Tonan Ajia Kenkyu (The Southeast Asian Studies) Vol. 10, No. 3 December 1972

Key to the Selected Genera of Fusuline

by

Swai SUNDHAROVAT* and Yasuo NOGAMI**

I General Considerations

The fusuline belonging to the so-called larger foraminifera has been regarded to be the ideal index fossil. It flourished extremely in the late Carboniferous to the late Permian, distributed world-widely, and had a hard shell fit for preservation. In addition, the fusuline seems to have been very sensitive to the physical environments.

The fusuline shell is minute enough to be found even in drilling cores for oil prospecting, and has rather complicated internal structure. Orientated thin sections of shell allow to assess the structural features and also to determine the phylogenetic relations, because the shell has preserved all the ontogenetic growth stages. An axial section is passing through the initial chamber (**proloculus**) and the axis of coiling. A sagittal section is passing through the proloculus and at right angles to the axis of coiling. These two sections are necessary. Furthermore, a tangential section and a cross section are desirable, which are cutting parallel and at right angles to the axis of coiling, respectively, but not passing through the proloculus.

1. Terminology

The shell is constituted from several volutions. The wall of each volution is termed **spirotheca**. Each volution is divided by **septa** into many chambers. The septa are plane in less advanced members of a primitive group, but they are fluted (or folded) more or less strongly in the course of development. The fluting is first seen in the axial regions.

Each septum is provided with a **foramen**, and a sequence of foramen forms a **tunnel** in the direction of coiling. Both sides of tunnel are limited by a pair of secondarily secreted pillars (**chomata**). The **pseudochomata** can be distinguished from the chomata in forming discontinuous spiral pillar (see Fig. 1).

The septa of another advanced group are plane, but the internal structure is more complicated. Each septum is provided with many foramina, so the multiple,

*Faculty of Science, Chulalongkorn University, Bangkok, Thailand
**野上裕生, Faculty of Science, Kyoto University, Kyoto, Japan

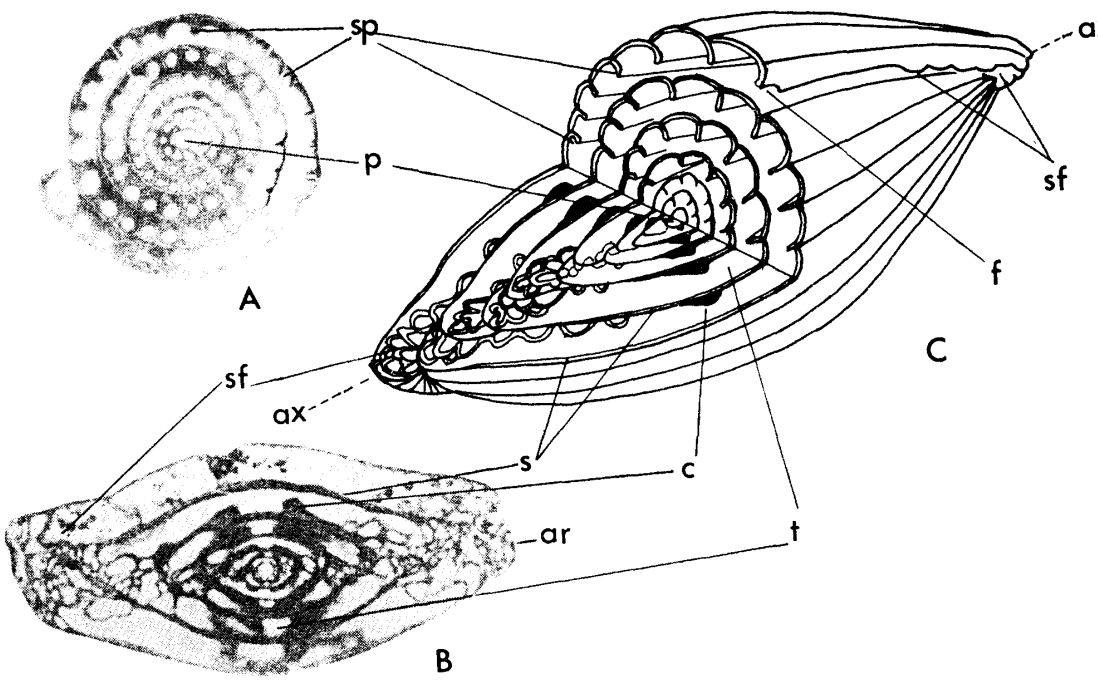


Fig. 1 Primitive fusuline and terminology

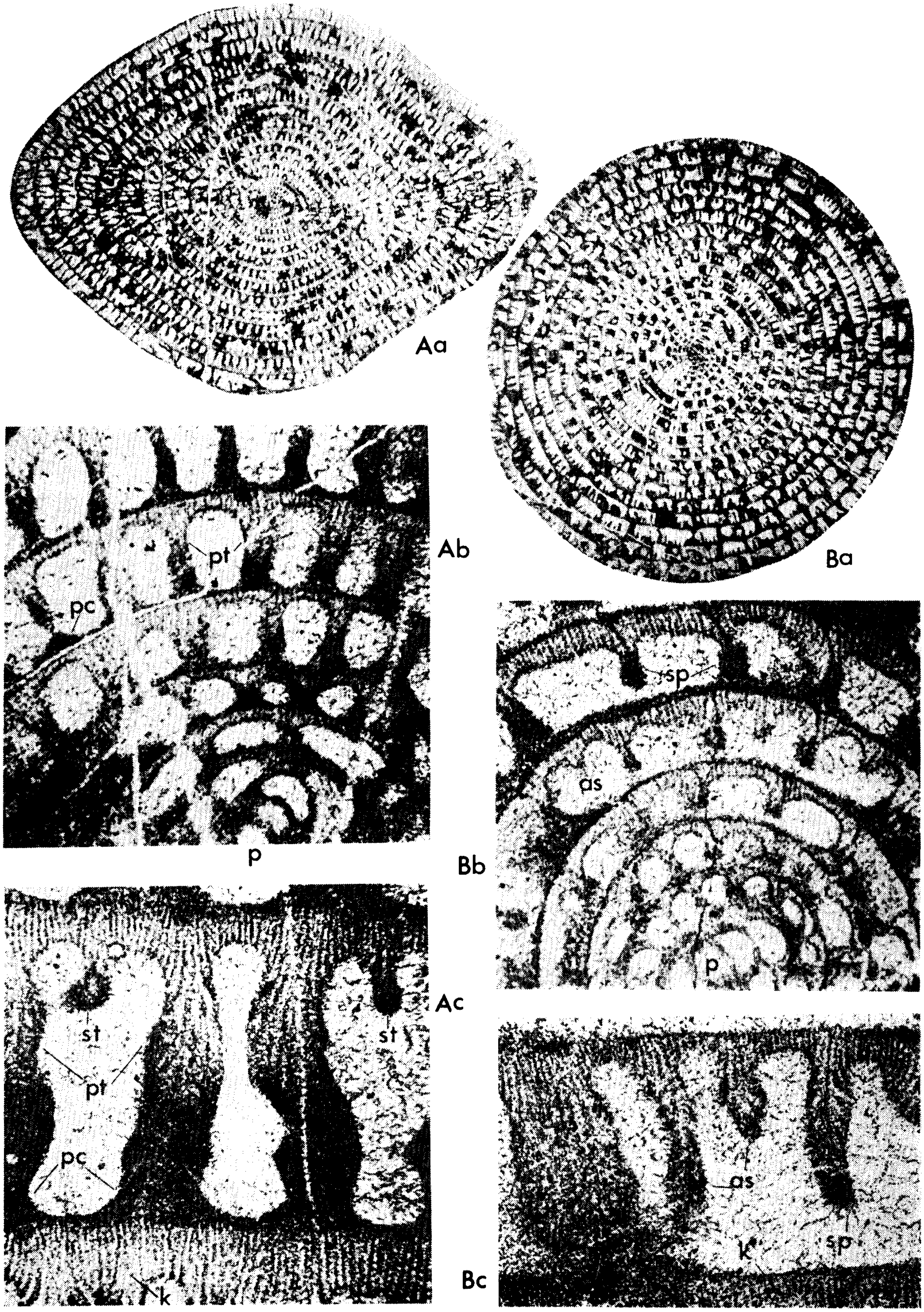
A, B. Saggital section and axial section of *Fusulinella simplicata* TORIYAMA, Moscowian, Japan, × 15.
C. Schematic drawing of shell, partly cut to show internal structures.
p: proloculus, s: spirotheca, f: foramen, t: tunnel, c: chomata,
sp: septa, sf: septal fluting (or folding), ar: axial region, ax: axis of coiling.

secondarily secreted pillars (**parachomata**) are formed. The spirotheca contains small ridges (**septula**), which are hanging down into the chambers.

The septula are transverse to the axis of coiling in the primitive members. The advanced members have, however, two sets of septula, of which one is transverse, and the other is parallel to the axis of coiling. The former set (**primary transverse**

Fig. 2 Advanced fusuline and terminology

A. Axial section of *Yabeina globosa* (YABE) [=*Yabeina inouei* DEPRAT], type species, Basleoian, Japan. a) whole section, × 10; b, c) enlarged parts of the juvenile stage and adault stage, respectively, × 100.
B. Sagittal section of the same species, Basleoian, Japan. a) whole section, × 10; b, c) enlarged parts of the juvenile stage and adault stage, respectively, × 100.
p: proloculus, k: keriotheca, pc: parachomata, sp: septa, as: axial septula, pt: primary transverse septula, st: secondary transverse septula.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septula) is seen in the axial and tangential sections, while the latter set (**axial septula**) is observed in the sagittal and cross sections. The highly advanced members have one or two short, **secondary transverse septula** between two adjacent primary ones in the outer volutions (see Fig. 2).

2. Development of shell shape and size

The fusuline shell has changed in shape and size more rapidly than has been recognized in almost all macrofossils. Figure 3 shows a phylogenetic trend of fusuline.

The most primitive genus *Pseudostaffella* is sphaerical in shape and measures a fraction of a millimeter in diameter. *Profusulinella* derived from *Pseudostaffella* is usually subsphaerical to ellipsoidal in shape, and attains to a few millimeters in length. The rather advanced genus *Fusulinella* is ellipsoidal to fusiform in shape and some millimeters long. *Beedeina* is widely differentiated, inflated fusiform to subcylindrical in shape, and several millimeters long. An end member of the trend, *Kansanella*, is subcylindrical in shape and attains to a centimeter in length.

Many other phylogenetic trends of fusuline can be distinguished with assurrence. In each trend an evolutional tendency is confirmed; the shell has become larger, and has changed in shape from sphaerical to fusiform or subcylindrical. Furthermore, such minor changes as decreasing of chomata and increasing of septal fluting can be recognized.

3. Development of spirotheca

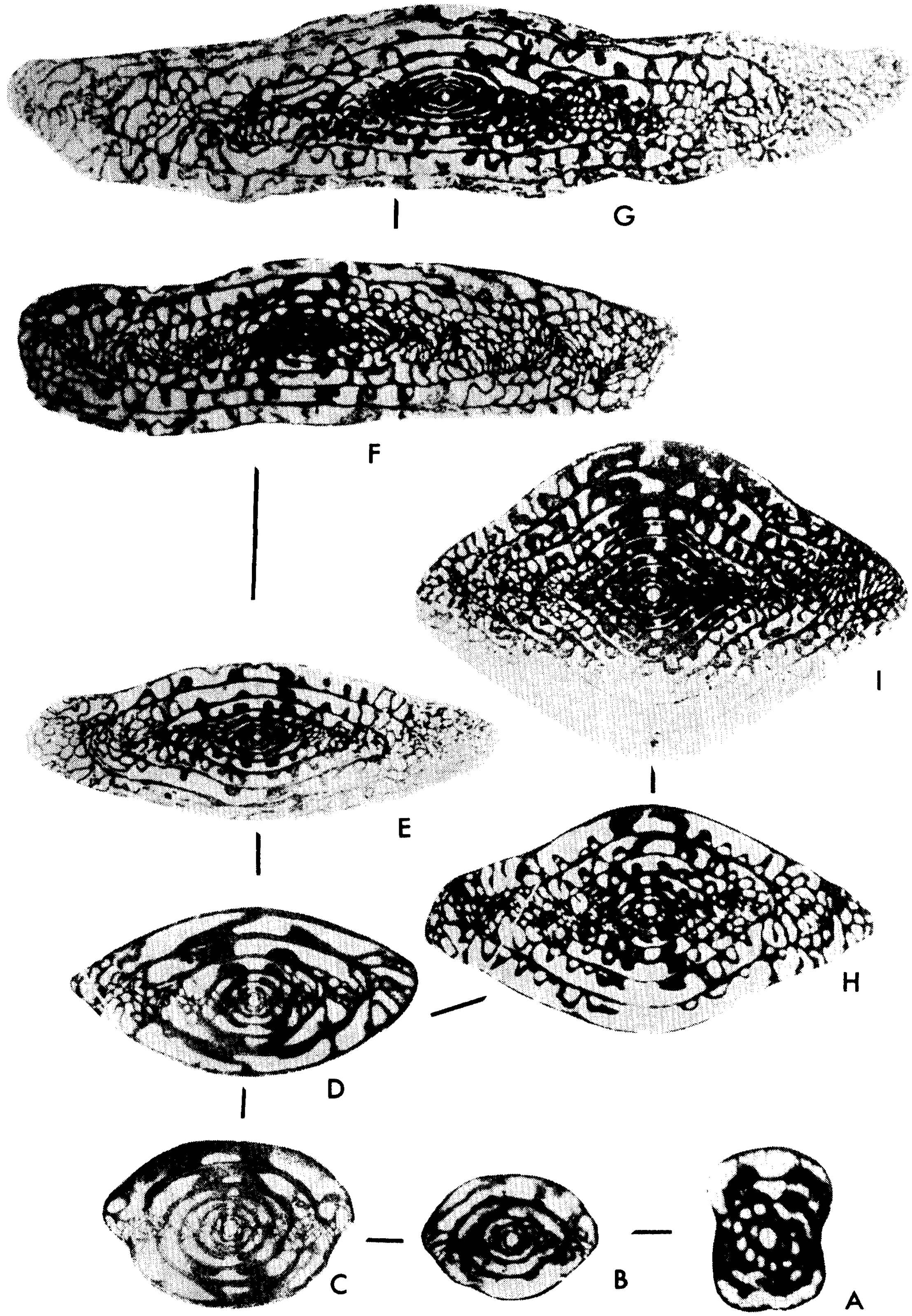
Rather definite trends are observed in the evolutional development of spirotheca. Figure 4A shows a representative trend (see also Fig. 3).

The spirotheca of *Pseudostaffella* and *Profusulinella* is composed of a **tectum**

Fig. 3 Development of shell shape and size

A. *Pseudostaffella needhami* THOMPSON, Baschkirian, New Mexico, × 50.
B. *Profusulinella copiosa* THOMPSON, Baschkirian, Texas, × 20.
C, D. *Fusulinella bocki* MÖLLER, type species, Moscowian, Japan, × 15.
E. *Beedeina leei* (SKINNER), Moscowian, Oklahoma, × 15.
F. *Beedeina eximia* (THOMPSON), Moscowian to Uralian, Iowa, × 15.
G. *Kansanella joensis* THOMPSON, Uralian, Missouri, × 15.
H. *Beedeina ichinotaniensis* (IGO), Moscowian, Japan, × 15.
I. *Beedeina girtyi* (DUNBAR and CONDRA), type species, Moscowian, Illinois, × 15.

Arrow showing evolutional trend.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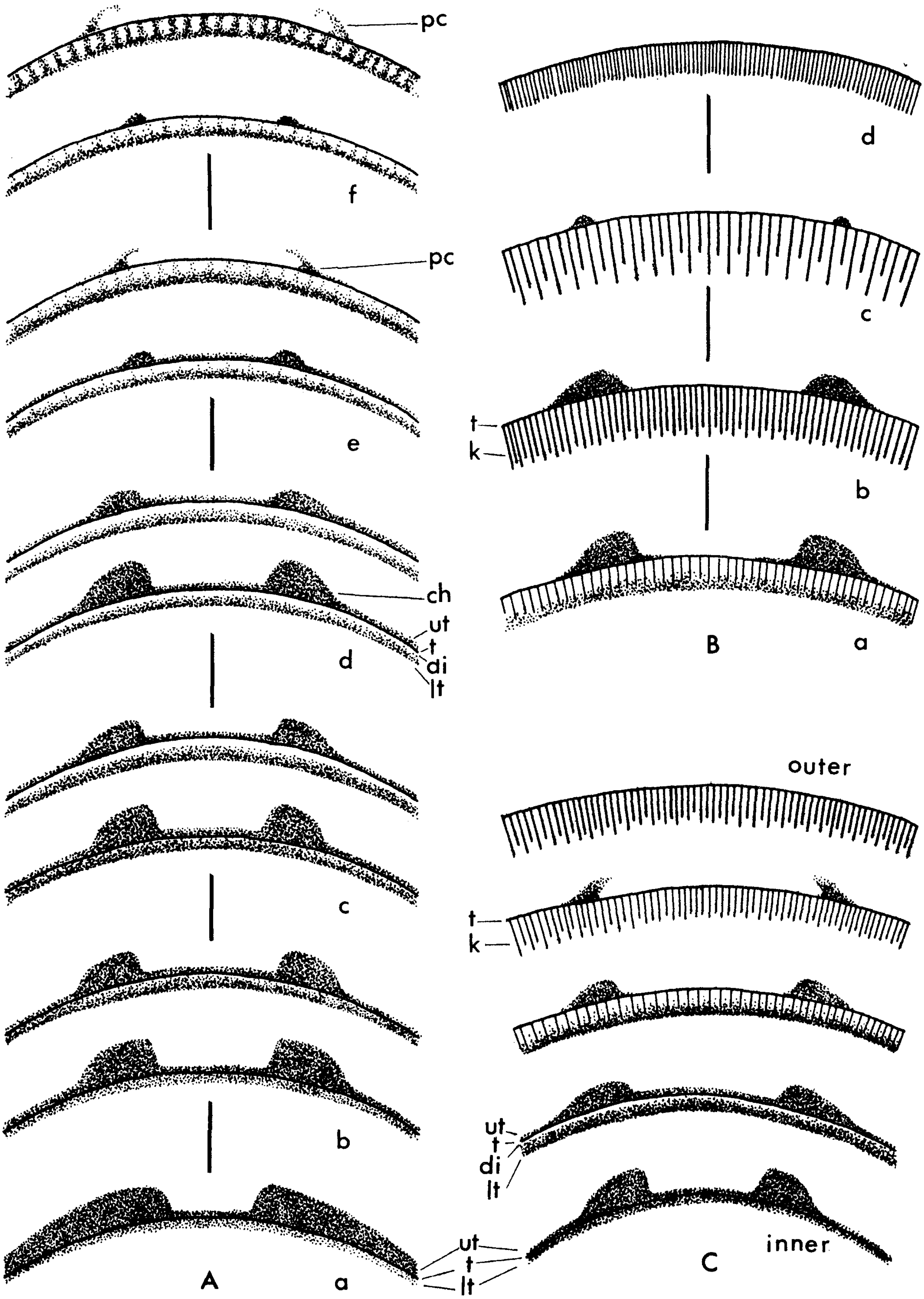
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and **lower** and **upper tectoria.** The tectum has been primarily secreted, while the tectoria have been secondarily formed. The three layered spirotheca has developed into the four layered one of *Fusulinella* and *Beedeina.* An inner less dense layer (**diaphanotheca**) has gradually increased in thickness, while the tectoria have rapidly decreased. In the highly advanced members the thick diaphanotheca has been provided with fine lines vertical to the tectum, and the tectoria have been sometimes absent.

Figure 4B shows another trend. The structure of spirotheca has not essentially changed in the course of development. Only the **keriotheca** has become thicker and coarser. But the keriotheca has reduced again in *Parafusulina.*

All the ontogenetic stages are well preserved in the shell. According to HAECKEL's biological principle, the ontogeny is an abbreviated recapitulation of phylogeny. Figure 4C shows the ontogenetic development of spirotheca found in *Triticites secalis* (SAY). The initial parts (inner two volutions) recapitulate the ancestral *Pseudostaffella* and *Profusulinella* stage, and new phylogenetic features appear at the later stage (outer three volutions).

4. Intragenetic development

The minor development within a genus as well as the supergenetic major evolution can be cons idered. Figure 5 is the classical example studied by RAUZER-CERNOUSOVA (1949).

In a specific evolutional sequence *Pseudostaffella antiqua* (DUTKEVICH) — *P. sphaeroidea* (EHRENBERG), the shell and proloculus have rapidly enlarged, and the chomata have become heavier. To say in more detail, A and B forms have weak, half-circular chomata, C form recapitulates the stage of A and B forms in the inner volutions, and has high subsequadrate chomata in the last volution. D form adds a new stage with heavy rectangular chomata to the ancestral stages of B and C forms. E form is provided with high ribbon-like chomata. The ontogeny of G form shows the ancestral features as yet. Only H form holds the newly obtained character throughout all the ontogenetic stages.

Fig. 4 Development of spirotheca

A. An evolutional trend. a) *Pseudostaffella*; b) *Profusulinella*; c)*Fusulinella*; d, e) *Fusulinella* and *Beedeina*; f) *Kansanella*. See also Fig. 3.

B. Another evolutional trend. a) *Triticites*; b) *Triticites, Schwagerina* and *Pseudoschwagerina*; c) *Pseudofusulina* and *Schwagerina*; d) *Parafusulina.*

C. Ontogenetic development of spirotheca, showing the juvenile stage to the adault stage of *Triticites secalis* (SAY).

ch: chomata, pc:pseudochomata, t: tectum, ut: upper tectorium, lt: lower tectorium, di: diaphanotheca, k: keriotheca.

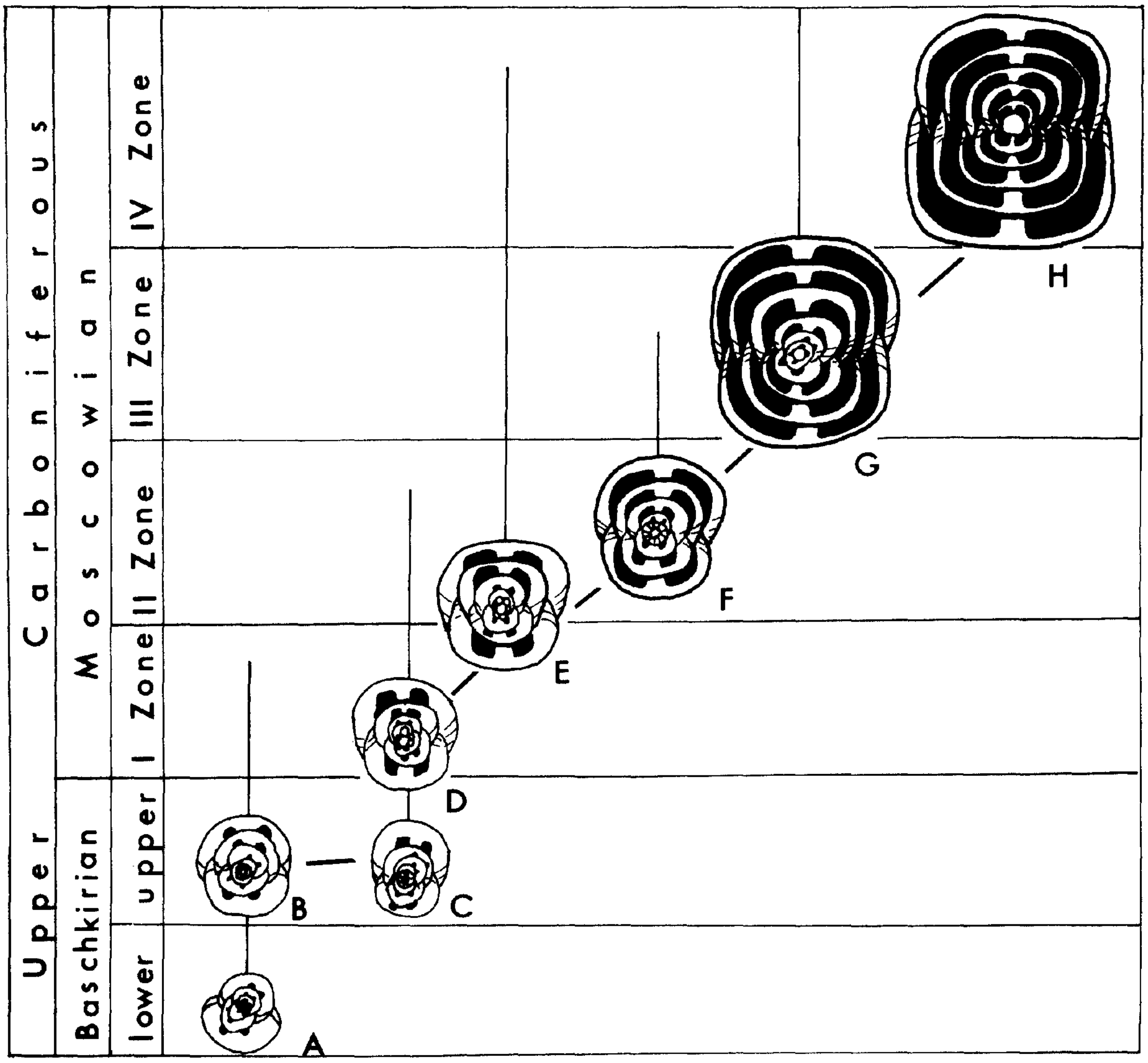


Fig. 5 Specific evolutional sequence

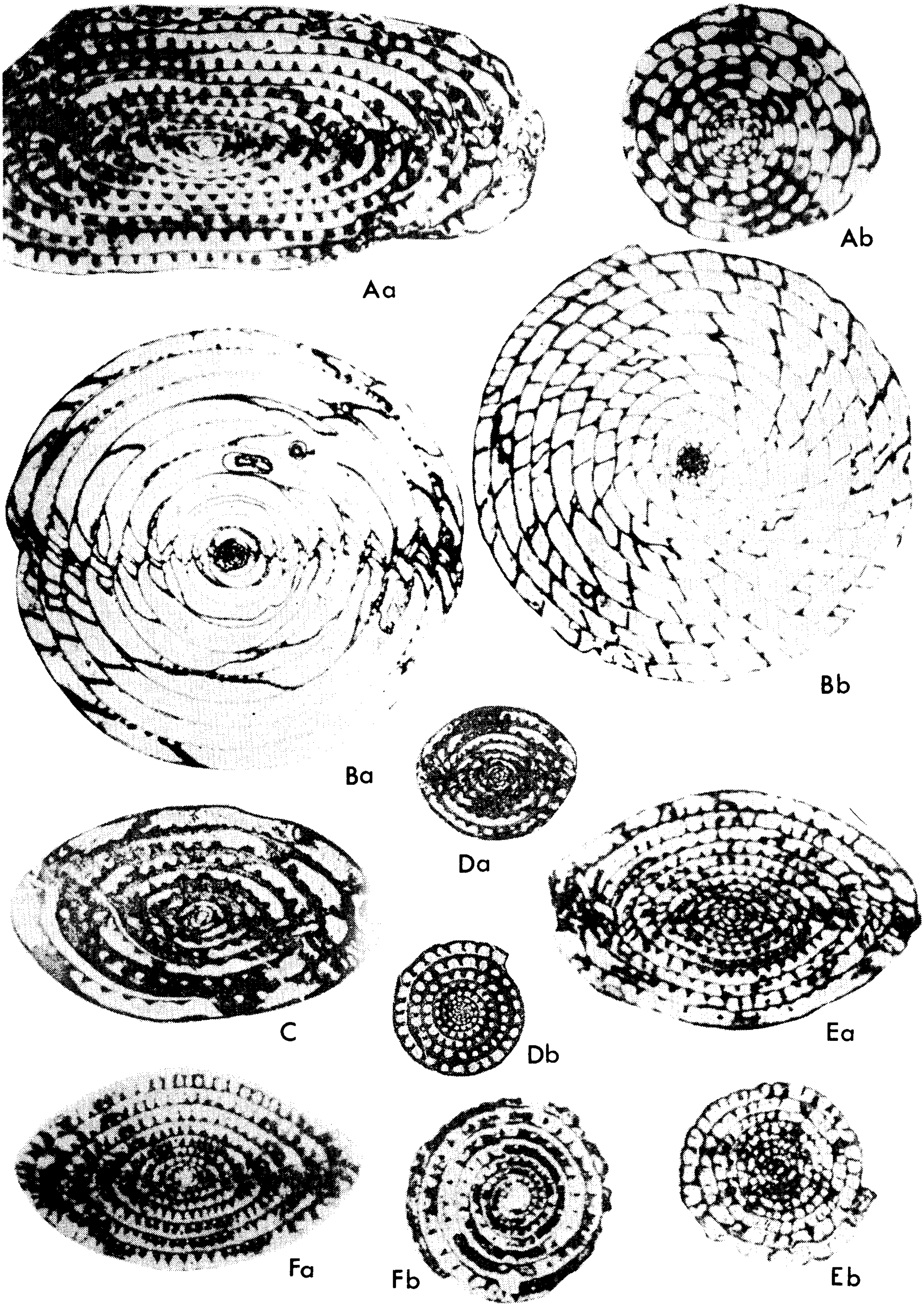
A. *Pseudostaffella antiqua antiqua* (Dutkevich)
B. *Pseudostaffella antiqua grandis* Shlykova
C. *Pseudostaffella praegorskyi* Rauzer-Cernousova
D–F. *Pseudostaffella gorskyi* (Dutkevich)
G, H. *Pseudostaffella sphaeroides* (Ehrenberg)
Fine line showing specific range.

The same kind of development is also to be observed in many other sequences. Especially, the degree of septal fluting, form of septula, size and number of parachomata, and thickness of spirotheca should be carefully observed.

II Key to Genera

More than 50 genera of fusuline have been described for about 150 years. Among them, 19 genera are selected for field geologists and students from the stratigraphical and palaeogeographical points of view.

1. Parachoma present ········· see 2
   Chomata or pseudochomata present ········· see 19
2. Primary transverse septula absent ········· see 3
   present ········· see 8
3. Keriotheca absent or indistinct ········· see 4
   present ········· see 5
4. Mature shell elongated ellipsoidal to cylindrical, composed of 12–20 volutions, 5–8 mm long and 2–4 mm wide. Proloculus small to medium. Spirotheca composed usually of a dense layer, but rarely of tectum and indistinct keriotheca in outer volutions. Parachomata high ········· *Pseudodoliolina* YABE & HANZAWA, 1932, see Fig. 6A; Fig. 10.
5. Shell medium to large, sphaerical ········· see 6
   small, oval to ellipsoidal ········· see 7
6. Mature shell composed of 10–20 volutions, 5–14 mm long and wide, provided with slightly umbilicated axial regions. Proloculus minute, inner 2–4 volutions coiled tightly, following expanded rapidly. Parachomata small, half-circular ·········*Verbeekina* STAFF, 1909, see Fig. 6B; Fig. 10.
7. Mature shell composed of less than 9 volutions, 2–4 mm long. Proloculus minute to small, inner 2 or 3 volutions umbilicated in axial regions. Parachomata narrow, high ········· *Misellina* SCHENK & THOMPSON, 1940, see Fig. 6C,D; Fig. 10.
8. Axial septula absent or rudimentarily present ········· see 9
   distinctly present ········· see 10
9. Mature shell minute to small, inflated fusiform, composed of 8–12 volutions, 2–4 mm long and 1–3 mm wide. Proloculus small. Primary transverse septula present only in outer volutions. Axial septula usually absent, but rudimentary one seen rarely in outer volutions. Spirotheca very thin. Parachomata narrow, high········· *Cancellina* HAYDEN, 1909, see Fig. 6E; Fig. 10.
10. Secondary transverse septula absent ········· see 11
    present ········· see 12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11. Mature shell medium, sphaerical to fusiform, composed of 10–17 volutions, 4–10 mm long and 2–6 mm wide. Proloculus minute to large. Septa and septula pointed triangular to bar-shaped. Axial and primary transverse septula present, secondary transverse ones usually absent, but sometimes rudimentary ones seen in outer volutions. Parachomata small, half-circular ……………… *Neoschwagerina* YABE, 1903, see Fig. 7C ; Fig. 10.

12. Septula pendant-shaped ………………………………………………………… see 13
    bar-shaped ………………………………………………………………… see 16

13. Shell inflated fusiform ………………………………………………………… see 14
    elongated fusiform to subcylindrical ………………………………………… see 15

14. Mature shell small to medium, composed of 9–13 volutions, 3–5 mm long and 2–4 mm wide. Proluculus small. Spirotheca very thin. Septula pendant-shaped; 1 or 2 axial septula present in inner volutions, 2 or 3 in outer volutions, 1 secondary transverse septulum present in inner volution, 1 or 2 septula in outer volutions. Parachomata small, halfcircular …………… *Afghanella* THOMPSON, 1946, see Fig. 6F; Fig. 7A; Fig. 10.

15. Mature shell medium, composed of 8–10 volutions, 6–10 mm long and 1.5–3 mm wide. Proloculus medium to large. Spirotheca very thin. Septula pendantshaped; 2 or 3 axial septula present in inner volutions, 3 or 4 in outer volutions, 1 or 2, sometimes 3, secondary transverse septula present. Parachomata very small …… *Sumatrina* VOLZ, 1904, see Fig. 7B; Fig. 10.

16. Proloculus minute to small ………………………………………………………… see 17
    medium to large ………………………………………………………………… see 18

17. Mature shell medium to large, subsphaerical to inflated fusiform, composed of 15–20 volutions, 7–12 mm long and 4–9 mm wide. Spirotheca rather thin. Septula

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Fig. 6

A. *Pseudodoliolina ozawai* YABE and HANZAWA, type species, a) axial section, b) sagittal section, Artinskian, Japan, × 15.
B. *Verbeekina verbeeki* (GEINITS), type species, a) axial section, b) sagittal section, Basleoian to Chideruian, Cambodia, × 10.
C. Axial section of *Misellina ovalis* (DEPRAT), type species, Sakumarian, Viet Nam, × 15.
D. *Misellina claudiae* (DEPRAT), a) axial section, b) sagittal section, Sakmarian, Japan, × 10.
E. *Cancellina nipponica* (OZAWA), a) axial section, b) sagittal section, Artinskian, Japan, × 15.
F. *Afghanella ozawai* HANZAWA, a) axial section, b) sagittal section, Artinskian, Japan, × 15.

triangular to bar-shaped; 1 or 2 axial septula present in inner volutions, 2-4 in outer volutions, 1 secondary transverse septulum present between 2 adjacent primary ones in middle to outer volutions. Parachomata small ………… *Yabeina* DEPRAT, 1914, see Fig. 2 : Fig. 10.

18. Mature shell large, inflated fusiform to subcylindrical, composed of 14-22 volutions, 9-15 mm long and 3-8 mm wide. Spirotheca very thin. Septula bar-shaped to somewhat pendant-shaped; 2 or 3 axial septula present in inner volutions, 3-5 in outer volutions, 1 or 2 secondary transverse septula present. Parachomata very small ………… *Lepidolina* LEE, 1933, see Fig. 7D; Fig. 10.

19. Keriotheca present ……………………………………………………………… see 20
absent ……………………………………………………………… see 29

20. Septal fluting limited to axia l regions ………………………………………… see 21
more or less intense throughout volution ……………………… see 24

21. Shell small to medium, fusiform ………………………………………………… see 22
medium to large, subsphaerical ……………………………………… see 23

22. Mature shell composed of 5-10 volutions, 3-10 mm long and 2-5 mm wide. Proloculus small, shell expanded slowly. Septa fluted weakly in axial regions. Chomata developed strongly, but replaced by Pseudochomata sometimes in outer volutions ……………… *Triticites* GIRTY, 1904, see Fig. 8A, B; Fig. 10.

23. Mature shell highly inflated fusiform to sphaerical, composed of 6-8 volutions, 8-15 mm long and 6-14 mm wide. Proloculus small, inner 2 or 3 volutions coiled tightly, following expanded rapidly. Septa fluted weakly in axial regions. Chomata distinct only in inner volutions …………… *Pseudoschwagerina* DUNBAR & SKINNER, 1936, see Fig. 8C; Fig. 10.

24. Septa fluted widely and irregularly …………………………………………… see 25
narrowly and highly ……………………………………………………… see 26

25. Mature shell medium to large, inflated to elongated fusuform, composed of 5-8 volutions, 6-15 mm long and 3-6 mm wide. Proloculus moderate to large, shell

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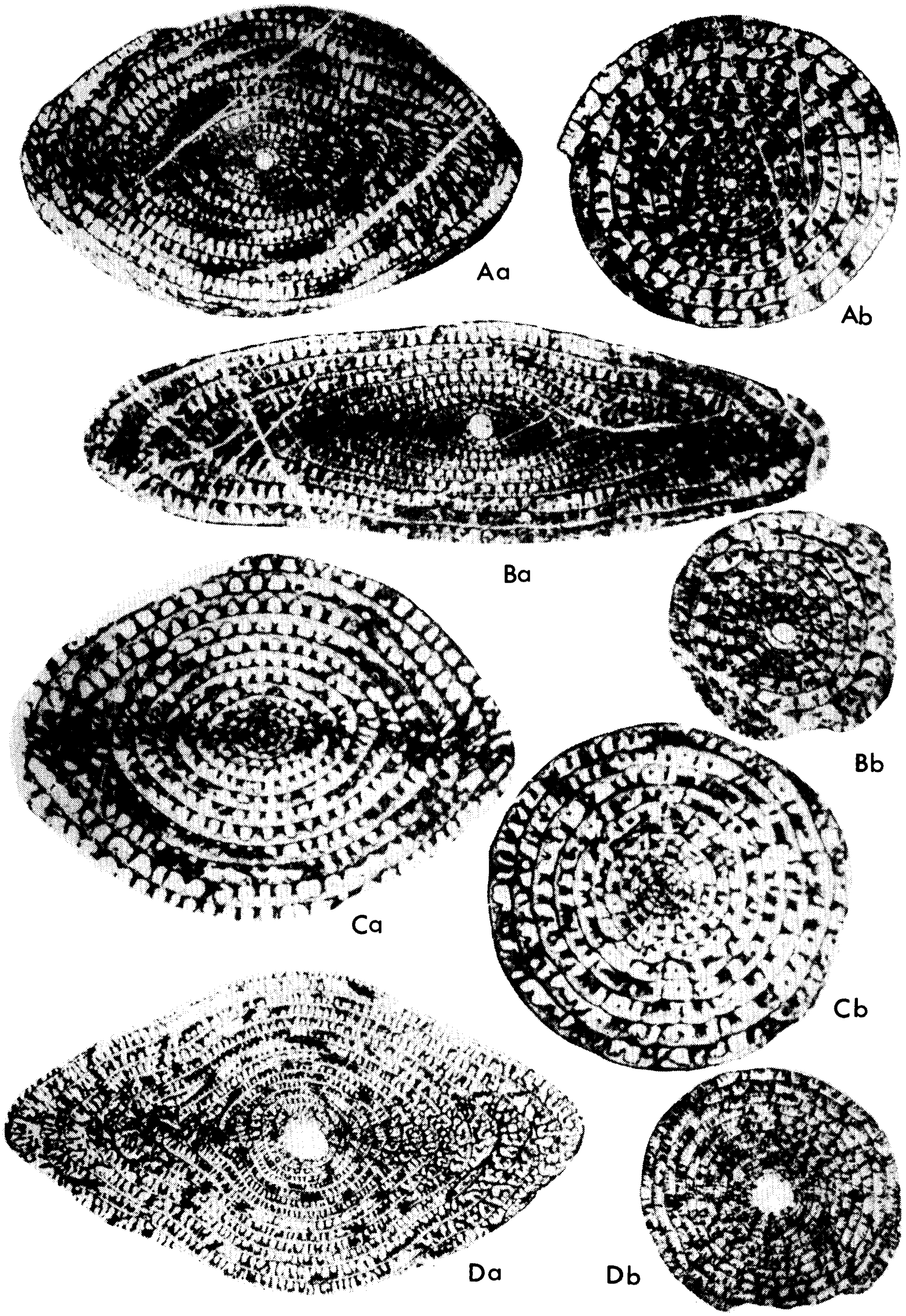
Fig. 7

A. *Afghanella sumatrinaeformis* (GUBLER), a) axial section, b) sagittal section, Sosioian, Viet Nam, × 15.
B. *Sumatrina annae* VOLZ, type species, a) axial section, b) sagittal section, Sosioian to Basleoian, Thailand, × 15.
C. *Neoschwagerina haydeni* DUTKEVICH and KHABANOV, a) axial section, b) sagittal section, Sosioian, Afghanistan, × 15.
D. *Lepidolina multiseptata* (DEPRAT), type specles, a) axial section, b) sagittal section, Basleoian to Chideruian, Cambodia, × 10.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coiled rather loosely. Septa fluted widely and low. Chomata indistinct, replaced by pseudochomata in outer volutions ············ *Pseudofusulina* DUNBAR & SKINNER, 1931, see Fig. 9A, B; Fig. 10.

26. Shell small to medium, fusiform ·· see 27
medium to large, subcylindrical··· see 28

27. Mature shell more or less inflated fusiform, composed of 6–9 volutions, 5–11 mm long and 3–5 mm wide. Proloculus small, shell expanded rather slowly. Spirotheca relatively thin. Septa fluted regularly and highly. Chomata usually indistinct, replaced by pseudochomata in outer volutions ················· *Schwagerina* MÖLLER, 1877, see Fig. 8D, E; Fig. 10.

28. Mature shell elongated fusiform to cylindrical, large in size. Proloculus medium to large, shell expanded rather rapidly. Spirotheca thin. Septa fluted highly and regularly. Chomata indistinct in almost all volutions ··········· *Parafusulina* DUNBAR & SKINNER, 1931, see Fig. 9C; Fig. 10.

29. Diaphanotheca absent ·· see 30
present ··· see 33

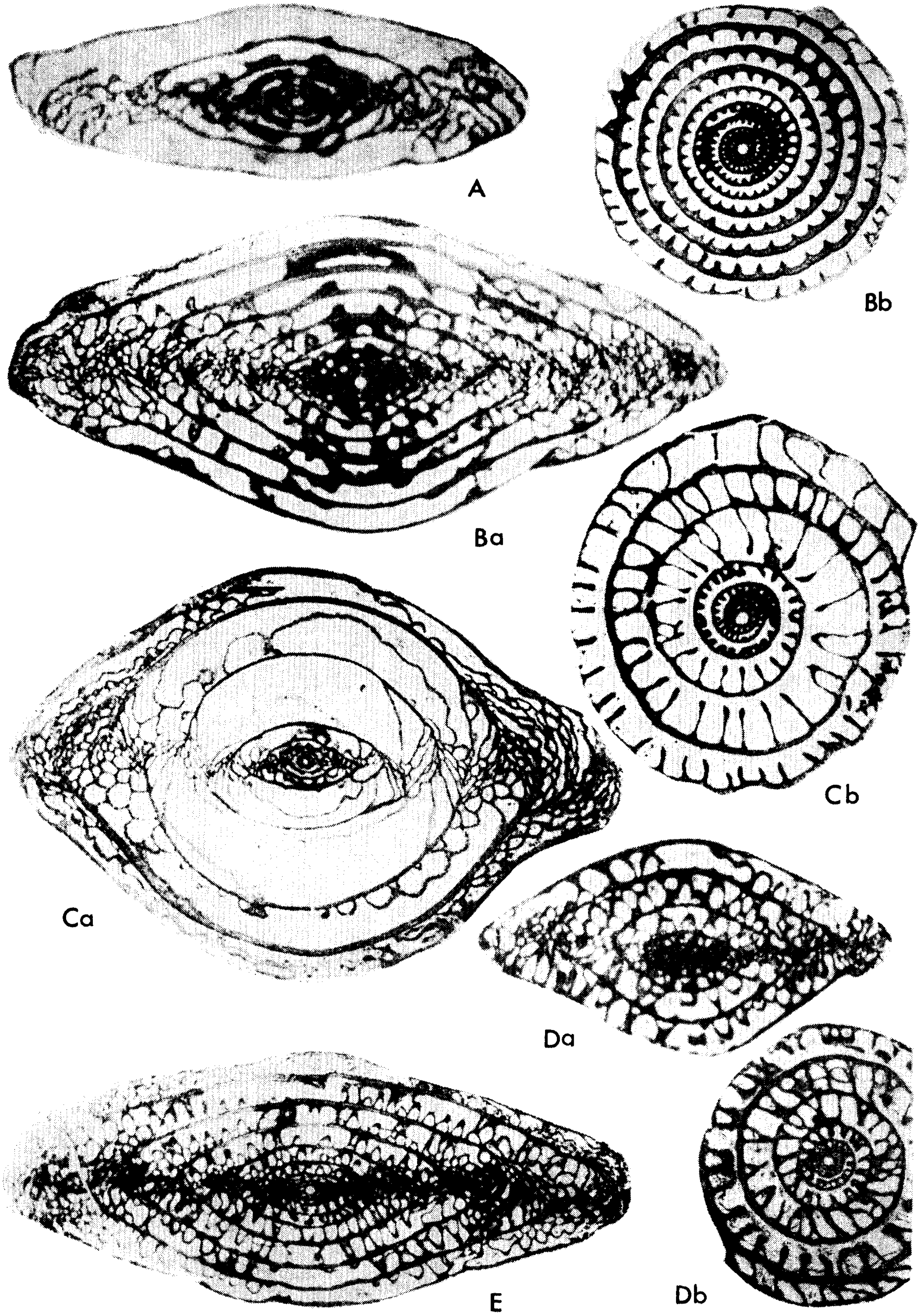
30. Shell rhomboidal to sphaerical ··· see 31
ellipsoidal to fusiform ·· see 32

31. Mature shell minute, provided with umbilicated axial regions and short axis of coiling, composed of 4–7 volutions, 0.5–2 mm long and wide. Spirotheca composed of tectum and tectoria. Septa unfluted. Chomata heavy, half-circular to ribbon-like ········ *Pseudostaffella* THOMPSON, 1942, see Fig. 3A; Fig. 5; Fig. 9D; Fig. 10.

32. Mature shell small, composed of 4–7 volutions, 1–3 mm long and 0.5–2 mm wide. Proloculus minute to small, inner 1 or 2 volutions usually umbilicated. Spirotheca thin, composed of tectum and tectoria, but diaphanotheca sometimes seen in outer volutions. Chomata formed strongly ··········· *Profusulinella* RAUZER-CERNOUSOVA, 1936, see Fig. 3B; 9E, F; Fig. 10.

Fig. 8

A. Axial section of *Triticites obsoleta* (SCHELLWIEN), very primitive form, Uralian, USSR, × 20.
B. *Triticites ventricosus* (MEEK and HAYDEN), a) axial section, b) sagittal section, Sakmarian, Kansas, × 10.
C. *Pseudoschwagerina uddeni* (BEEDE and KNIKER), type species, a) axial section, b) sagittal section, Sakmarian, Texas, × 10.
D. *Schwagerina fax* THOMPSON and WHEELER, a) axial section, b) sagittal section, Sakmarian, California, × 10.
E. Axial section of *Schwagerina elongata* THOMPSON, Sakmarian, Texas, × 10.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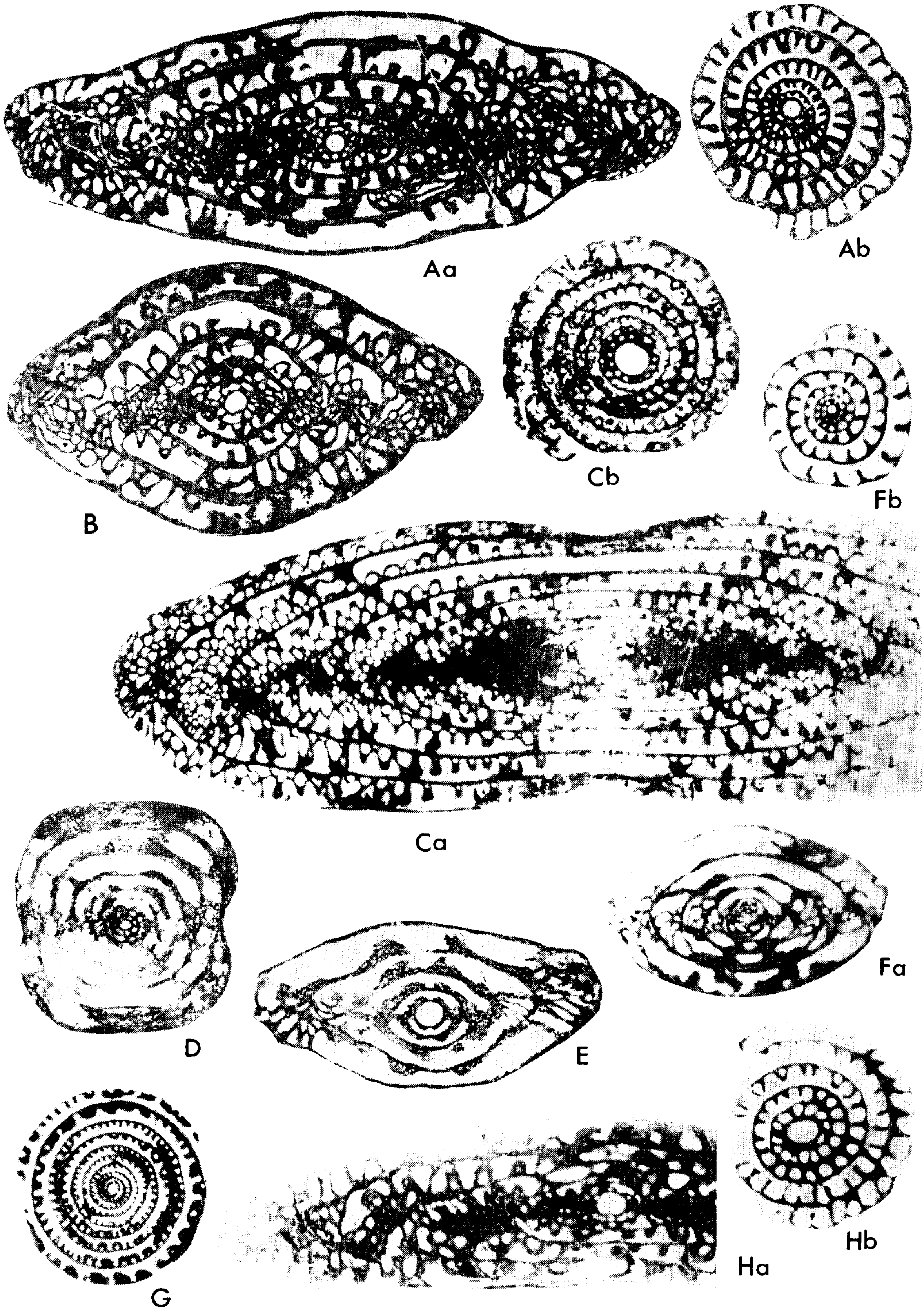
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33. Septa fluted only in axial regions ········· see 34
throughout volution ········· see 35

34. Mature shell small to medium, ellipsoidal to fusiform, composed of 6–9 volutions, 1.5–4.5 mm long and 0.5–3.5 mm wide. Proloculus small to moderate. Diaphanotheca observed clearly in outer volutions. Septa fluted usually only in axial regions. Chomata heavy, gradually decreasing in development from middle to outer volutions ········· *Fusulinella* MÖLLER, 1877, see Fig. 1A, B; Fig. 3C, D; Fig. 10.

35. Inner 1 or 2 volutions inflated fusiform ········· see 36
ellipsoidal ········· see 37

36. Mature shell small to medium, inflated fusiform to subcylindrical, composed of 6–10 volutions, 2–6 mm long and 1–3 mm wide. Proloculus small. Diaphanotheca rather thick. Septa fluted widely and highly. Chomata indistinct, replaced by pseudochomata in outer volutions ········· *Beedeina* GALLOWAY, 1933, see Fig. 3E, F, H, I; Fig. 9G; Fig. 10.

37. Mature shell small to medium, ellipsoidal to cylindrical, composed of 5–7 volutions. Proloculus small to moderate, inner 1 or 2 volutions subsphaerical to ellipsoidal, provided with less heavy chomata. Diaphanotheca rather thin. Septa fluted highly and narrowly. Pseudochomata present in middle to outer volutions ········· *Fusulina* DE WALDHEIM, 1829, see Fig. 9H; Fig .10.

Fig. 9

A. ***Pseudofusulina ambigua*** (DEPRAT), a) axial section, b) sagittal section, Sakmarian to Artinskian, Japan, × 10.

B. Axial section of ***Pseudofulina vulgaris*** (SCHBLLWIEN), Sakmarian, Japan, × 10.

C. ***Parafusulina loeyensis*** PITAKPAIVAN, a) axial section, b) sagittal section, Artinskian to Sosioian, Thailand, × 10.

D. Axial section of ***Pseudostaffella quadrata*** (DEPRAT), Baschkirian, Viet Nam, × 30.

E. Axial section of ***Profusulinella pararhomboides*** RAUZER – CERNOUSOVA and BELJAEV, type species, Moscowian, USSR, × 30.

F. ***Profusulinella decora*** THOMPSON, a) axial section, b) sagittal section, Baschkirian, Texas, × 20.

G. Sagittal section of ***Beedeina girty*** (DUNBAR and CONDRA), type species, Moscowian, × 10, see also Fig. 3I.

H. ***Fusulina cylindrica*** DE WALDHEIM, type species, a) axial section, b) sagittal section, Moscowian, USSR, × 20.

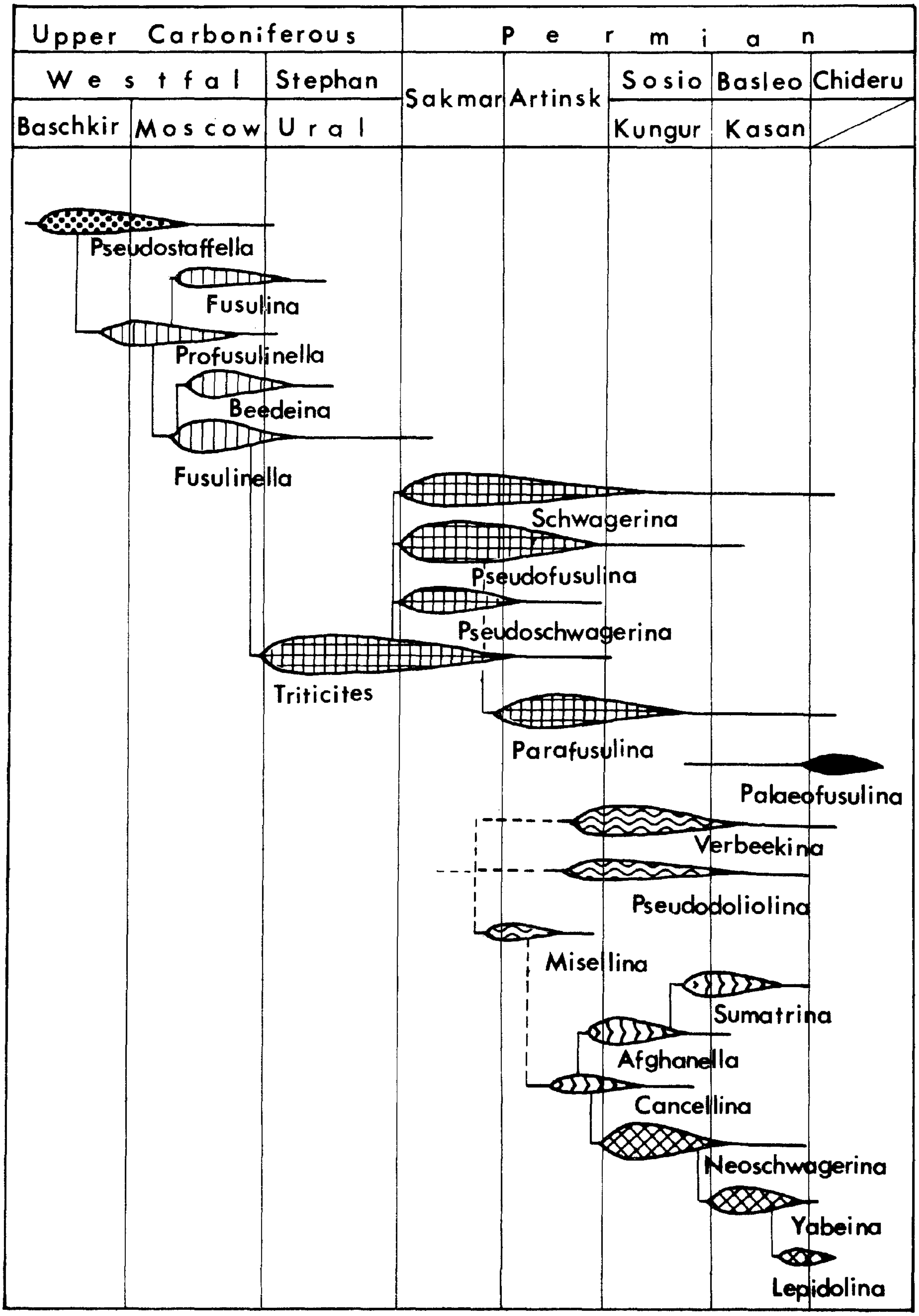

Fig. 10　Range chart of selected fusuline genera