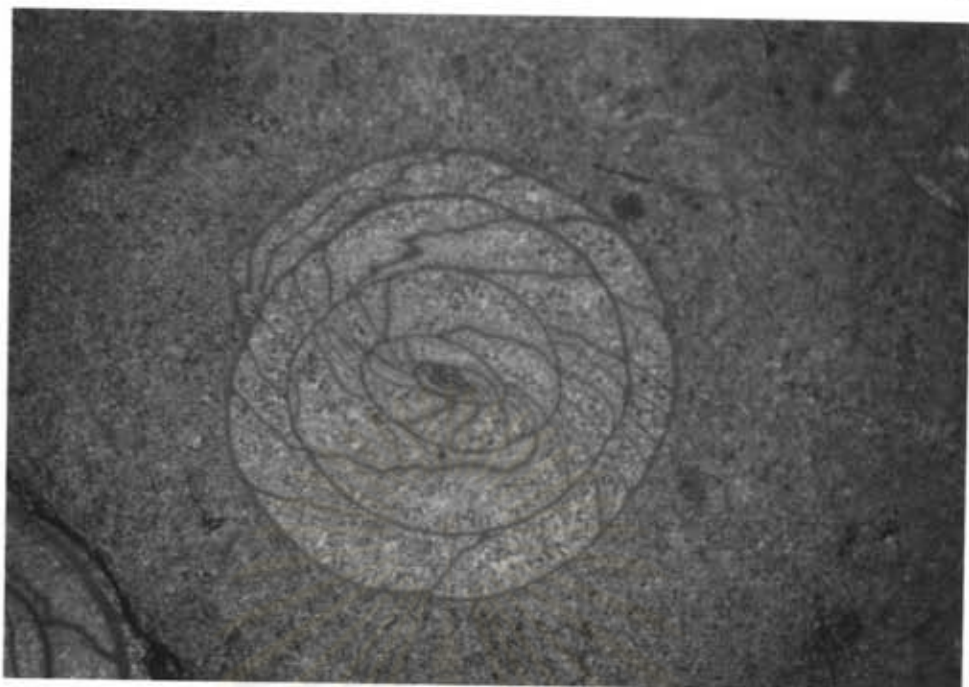
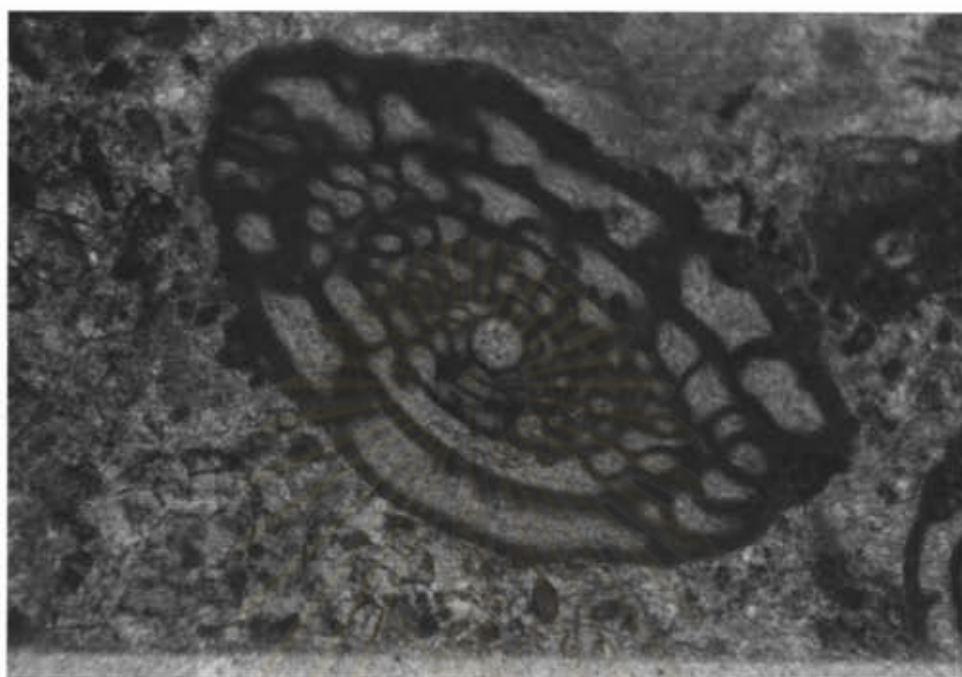


Figure 67 A tangential section of *Pseudoschwagerina* sp.

Sample no. TCM 94-4-8.

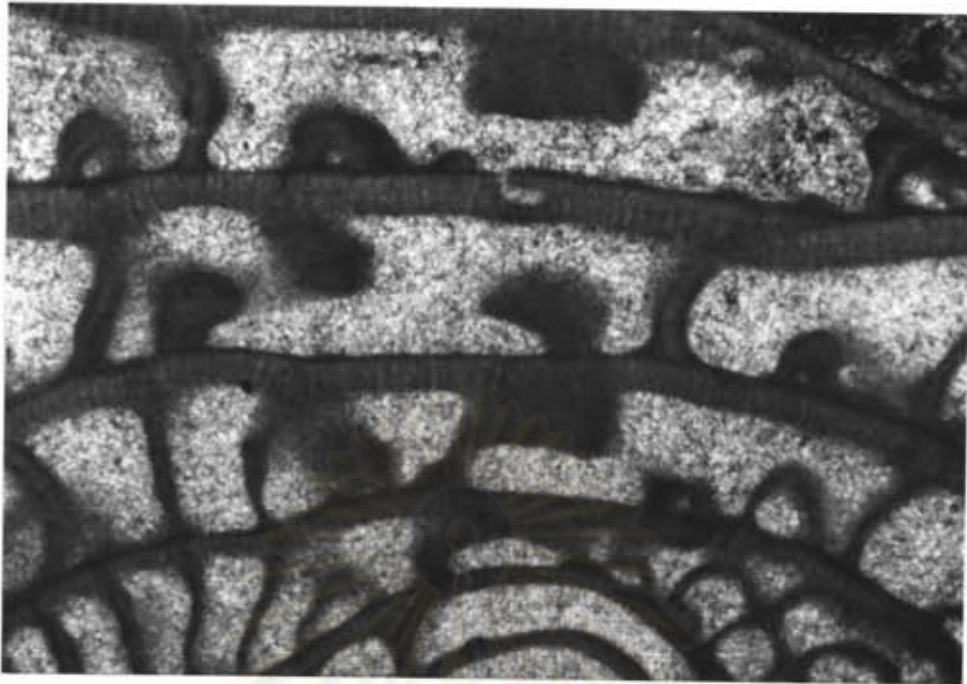


Figure 68 A sagittal section of *Pseudoschwagerina* sp. Sample no. TCM 94-4-8.



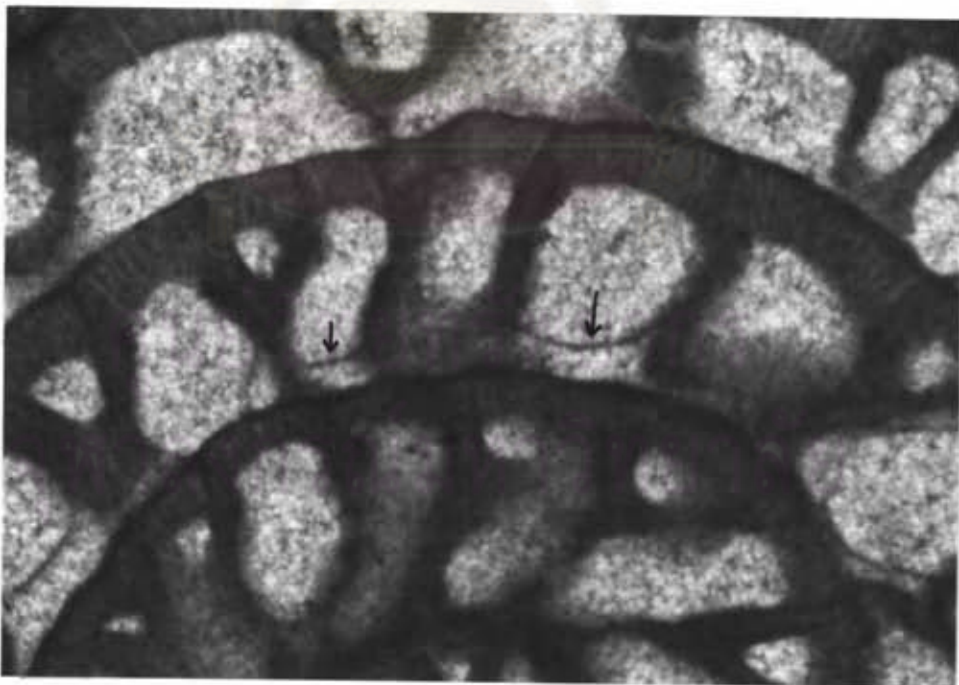
1 mm

Figure 69 Axial sections of *Darvasites* sp. Location TCM 94-8.



0.5 mm

Figure 70 *Pseudofusulina* sp. showing chomata, septa, tectum and keriotheca.



0.5 mm

Figure 71 *Pseudofusulina* sp. showing phrenotheca.

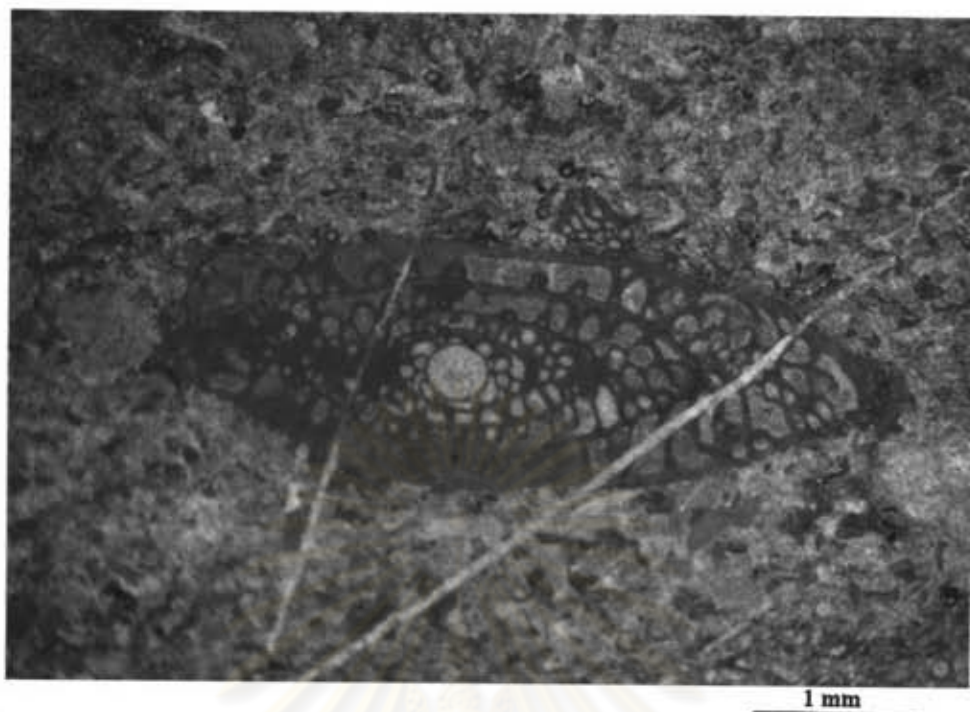


Figure 72 An axial section of *Pseudofusulina* sp. Sample no. TCM 94-9-13.



Figure 73 An axial section of *Pseudofusulina* sp. Sample no. TCM 94-9-30.

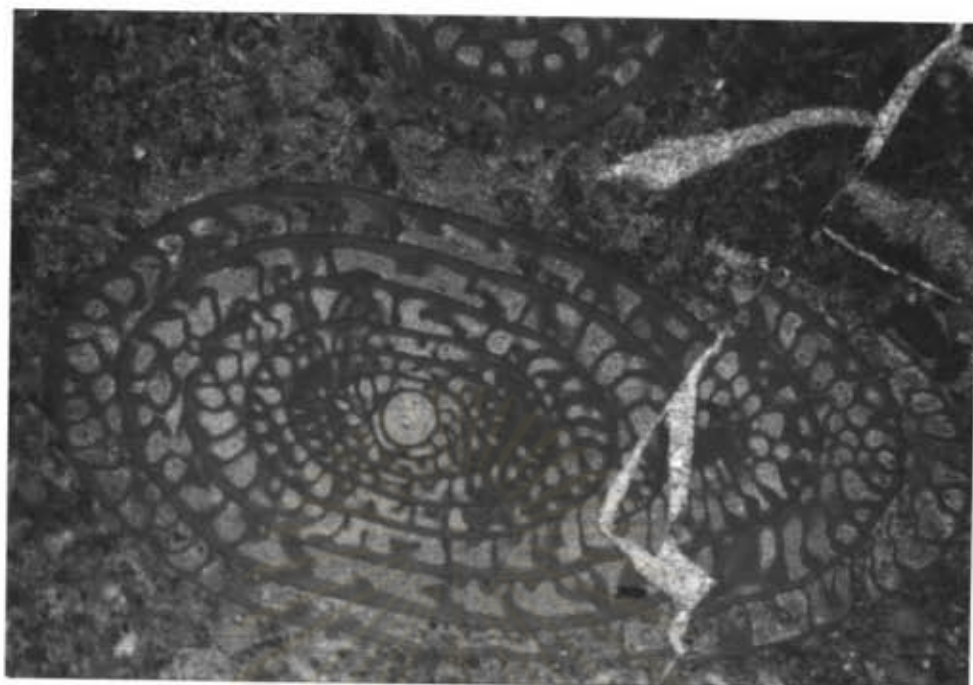


Figure 74 An axial section of *Pseudofusulina* sp. Sample no. TCM 94-9-30.

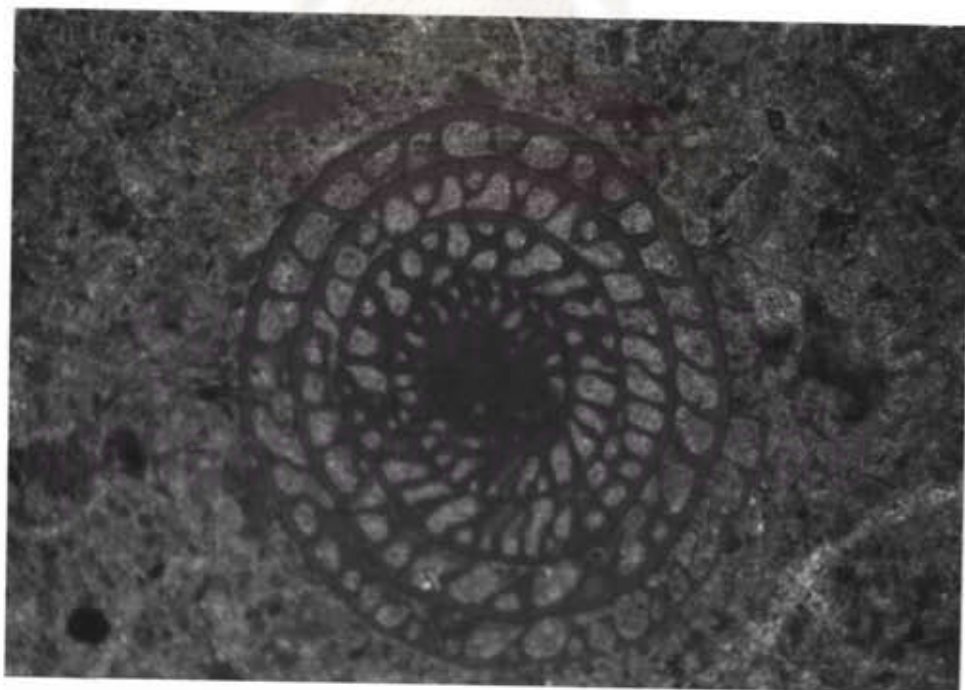


Figure 75 A parallel section of *Pseudofusulina* sp. Sample no. TCM 94-9-30.

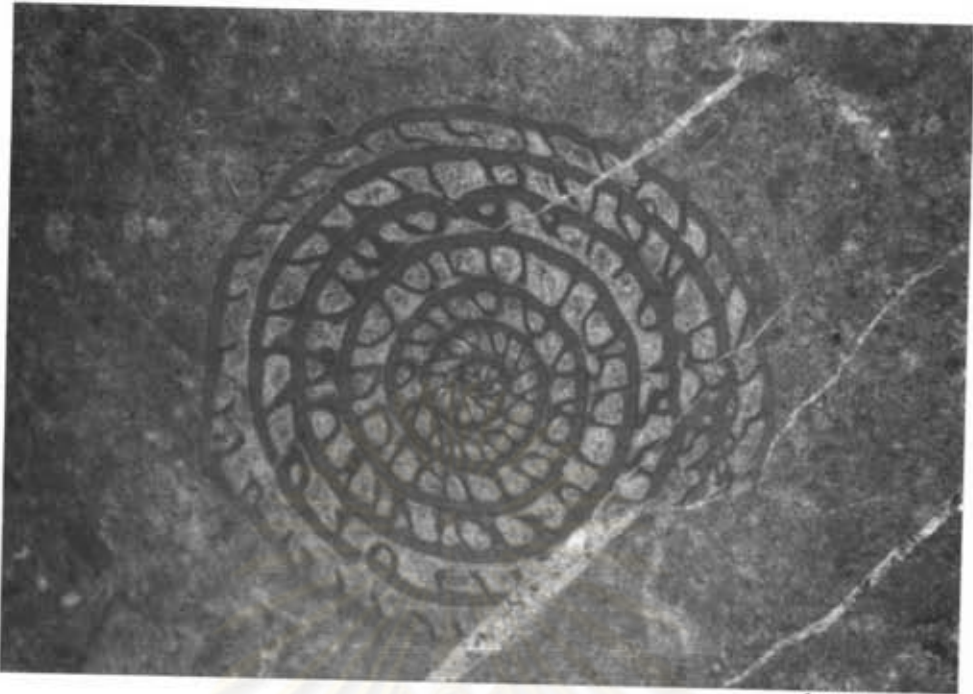
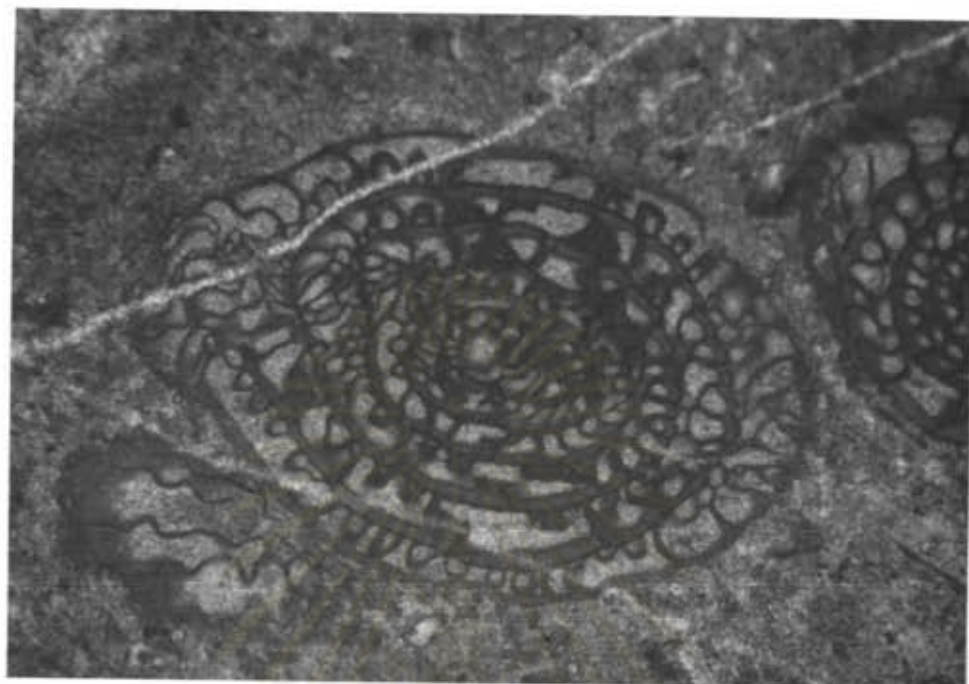


Figure 76 A parallel section of *Pseudofusulina* sp. from the upper part of Location TCM 94-10.



Figure 77 An axial section of *Pseudofusulina* sp. from the upper part of Location TCM 94-10.



1 mm

Figure 78 Axial sections of *Pseudofusulina* sp. from the upper part of Location TCM 94-10.

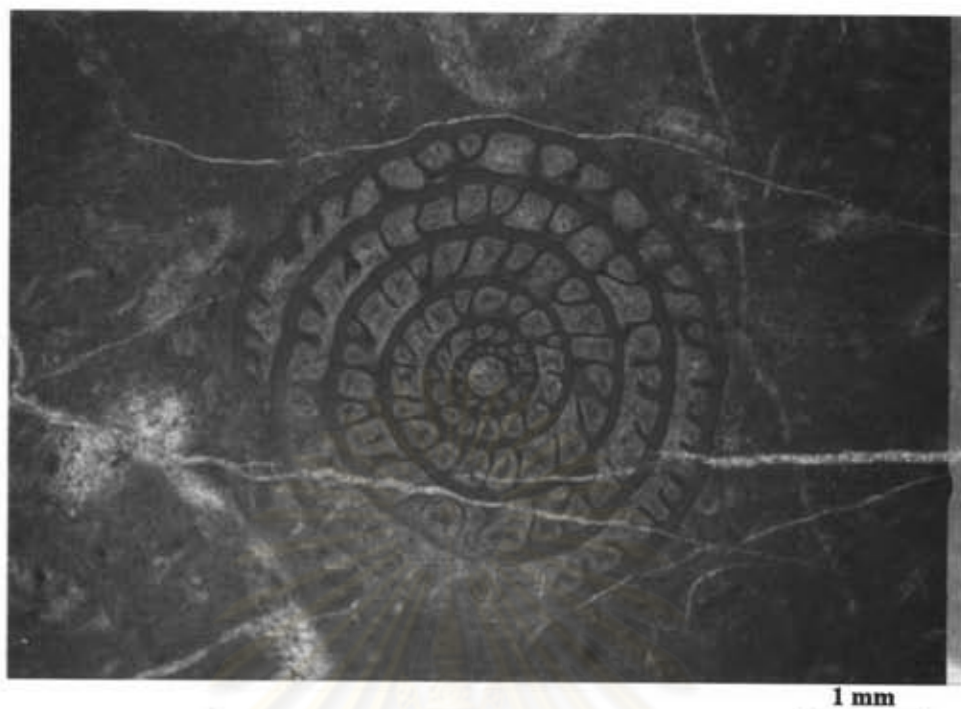
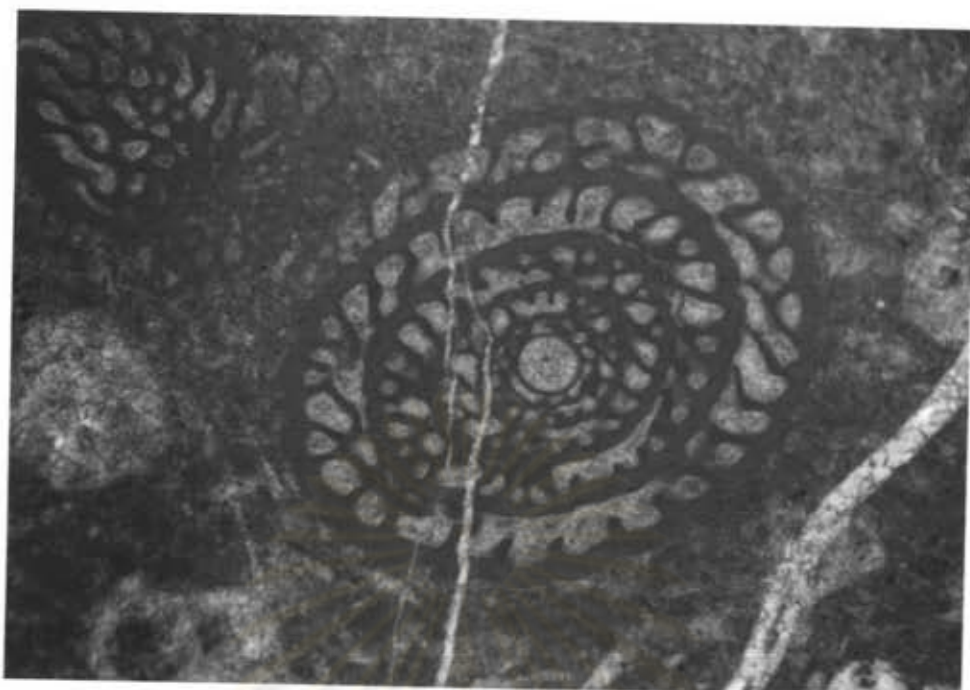


Figure 79 A sagittal section of *Pseudofusulina* sp. from the upper part of Location TCM 94-10.



Figure 80 An axial section of *Pseudofusulina* sp. Sample no. TCM 94-11-15.



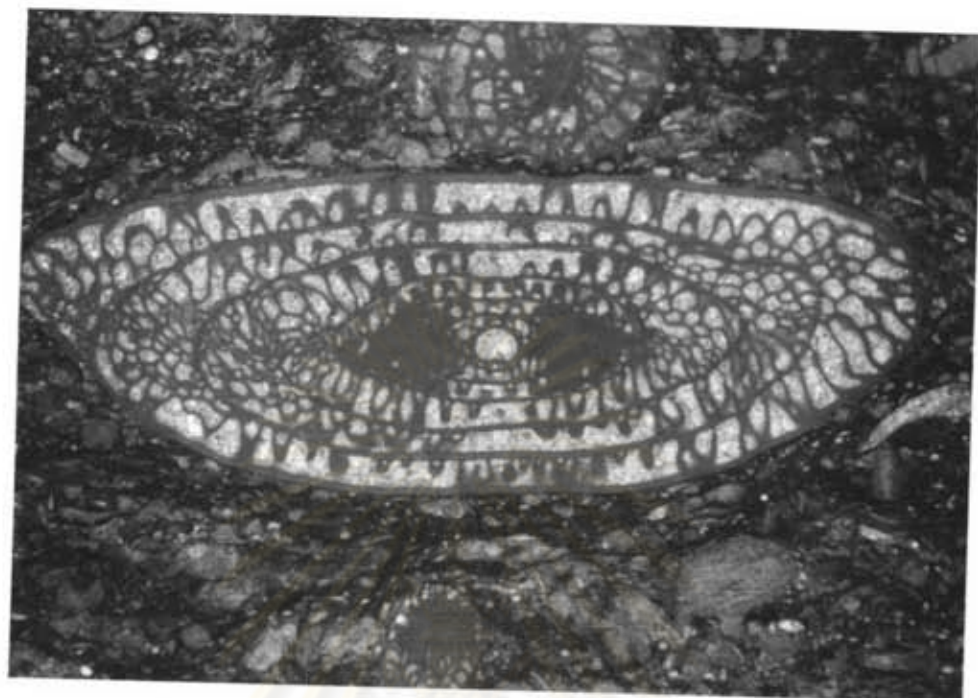
1 mm

Figure 81 A sagittal section of *Pseudofusulina* sp. Sample no. TCM 94-11-15.



1 mm

Figure 82 An axial section of *Pseudofusulina* sp. Sample no. TCM 94-11-15.



1 mm

Figure 83 Axial sections of *Parafusulina* sp. Sample no. TCM 94-9-16.



1 mm

Figure 84 A tangential section of *Parafusulina* sp. Sample no. TCM 94-9-16.

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จุฬาลงกรณ์มหาวิทยาลัย



1 mm

Figure 85 An axial section of *Parafusulina* sp. Sample no. TCM 94-9-17.



1 mm

Figure 86 An axial section of *Parafusulina* sp. Sample no. TCM 94-9-22.



Figure 87 A tangential section of *Parafusulina* sp. Sample no. TCM 94-9-30.



Figure 88 An axial section of *Parafusulina* sp. Sample no. TCM 94-9-30.

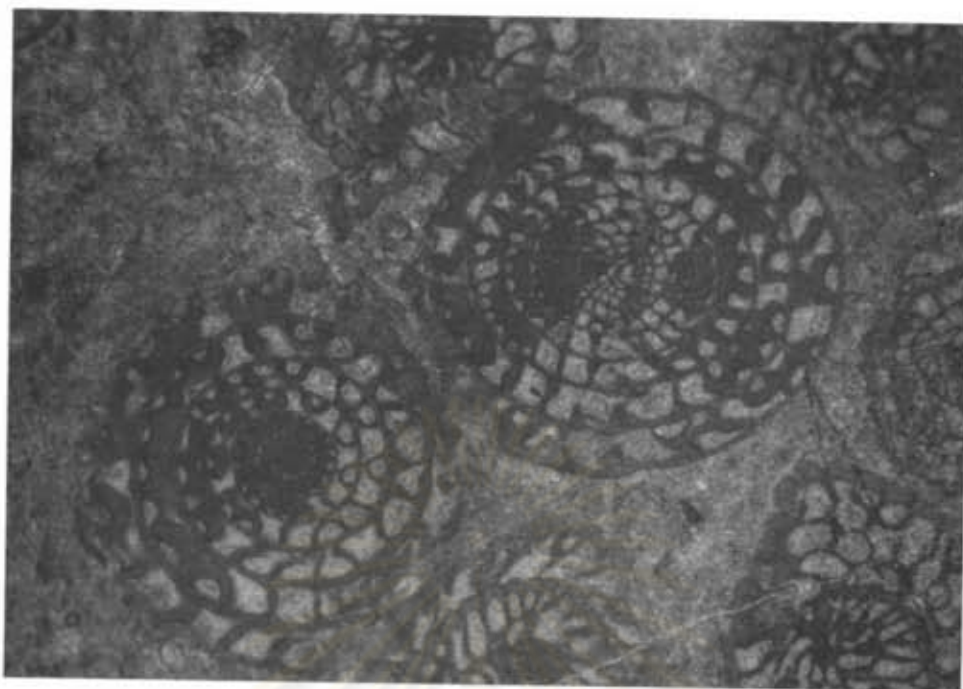
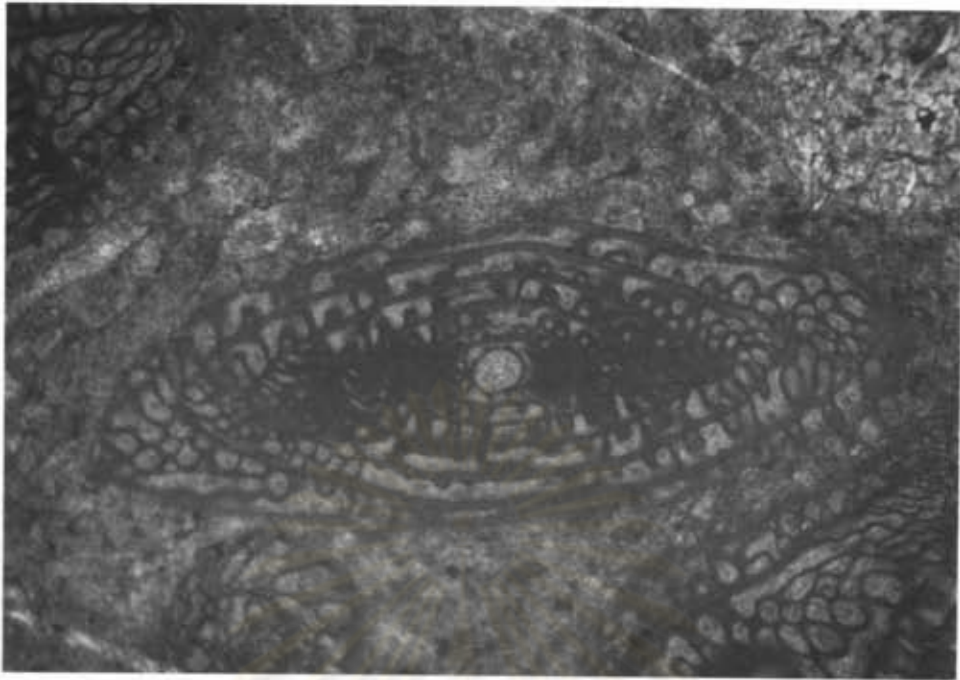


Figure 89 A parallel section of *Parafusulina* sp. from the upper part of Location TCM 94-10.



Figure 90 Parallel and sagittal sections of *Parafusulina* sp. from the upper part of Location TCM 94-10.



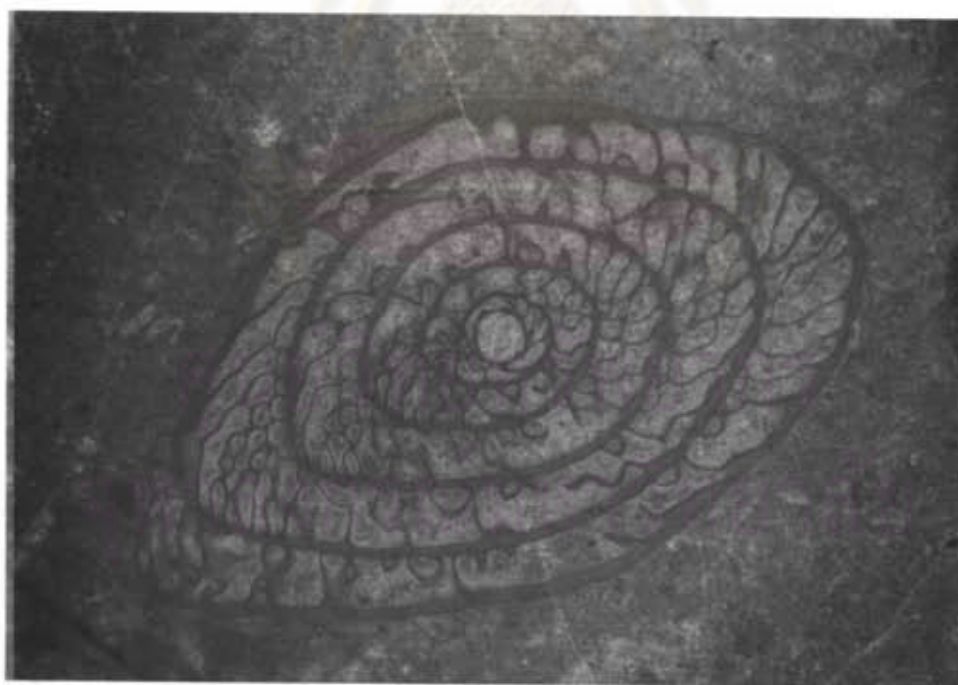
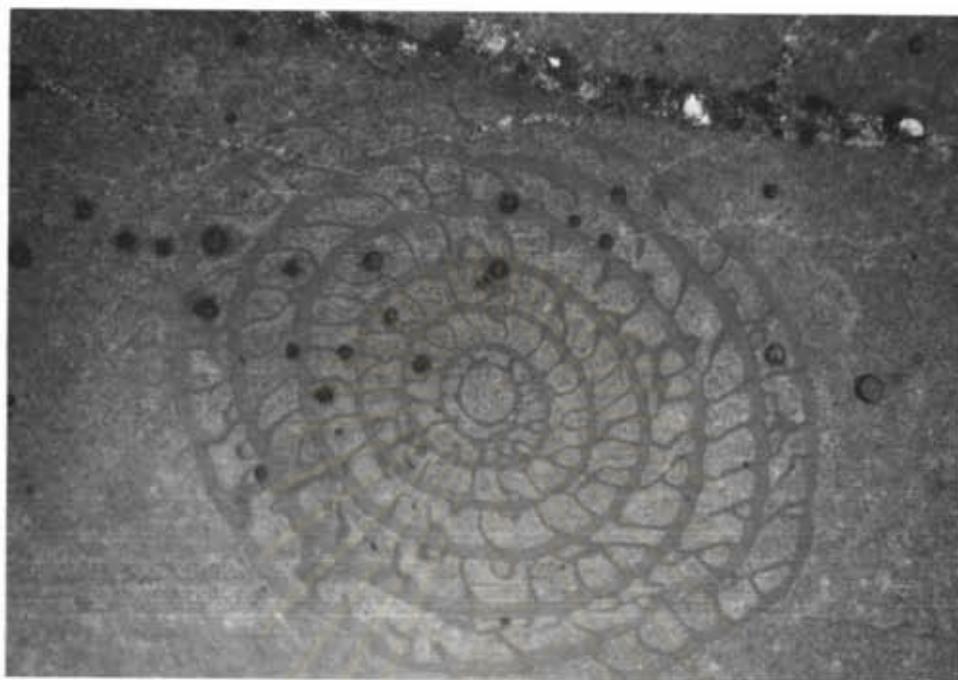
1 mm

Figure 91 An axial section of *Parafusulina* sp. from the upper part of Location TCM 94-10.



1 mm

Figure 92 *Parafusulina* sp. showing sections cutting through various directions. This specimen is in the upper part of Location TCM 94-10.



1 mm

Figure 93 Sagittal sections of *Chalaroschwagerina* sp. from the upper part of Location TCM 94-10.



Figure 94 A parallel section of *Verbeekina* sp. Sample no. TCM 94-9-21.



Figure 95 *Verbeekina* sp. showing parachomata which is present on the wall.

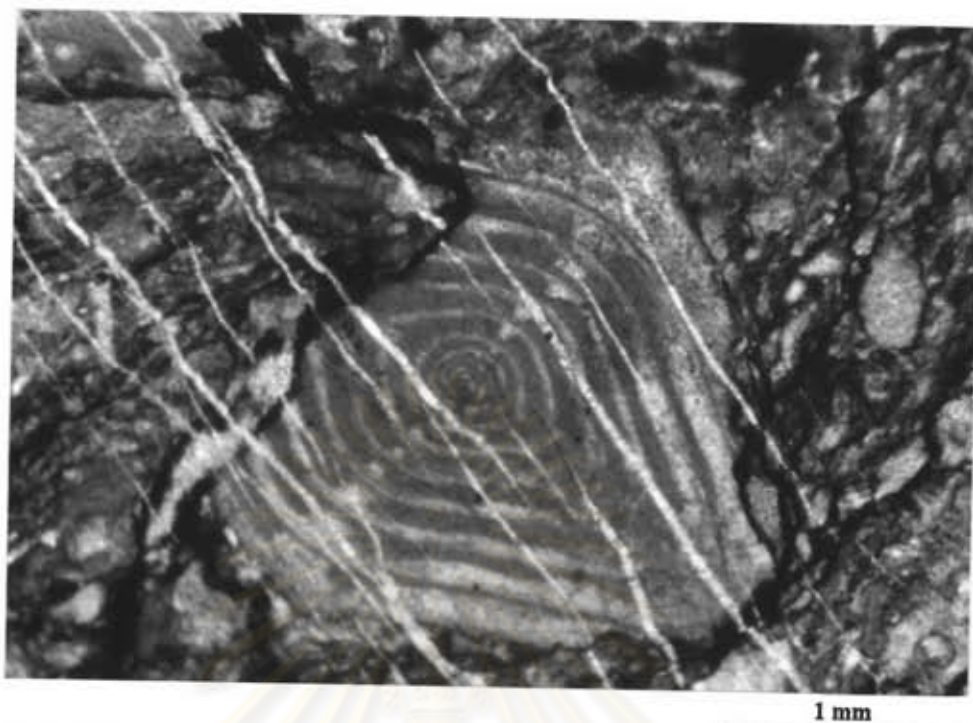


Figure 96 An axial section of *Yangchienia* sp. showing clear chomata.

Sample no. TCM 94-9-16.

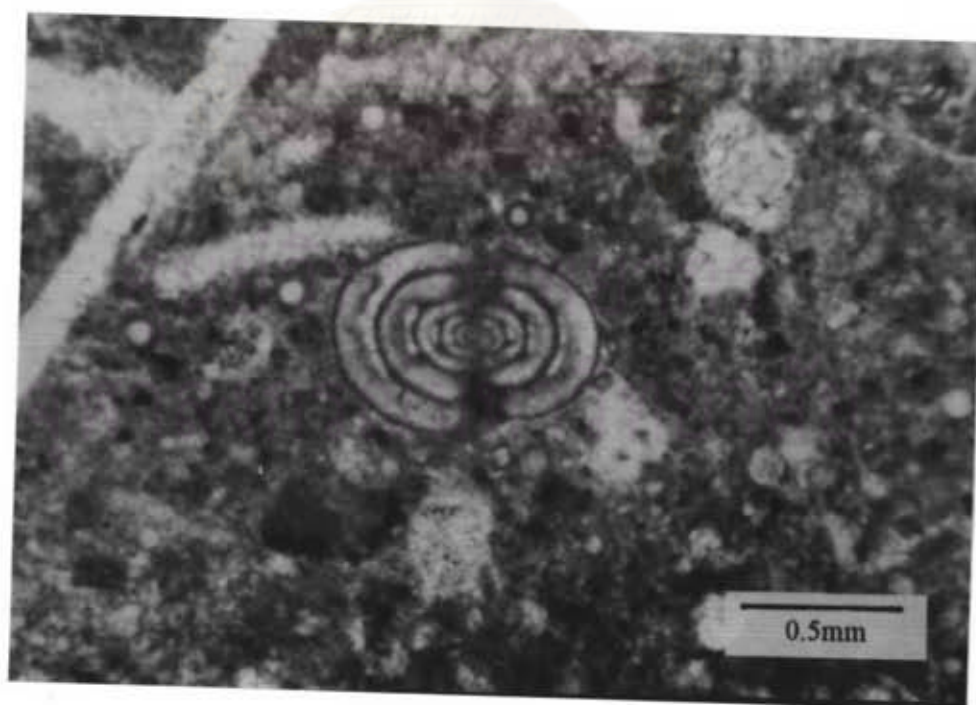


Figure 97 An axial section of *Pamirina* sp. Sample no. TCM 94-11-1.

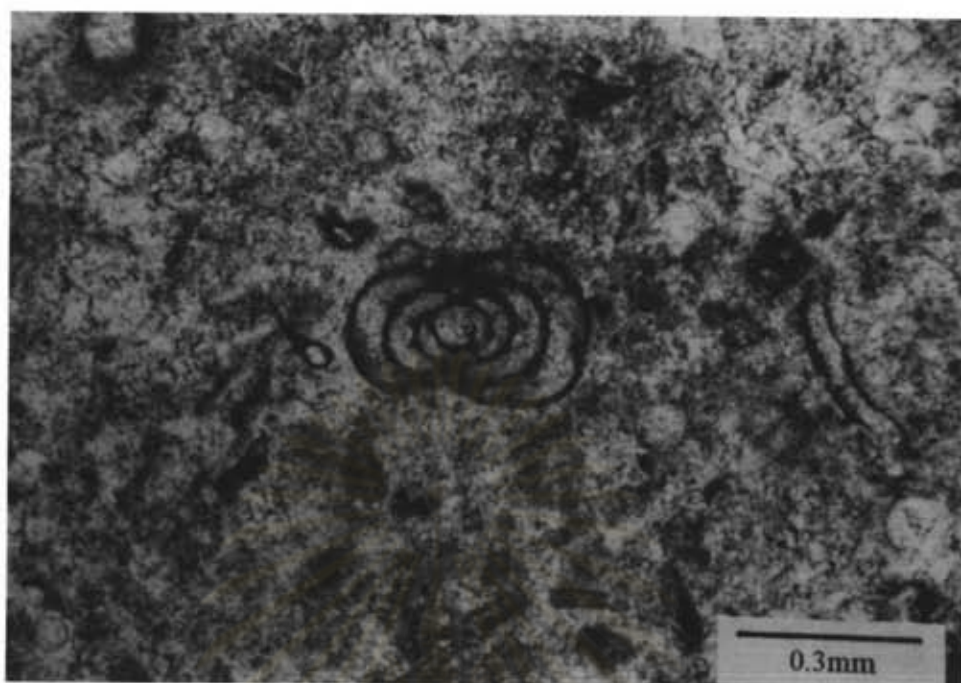


Figure 98 An axial section of *Pamirina* sp. Sample no. TCM 94-11-10.

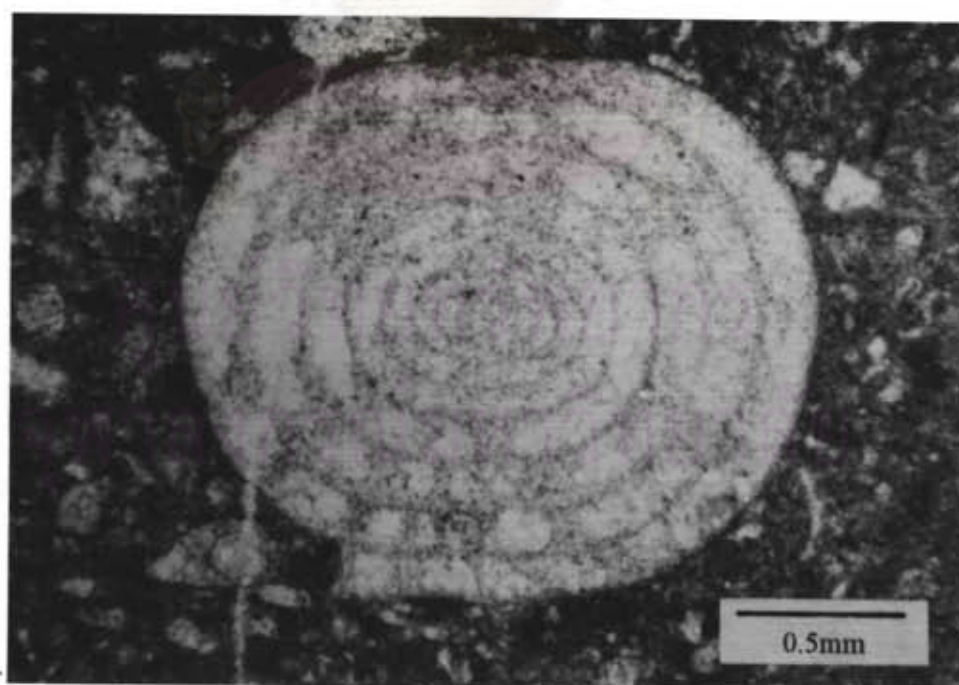


Figure 99 *Sphaerulina* sp. Sample no. TCM 94-11-14.