Nature and Human Activities, 11, 17-28, 2007

Original article

Late Middle Permian (Capitanian) foraminifers in the Mikata area, Hyogo, with special reference to plasticity deformation of their test and their paleobiogeographic affinity with South China — Late Paleozoic and Early Mesozoic foraminifers of Hyogo, Japan, Part 5 —

Fumio Kobayashi

Division of Earth Sciences, Institute of Natural and Environmental Sciences, University of Hyogo / Division of Natural History, Museum of Nature and Human Activities, Hyogo, Yayoigaoka 6, Sanda, Hyogo, 669-1546, Japan

Abstract

Foraminifers and other fossils of the Mikata area are undergone by a plasticity deformation of various degrees possibly due to dehydration from argillaceous matrix and fossil grains by the sedimentary load. The Capitanian Mikata foraminiferal fauna consists of 26 species assignable to 19 and two indeterminate genera. Diagnostic species are *Lepidolina maizurensis, Lantschichites cuniculata, Kahlerina ussurica, Nankinella inflata, Parafusulina?* sp., *Hemigordius* spp, and *Pachyphloia ovata*. The Mikata fauna bears some resemblances not only with the coeval fauna of the Maizuru Terrane but also with the *Lepidolina kumaensis* fauna of the South Kitakami-Kurosegawa Terrane. The distribution of large-sized *Nankinella, N. inflata* is wide but restricted in the Middle and Upper Permian of South China, South East Asia, and Southern Tibet. While, this species is totally absent in the Panthalassan Circum-Pacific terranes.

Key words: Foraminifers, plasticity deformation, faunal affinity, late Middle Permian (Capitanian), Mikata area.

Introduction

The Permian and Triassic formations in the Mikata area, Ichinomiya-cho, Shiso city are important to discuss the P-T boundary problems and tectonic development of the Maizuru Terrane (Kobayashi, 2003). Permian rocks were originally subdivided into the Iuchi, Mikata, Yokoyama, and Kuratoko formations in ascending order by Shimizu (1962). Their stratigraphic order and geologic structure were revised by Kanmera and Nakazawa (1973) and Working Group on the Permian-Triassic System (1975). Limestone blocks and clasts in the Yokoyama Formation contain the Capitanian *Lepidolina kumaensis* fauna, and those in the Mikata Formation do the Changhsingian *Palaeofusulina-Colaniella* fauna. They were concluded to have been originally deposited on the continental shelf of the eastern continental margin of South China and subsequently redeposited on the deeper continental slope (Kobayashi, 1999; 2003).

This paper describes and discusses Capitanian foraminifers of the Yokoyama Formation to show in detail the fundamental data cited in Kobayashi (2003), as the fifth of the serial descriptive works under the title of Late Paleozoic and Early Mesozoic foraminifers of Hyogo, Japan. Three papers of Late Paleozoic foraminifers of the Maizuru Terrane were already published. They are the Capitanian foraminifers from the Miharaiyama area (Kobayashi, 2006a), Changhsingian ones from the Mikata (Kobayashi, 2006b), and Wuchiapingian ones from the Tatsuno (Kobayashi, 2006c). One of worthy to note in this paper is the preservation of foraminifers

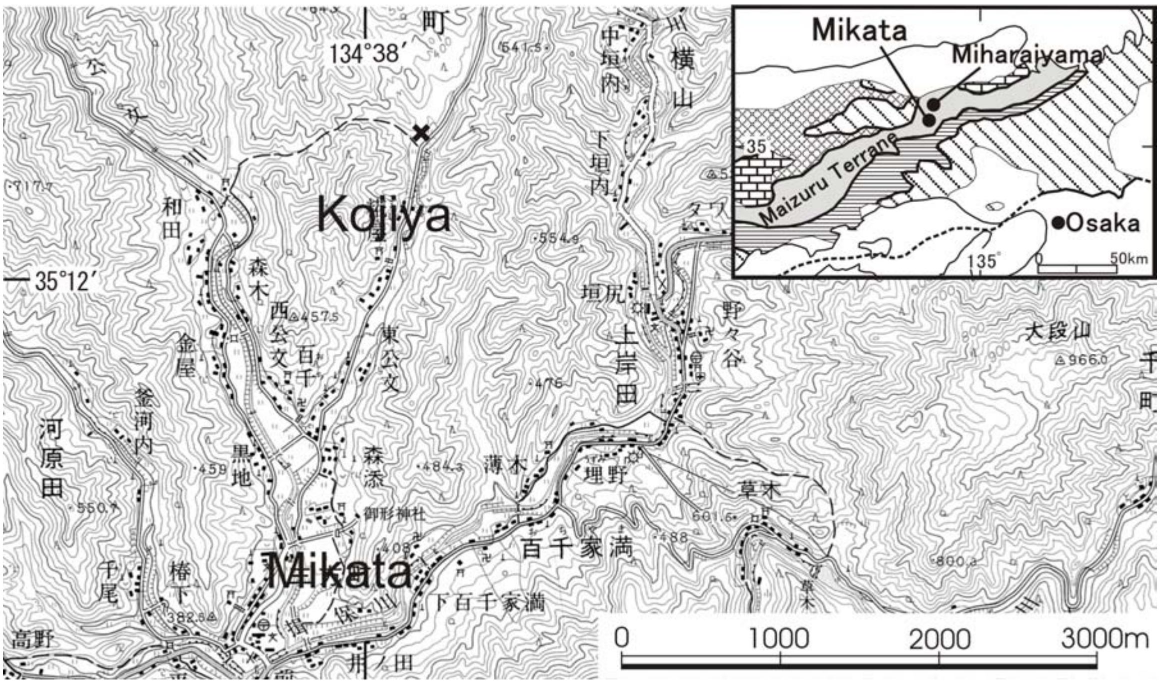


Figure 1. Sample location in the Mikata area. Topographic map is from 1:50,000 map "Oyaichiba" of Geographical Survey Institute of Japan.

and other fossils to have been undergone by a plasticity deformation of various degrees. The other is its faunal composition, including the large-sized *Nankinella, N. inflata* (Colani), supporting the Kobayashi's (2003) view that all limestone blocks and clasts were derived from South China and the Akiyoshi Seamount.

All limestone thin sections used in this paper are stored in the collection of the Museum of Nature and Human Activities, Sanda, Hyogo, Japan (Fumio Kobayashi Collection, MNHAH).

Materials

The occurrence of the "*Lepidolina* fauna" was reported from the granule conglomerate at nine localities in the Mikata area by Shimizu (1962) without description and illustration. All these localities are restricted to the distribution area of the Yokoyama Formation (Kobayashi and Takemura, 1995). The granule conglomerate with fusulinoideans, however, has been recognized nowhere at these localities during my field survey in the Mikata area. Instead of them, fossiliferous limestone blocks and breccias were newly found out at the road-side cliff, 300 m north of Kojiya, Mikata area (Figure 1). They are mostly fossiliferous, irregularly-shaped, less than 50 cm in longer diameter, and surrounded by black argillaceous rocks, together with more dominant blocks of sandstone, chert, acidic tuff, and basaltic rocks. Bioclasts of foraminifers and other fossils are also contained in the argillaceous matrix. Fossils of the Mikata area occur mainly in limestone blocks, whereas those of the Miharaiyama area exlusively occur in bioclasts and limestone clasts less than a few centimeters (Kobayashi, 2006a).

Two limestones (Samples A and C) and one conglomeratic limestone (Sample E) samples including foraminifers were examined herein. They are dark gray to black, highly fossiliferous, and rich in sponges, bryozoans, foraminifers, marine algae, and corals (Figure 2). Detrital quartz grains and argillaceous materials, and other fossils such as crinoids, gastropods, brachiopods, ostracodes are also contained in these limestones.

Plasticity deformation of fossils

Almost all fossils from the Yokoyama Formation reported in this paper are more or less undergone by the plasticity deformation of various degrees, regardless their sizes and taxa. As to foraminifers, the outer part of the test is strongly deformed and

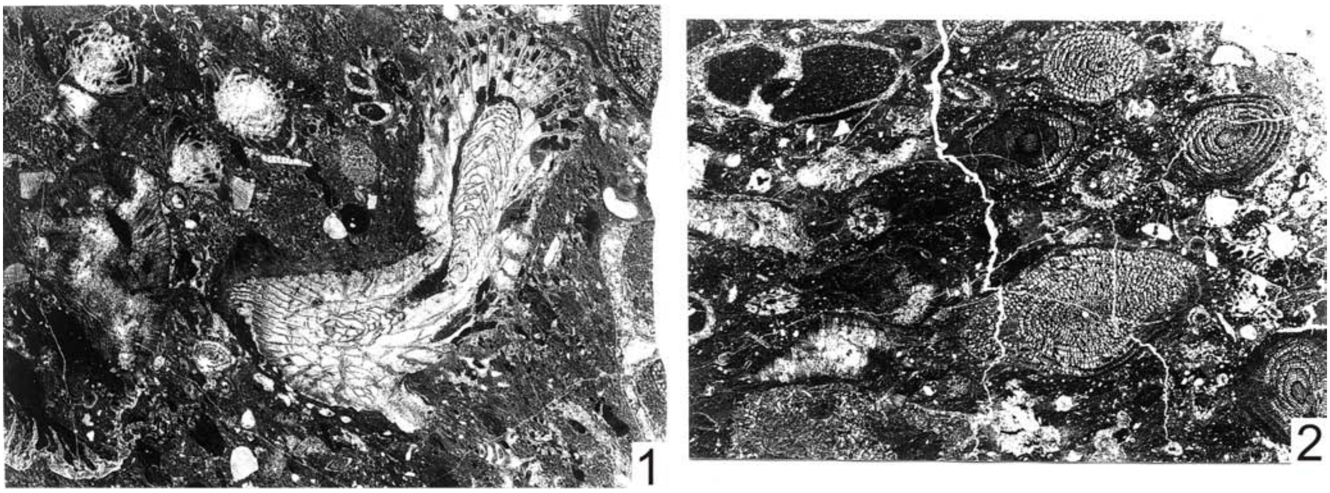


Figure 2. Photographs of the limestone containing many fossils undergone by a plasticity deformation in the Mikata area. 1. ×4.3, 2. ×3.5.

crushed in various directions, on the other hand, the inner part is hardly or not damaged in the coiled forms (e.g., Pl. 1, Figs. 4, 6–9; Pl. 2, Figs. 3, 6, 7, 17; Pl. 3, Figs. 1, 6, 35, 36). Fabrics showing syn- to post-depositional flow structure of lime-mud and bioclasts probably due to sedimentary load are clearly visible in the matrix of strongly deformed fossils (e.g., Figure 2; Pl. 1, Figs. 7, 9; Pl. 2, Fig. 6). Fossils as well as their surrounding lime-mud matrix which had undergone plasticity deformation are penetrated by calcite veinlets.

Similar type deformation to the present one is sometimes observable in other examples, e.g., in the Akasaka Limestone of Japan (Figure 3-1) and the Marble Canyon Limestone of British Columbia (Figure 3-2). Limestone lithology consisting of bituminous lime-mud matrix is common between these two samples. More remarkable destruction is observed in structurally delicate test of *Verbeekina verbeeki* (Geinitz) in the Akasaka Limestone, of which outer whorls had been crushed into pieces like powdered dust (Figire. 3-1). Kinetic strength of the test between *Yabeina columbiana* (Dawson) in the Marble Canyon and *Lepidolina maizurensis* Nogami in the present examples seems to be roughly equal. Severer test deformation and destruction in *Y. columbiana* than in *L. maizurensis* are thought to have been resulted primarily from syn- to post-depositional sediments load and secondarily from strain stress at the time of the subduction of the Marble Canyon Seamount.

There is an example of a proposal of the new

Figure 3. Two examples of the Middle Permian limestone containing deformed and destructed fusulinoideans within bituminous lime-mud matrix. 1. Akasaka Limestone of Japan, ×4.6. 2. Marble Canyon Limestone of British Columbia, ×4.6.

genus and species of *Metaschwagerina ovalis* by Minato and Honjo (1958), and Honjo (1959) for the deformed forms of fusulinoideans from the Akasaka Limestone. Partially four layered-wall appearance of *Metaschwagerina ovalis* is apparently due to the test destruction, and not the original wall structure as Minato and Honjo (1958), and Honjo (1959) thought.

In addition to various deformation style and destruction pattern of the fusulinoidean test, the driving force and its trigger of the plasticity deformation are important and interesting taphonomically. They are, however, still uncertain and not easily explained. The Mikata example suggests that fossils randomly-orientated in the unconsolidated lime-mud matrix were plastically deformed by dehydration from the flexible argillaceous matrix and fossil grains, which had been caused by the sedimentary load. Plasticity deformation of the present example may have been related to the transport of a great amount of unconsolidated sediments into deeper continental slope when the Maizuru Group was deposited in Late Permian time, as considered by Kobayashi (2003).

Foraminiferal fauna

Twenty-six species assignable to 19 and two indeterminate genera of foraminifers were identified in three samples of limestone and conglomeratic limestone blocks of the Yokoyama Formation in the Mikata area by the microscopic observation of 112 limestone thin sections (Table 1, Plates 1–3). The most representative species is *Lepidolina maizurensis* Nogami. It is abundant in Samples A and E, but exceedingly rare in Sample C. Fewer species composition in Sample E is thought to be resulted from fewer numbers of thin sections.

Age-diagnostic species in the Mikata fauna are *Lepidolina maizurensis, Lantschichites cuniculata* (Kanmera), and *Kahlerina ussurica* (Sosnina). They are also characteristic in the Midian foraminiferal fauna of the Miharaiyama area (Kobayashi, 2006a).

Table 1. Late Middle Permian foraminifers discriminated in the Mikata area.

	Sample A	Sample C	Sample E	Plate (Figure)
Ladiodiscus sp.	X			
Pseudoglomospira sp.		X		
Climacammina valvulinoides Lange	X	X		3 (19)
Palaeotextulariidae gen. and sp. indet.	X	X	X	3 (18)
Tetrataxis sp. A	X	X	X	3 (8–10)
Tetrataxis sp. B		X		3 (21)
Abadehella coniformis Okimura and Ishii		X		3 (16, 17)
Kahlerina ussurica (Sosnina)	X	X	X	2 (14–18)
Sichotenella sp..	X	X		2 (21)
Dunbarula sp.		X		2 (19, 20)
Lantschichites cuniculata (Kanmera)	X	X	X	2 (8–12)
Chusenella sp.	X	X		2 (3, 4)
Parafusulina? sp.	X		X	2 (5–7)
Lepidolina maizurensis Nogami	X	X	X	1 (1–9), 2 (1)
Yabeina cf. *higoensis* Kobayashi	X			2 (2)
Nankinella inflata (Colani)	X	X	X	3 (1–4, 6, 7)
Nankinella sp. A	X	X	X	2 (13)
Nankinella sp. B		X		2 (22, 23)
Agathammina sp.		X		3 (30, 31)
Baisalina? sp.		X		
Hemigordius sp. A	X	X		3 (27–29)
Hemigordius spp.	X	X	X	3 (32–36)
Pachyphloia ovata Lange	X	X	X	3 (22–26)
Pachyphloia schwageri Ser. De Civ. and Dess.	X	X	X	3 (11–15)
Geinitzina sp.	X	X		3 (20)
Ichthyolariidae gen. and sp. indet.	X			3 (5)

On the other hand, forms undoubtedly referable to *Lepidolina kumaensis* Kanmera and *L. multiseptata* (Deprat) dominant in the Miharaiyama fauna are not discriminated in the present Mikata fauna. *Metadoliolina multivoluta* (Sheng) is also absent in the latter. Two neoschwagerinid genera, *Afghanella* and *Sumatrina* exclusively known from the Maizuru and Akiyoshi terranes among the Japanese Middle Permian have not been found in the Miharaiyama and Mikata areas.

Nankinella inflata and *Parafusulina*? sp. characteristic in the Mikata fauna were not found in the Miharaiyama. The large-sized *Nankinella* represented by *N. inflata* and its similar species are very common in the Middle and Upper Permian (Wuchiapingian) of South China (e.g., Lee, 1934; Chen, 1956; Sheng, 1963) and South East Asia (e.g., Colani, 1924). They are also known from the Middle Permian (Murgabian) of Xainza, Lhunzhub, and Rawu, Southern Tibet (Wang et al., 1981). The large-sized *Nankinella* of Early Permian age such as N. *orbiculeria* Lee are reported from South China (e.g., Lee, 1934; Chen, 1934). However, these forms have not been known from the Upper Paleozoic in Japan, Primorye, and other Circum-Pacific regions.

The elongate form of schwagerinids questionably assigned to *Parafusulina* is closely similar to and probably the same as the schwagerinids named *Parafusulina*? sp. from the Kuma Formation by Kanmera (1954) and by Kobayashi (2001). Non-fusulinoidean foraminifers of the Mikata fauna are dominated by *Hemigordius* spp. and *Pachyphloia ovata* Lange. They are common in the examined three samples. On the other hand, forms assignable to *Globivalvulina* and Endothyriidae mostly associated with the Middle Permian fauna of Japan and Tethyan regions are lacking in the present fauna.

In conclusion, the Mikata fauna bears some resemblances not only with the coeval fauna of the Maizuru Terrane but also with the *Lepidolina kumaensis* fauna of the South Kitakami-Kurosegawa Terrane. Foraminiferal taxa distinguished in the Mikata fauna are all indicators of the Capitanian age and completely lack the pre-Capitanian genera and species. Large-sized *Nankinella*, *N. inflata* is significant paleobiogeographically on account of its wide distribution in the regions assignable to Province B (Eastern Tethyan Province), and the total absence in the Circum-Pacific terranes belonging to the Province C (Panthalassan Province) (Kobayashi, 1997a; 1997b). Its occurrence in the Mikata area supports that all limestone blocks and clasts of the Maizuru Terrane were derived from South China and the Akiyoshi Seamount (Kobayashi, 2003).

Systematic paleontology

Order FORAMINIFERIDA Eichwald, 1830
Suborder FUSULININA Wedekind, 1937
Superfamily Fusulinoidea von Möller, 1879
Family Schubertellidae Skinner, 1931
Genus ***Lantschichites*** Tumanskaya, 1953
Lantschichites cuniculata (Kanmera)
Plate 2, Figures 8–12

Codonofusiella cuniculata Kanmera, 1954, p. 6, 127, pl. 3, figs. 12, 14–19.
Paraboultonia inuboensis Chisaka, 1960, p. 242, pl. 1, figs. 1–6.
Codonofusiella inuboensis (Chisaka). Choi, 1970, p. 316–318, pl. 8, figs. 7–12.
Lantschichites cuniculata (Kanmera). Kobayashi, 2001, p. 71, pl. 3, figs. 3–9.

Material.—One axial, one tangential, one sagittal, one parallel, and one oblique sections.

Discussion.—Diagnostic characters of this species became clearer by the topotype specimens examined by Kobayashi (2001). They have larger test and more strongly fluted septa than the original ones described by Kanmera (1954) from the Kuma Formation. These characters are common among the Kuma, Miharaiyama (Kobayashi, 2006a) and present materials. Specimens named as *Paraboultonia inuboensis* Chisaka from the Takagami Conglomerate (Chisaka, 1960) and *Codonofusiella inuboensis* (Chisaka) from Iwaizaki Limestone (Choi, 1970) were concluded to be a junior synonym of this species by Kobayashi (2001), based on various appearance of size and shape of the test and wide morphologic variation of this species.

Occurrence.—Common to rare in Samples A and C.

Family Schwagerinidae Dunbar and Henbest, 1930
Genus ***Chusenella*** Hsu, 1942
Chusenella sp.
Plate 2, Figures 3, 4

Material.—One axial and one sagittal sections.

Discussion.—A few well-oriented axial and sagittal sections obtained are assigned to *Chusenella* from the clear juvenile stage of the test which is represented by tightly coiled inner whorls with thin wall. Though it is deformed, it resembles forms named *Schwagerina* aff. *acris* Thompson and Wheeler from the Kuma Formation (Kanmera, 1954), and *Chusenella acris* (Thompson and Wheeler) from the Kuma Formation (Kobayashi, 2001) and the Miharaiyama area (Kobayashi, 2006a). The present unnamed species has weaker and rather irregular septal fluting and more well-developed axial filling. It differs from the original materials of *Chusenella acris* from British Columbia by Thompson and Wheeler (1942) in having more distinct juvenile stage and weaker and more irregular septal fluting.

Occurrence.—Rare in Samples A and C.

Genus ***Parafusulina*** Dunbar and Skinner, 1931

Parafusulina? sp.

Plate 2, Figures 5–7

Material.—Two axial and one oblique sections.

Discussion.—Unidentified forms questionably assigned to *Parafusulina* from the Mikata area are thought to be nearly the same as those named *Parafusulina*? sp. from the Kuma Formation by Kanmera (1954) and by Kobayashi (2001) with respect to large cylindrical test, strongly and regularly fluted septa and obscure median tunnel. Other schwagerinids known from the Capitanian limestones of the Maizuru and South-Kitakami-Kurosegawa terranes are distinguished from *Parafusulina*? sp. by these diagnostic test characters.

Occurrence.—Rare in Samples A and E.

Family Neoschwagerinidae Dunbar and Condra, 1927

Subfamily Lepidolininae A. D. Miklukho-Maklay, 1958

Genus ***Lepidolina*** Lee, 1933 emend. Ozawa, 1970

Lepidolina maizurensis Nogami

Plate 1, Figures 1–9; Plate 2, Figure 1

Lepidolina toriyamai maizurensis Nogami, 1958, p. 106, 108, pl. 2, figs. 1–5.

Lepidolina maizurensis Nogami. Kobayashi, 2006a, p. 5–7, Figure 4-1, 4-2; pl. 1, figs. 2–4, 8, 9.

non. *Yabeina maizurensis* (Nogami). Zaw Win, 1999, p. 64, 65, pl. 13, figs. 1–4.

Material.—Seven axial, two sagittal, and one oblique sections.

Discussion.—This species was originally described as a subspecies of *Lepidolina toriyamai* Kanmera, synonymous with *L. kumaensis* Kanmera, from the Maizuru Group of Kyoto prefecture by Nogami (1958). The Mikata forms are closely similar to the original ones in many characters, though their test is remarkably undergone by a plasticity deformation. *L. maizurensis* is distinguished from *L. kumaensis* by its smaller proloculus, fewer number of transverse septula, and the first appearance of secondary transverse septula in the later ontogenetic stage as concluded by Kobayashi (2006a), and not always by its thicker wall as insisted by Nogami (1958). The three forms assigned to *Yabeina maizurensis* (Nogami) from the Akasaka Limestone by Zaw Win (1999) are excluded from this species, as Kobayashi (2006a) indicated.

Occurrence.—Abundant in Samples A and E, but exceedingly rare in Sample C.

Subfamily Neoschwagerininae Dunbar and Condra, 1927

Genus ***Yabeina*** Deprat, 1914

Yabeina cf. ***higoensis*** Kobayashi

Plate 2, Figure 2

Yabeina sp. Kobayashi, 2006a, p. 7, Plate 2, Figures 4, 7, 9, 10

Compare—*Yabeina higoensis* Kobayashi, 2001, p.72, Figure 6. 4, 8; pl. 5, figs.1–9.

Material.—One tangential section.

Discussion.—Illustrated and other specimens from the Mikata area are similar to the original *Yabeina higoensis* from the Kuma Formation (Kobayashi, 2001). They are more similar to *Yabeina higoensis* from Kaize, Nagano prefecture (Kobayashi, 2006d) than that from the Kuma Formation. Compared with specimens from Kuma and Kaize, present ones have larger test and more well-developed secondary transverse septula. Because of this difference and less number of well-oriented thin sections, the exact identification has been postponed in this paper. Four specimens named as *Yabeina* sp. from the Miharaiyama area by Kobayashi (2006a) are identical with the present ones by development of transverse septula and expansion of the test, though forms of the Miharaiyama area are abraded in their outer whorls.

Occurrence.—Rare in Sample A.

Family Staffellidae A. D. Miklukho-Maklay, 1949

Genus ***Nankinella*** Lee, 1934

Nankinella inflata (Colani)

Plate 3, Figures 1–4, 6, 7

Fusulinella inflata Colani, 1924, p. 77, pl. 15, figs. 3–5, 7–10, 13, 15.
Nankinella inflata (Colani), Chen, 1956, p.2, 19, pl. 1, figs. 4–7.

Material.—Three axial and three tangential sections.

Discussion.—Although the Mikata materials are strongly deformed in most specimens, diagnostic test characters prior to deformation are represented by large thick lenticular test with pointed to bluntly pointed periphery, straight lateral slopes, and protruding poles with shallow umbilical depressions. The number of whorl attains more than 10. Wall is rather thick and recrystallized. Tunnel is very narrow, and chomata are developed possibly throughout whorls. These test features closely resemble those of the *Nankinella inflata* originally described by Colani (1924) from North Vietnam.

Occurrence.—Common in Samples A, C, and E.

Acknowledgment

Thanks are due to Drs. Hisayoshi Igo and Atsushi Takemura for their critical reading of the manuscript, to Dr. Hiroshi Furutani for his help in the field, and to Ms. Atsuko Ujimaru for her computer inputting illustrations. This study was financially supported by the co-operative research program of the Museum of Nature and Human Activities, Hyogo in 2005 and 2006 (Paleozoic fossils of Hyogo), and by the Grant-in-Aid for Scientific Research of the Japan Society for the Promotion of Science in 2004 and 2005 (Project No. 16540428).

References

Chen, S. (1934) Fusulinidae of South China, Part 1, *Palaeont. Sinica, New Ser.*, B, **4**: 1–185.

Chen, S. (1956) Fusulinidae of South China, Part II, *Palaeont. Sinica, New Ser.*, B, **6**: 17–71.

Chisaka, T. (1960) On some Permian fusulinids from the Takagami Conglomerate, Choshi Peninsula, Chiba prefecture, Japan. *Jour. Coll. Arts Sci., Chiba Univ.*, **3**: 235–254.

Choi, D. R. (1970) On some Permian fusulinids from Iwaizaki N.E. Japan. *Jour. Fac. Sci., Hokkaido Univ. Ser. IV.*, **14**: 313–325.

Colani, M. (1924) Nouvelle contribution a l' étude des Fusulinidés de l' Extreme-Orient. *Indochine Service Géol., Mém.*, **1**: 1–76.

Honjo, S. (1959) Neoschwagerinids from the Akasaka Limestone (A paleontological study of the Akasaka Limestone, 1st report). *Jour. Fac. Sci., Hokkaido Univ. Ser. IV.*, **10**: 111–161.

Kanmera, K. (1954) Fusulinids from the Upper Permian Kuma Formation, southern Kyushu, Japan, with special reference to the fusulinid zone in the Upper Permian of Japan. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **4**: 1–38.

Kanmera, K. and Nakazawa, K. (1973) Permian-Triassic relationship and faunal changes in the eastern Tethys. In, Logan, A. and Hills, L. V. (eds.), *The Permian and Triassic Systems and their mutual boundary*, Can. Soc. Pet. Geol., Mem., **2**: 100–119.

Kobayashi, F. (1997a) Middle Permian biogeography based on fusulinacean faunas. In, Ross, C. A., Ross, J. R. P., and Brenckle, P. L. (eds.), *Late Paleozoic foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary*, Cushman Found. Foram. Res., Spec. Publ., no. 36: 73–76.

Kobayashi, F. (1997b) Middle Permian fusulinacean faunas and paleogeography of exotic terranes in the Circum-Pacific. In, Ross, C. A., Ross, J. R. P., and Brenckle, P. L. (eds.), *Late Paleozoic foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary*, Cushman Found. Foram. Res., Spec. Publ., no. 36: 77–80.

Kobayashi, F. (1999) Tethyan uppermost Permian (Zhulfian and Dorashamian) foraminiferal faunas and their paleogeographic and tectonic implications. *Palaeogeogr. Palaeoclim. Palaeoecol.*, **150**: 279–307.

Kobayashi, F. (2001) Faunal analysis of Permian foraminifers of the Kuma Formation in the Kurosegawa Belt of west Kyushu, Southwest Japan. In, Takemura, A. and Furutani, H. (eds.), *Proceedings of the Seventh Radiolarian Symposium*, News of Osaka Micropaleontologists, spec. vol., no. 11: 61–84.

Kobayashi, F. (2003) Palaeogeographic constraints on the tectonic evolution of the Maizuru Terrane of Southwest Japan to the eastern continental margin of South China during the Permian and Triassic. *Palaeogeogr. Palaeoclim. Palaeoecol.*, **195**: 299–317.

Kobayashi, F. (2006a) Late Middle Permian

(Capitanian) foraminifers in the Miharaiyama area, Hyogo—Late Paleozoic and Early Mesozoic foraminifers of Hyogo, Japan, Part 2—. *Nature and Human Activities*, **10**: 1–13.

Kobayashi, F. (2006b) Latest Permian (Changhsingian) foraminifers in the Mikata area, Hyogo—Late Paleozoic and Early Mesozoic foraminifers of Hyogo, Japan, Part 3—. *Nature and Human Activities*, **10**: 15–24.

Kobayashi, F. (2006c) Early Late Permian (Wuchiapingian) foraminifers in The Tatsuno area, Hyogo—Late Paleozoic and Early Mesozoic foraminifers of Hyogo, Japan, Part 4—. *Nature and Human Activities*, **10**: 25–33.

Kobayashi, F. (2006d) Middle Permian foraminifers of Kaize, southern part of the Saku Basin, Nagano prefecture, central Japan. *Paleont.* Res., **10**: 179–194.

Kobayashi, F. and Takemura, A. (1995) Part 1, Microfossils. In, Kobayashi, F, Takemura, A., Furutani, H., Chemise, D., Saegusa, H., Chinzei, K., Handa, K., and Uemura, K., Fossils reported in Hyogo until 1993. *Humans and Nature*, **5**: 47–91. (in Japanese)

Lee, J. S. (1934) Taxonomic criteria of Fusulinidae with notes on seven new Permian genera. *Mem. Nat. Res. Inst. Geol., Nanking (1933)*, **14**, 1–32.

Minato, M. and Honjo, S. (1958) Shell structure of *Metaschwagerina*, n. gen. from the Akasaka Limestone. *Earth Sci.*, no. 38, frontispiece. (in Japanese)

Nogami, Y. (1958) Fusulinids from the Maizuru Zone, Southwest Japan—Part 1. Ozawainellinae, Schubertellinae and Neoschwagerininae—. *Mem. Coll. Sci., Univ. Kyoto*, Ser. B, **25**: 97–115.

Sheng, J. C. (1963) Permian fusulinids of Kwangsi, Kueichow and Szechuan. *Palaeont. Sinica, New. Ser. B*, **10**: 1–247. (in Chinese and English)

Shimizu, D. (1962) The Permian Maizuru Group, its stratigraphy and syntectonic faunal succession through latest Permian orogeny. *Mem. Fac. Sci., Univ. Kyoto, Ser. B*, **28**: 571–609.

Thompson, M. L. and Wheeler, H. E. (1942) Permian fusulinids from British Columbia, Washington and Oregon. *Jour. Paleont.*, **16**: 700–711.

Wang, Y. J., Sheng, J. Z. and Zhang, L. X. (1981) Fusulinids of Xizang of China. In, *Paleontology of Xizang, Book 3*, p. 1–80, Scientific Publishing House, Beijing. (in Chinese with English abstruct)

Working Group on the Permian-Triassic System (1975) Stratigraphy near Permian-Triassic boundary in Japan and its correlation. *Jour. Geol. Soc. Japan*, **81**: 165–184. (in Japanese with English abstract)

Zaw Win (1999) Fusuline biostratigraphy and paleontology of the Akasaka Limestone, Gifu prefecture, Japan. *Kitakyushu Mus. Nat. Hist., Bull.*, **18**: 1–76.

Received: August 9, 2006
Accepted: November 7, 2006

Plate 1.

Figs. 1–9. *Lepidolina maizurensis* Nogami.
1: D2-035312a; 2: D2-029365; 3: D2-029379; 4: D2-029351; 5: D2-029353; 6: D2-029376; 7: D2-029373; 8: D2-029363a; 9: D2-029401, all: Sample A except for 1: Sample E, all ×10.

Plate 2.

Fig. 1. *Lepidolina maizurensis* Nogami.
D2-029372, Sample A; ×10.
Fig. 2. *Yabeina cf. higoensis* Kobayashi.
D2-029395, Sample A, ×10.
Figs. 3, 4. *Chusenella* sp.
3: D2-029399; Sample A, 4: D2-035286a; Sample C, both ×10.
Figs. 5–7. *Parafusulina*? sp.
5: D2-029370; 6: D2-029352; 7: D2-029382a, all Sample A, ×10.

Fig. 7. *Chusenella* sp.
D2-035286b, Sample C, ×10.
Figs. 8–12. *Lantschichites cuniculata* (Kanmera).
8: D2-035275a; 9: D2-035286c; 10: D2-035272; 11: D2-035263; 12: D2-035281, all Sample A, 8: ×40; 9, 10: ×30; 11, 12: ×20.
Figs. 13. *Nankinella* sp. A.
D2-029384a, Sample A, ×25.
Figs. 14–18. *Kahlerina ussurica* (Sosnina).
14: D2-035306a; 15: D2-035253a; 16: D2-035312b; 17: D2-029396; 18: D2-035295, 14, 16: Sample E; ×15, 15, 17: Sample A; ×20; 18: Sample C; ×20.
Figs. 19, 20. *Dunbarula* sp.
19: D2-035256; ×60, 20: D2-035262; ×40, both Sample C.
Fig. 21. *Sichotenella* sp.
D2-029355, Sample A, ×30.
Figs. 22, 23. *Nankinella* sp. B.
22: D2-035299; 23: D2-035300a, both Sample C, ×30.

Plate 3.

Figs. 1–4, 6, 7. *Nankinella inflata* (Colani).
1: D2-029364a; 2: D2-029382b; 3: D2-029380; 4: D2-029378; 6: D2-029390; 7: D2-035307, 1–4, 6: Sample A; 7: Sample E, 1–4: ×15; 6, 7: ×20.
Fig. 5. Ichthyolariidae gen. and sp. indet.
D2-029375, Sample A, ×30.
Figs. 8–10. *Tetrataxis* sp A.
8: D2-029381; 9:D2-029364b; 10: D2-029365, all Sample A, 8: ×25; 9, 10: ×20.
Figs. 11–15. *Pachyphloia schwageri* Sellier de Civrieux and Dessauvagie.
11: D2-035275b; Sample E; ×50, 12: D2-029391; Sample A; ×30, 13: D2-029384b; Sample A; ×30, 14: D2-035281b; Sample C; ×40, 15: D2-035306b; Sample E; ×40.
Figs. 16, 17. *Abadehella coniformis* Okimura and Ishii.
16: D2-035267; 17: D2-035254, both: Sample C, ×40.
Fig. 18. Palaeotextulariidae gen. and sp. indet.
D2-035308, Sample E, ×20.
Fig. 19. *Climacammina valvulinoides* Lange.
D2-029387, Sample A, ×15.
Fig. 20. *Geinitzina* sp.
D2-035275c, Sample C, ×40.
Fig. 21. *Tetrataxis* sp B.
D2-035264, Sample C, ×30.
Figs. 22–26. *Pachyphloia ovata* Lange.
22: D2-029389a; Sample A; ×25, 23: D2-035282; Sample C; ×40, 24: D2-035265; Sample C; ×40, 25: D2-029374a; Sample A; ×30, 26: D2-035275d; Sample C; ×40.
Figs. 27–29. *Hemigordius* sp. A
27: D2-035300b; Sample C, 28: D2-029389b; Sample A, 29: D2-035265; Sample C, all ×50.
Figs. 30, 31. *Agathammina* sp.
30: D2-035274; ×40, 31: D2-035275e; ×30, both Sample C.
Figs. 32–36. *Hemigordius* spp.
32: D2-029374b; Sample A; ×20, 33: D2-035297; Sample C; ×40, 34: D2-035253b; Sample C; ×20, 35: D2-029363b; Sample A; ×20, 36: D2-035312c; Sample E; ×30.

Plate 1

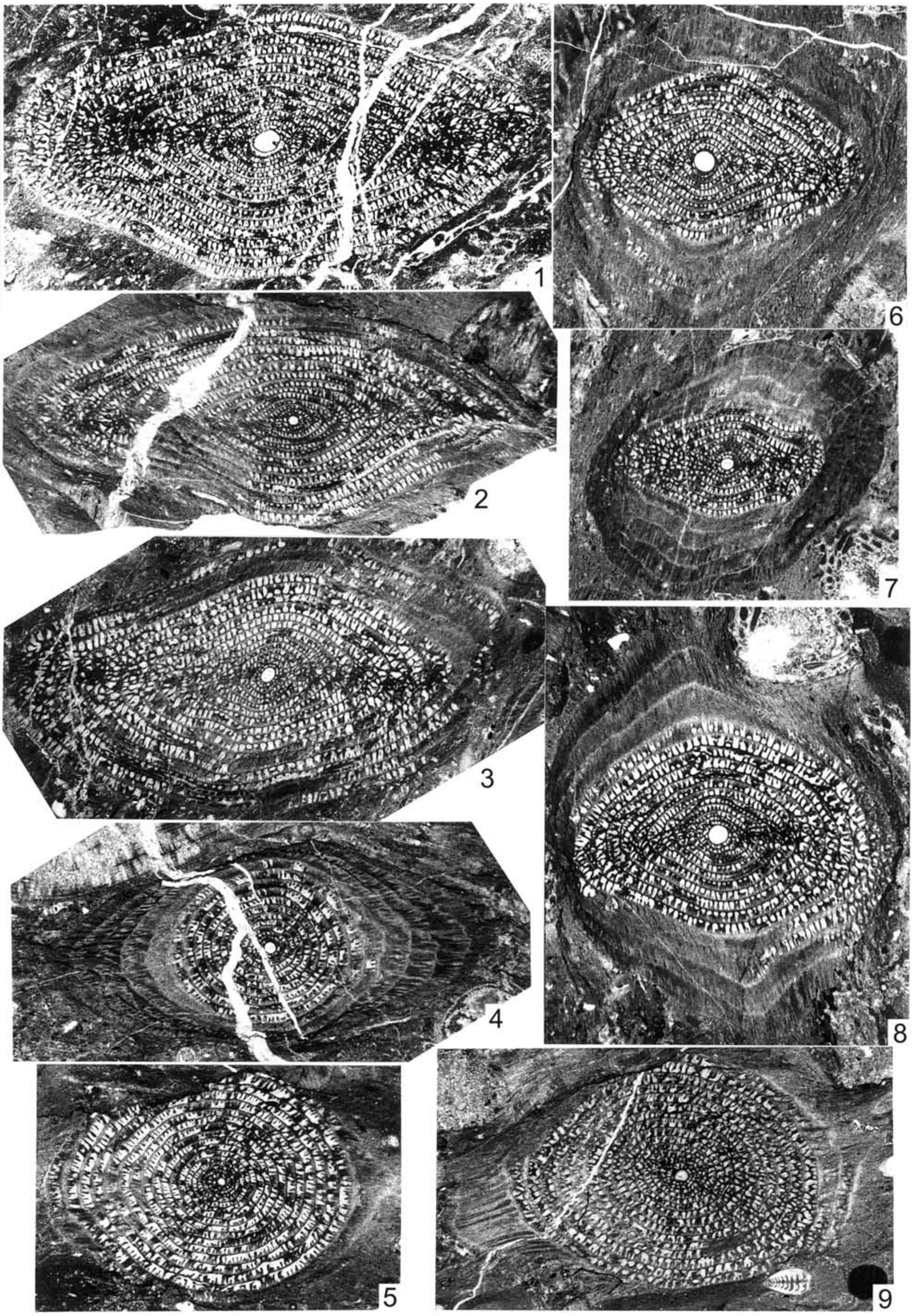


Plate 2

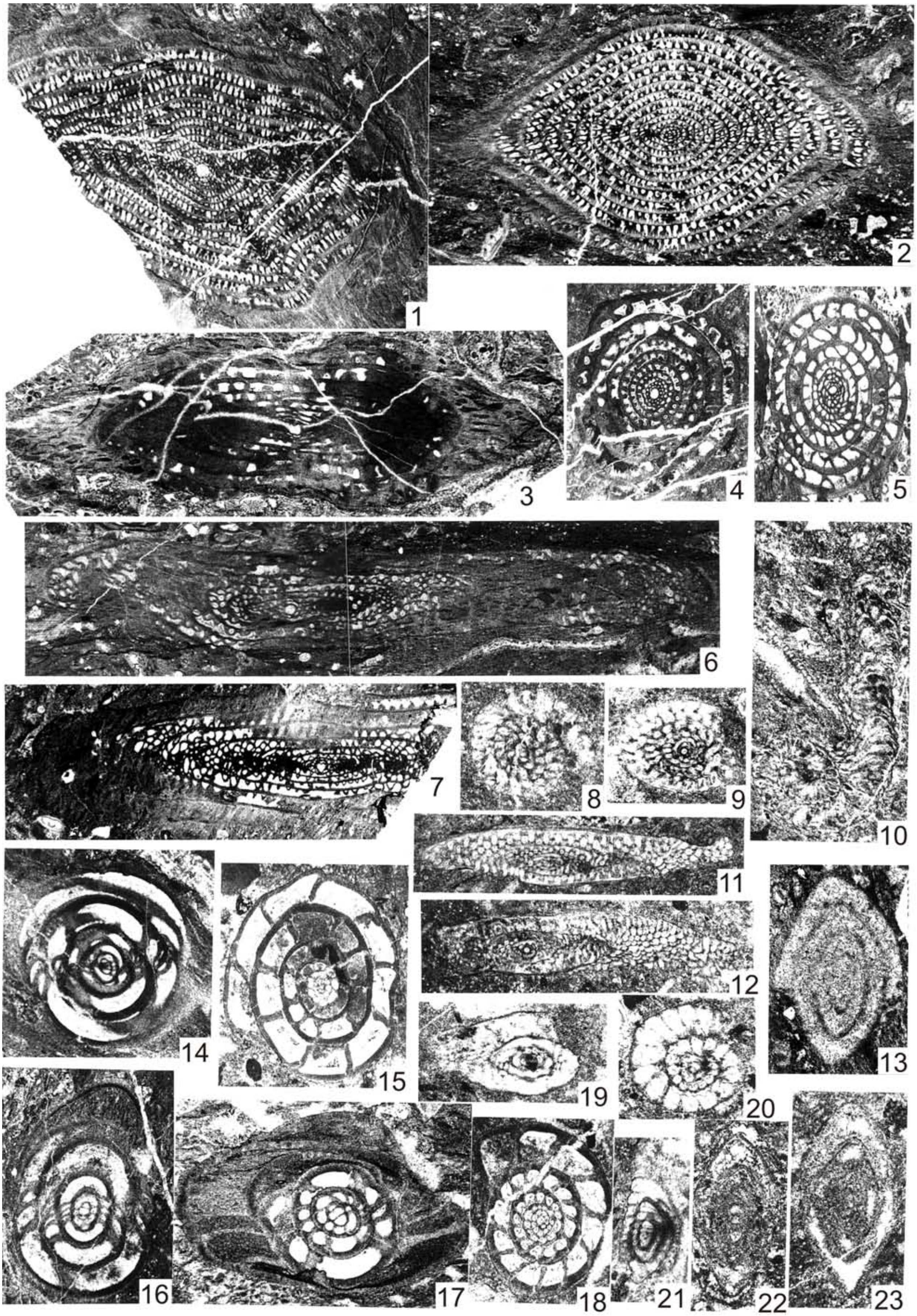
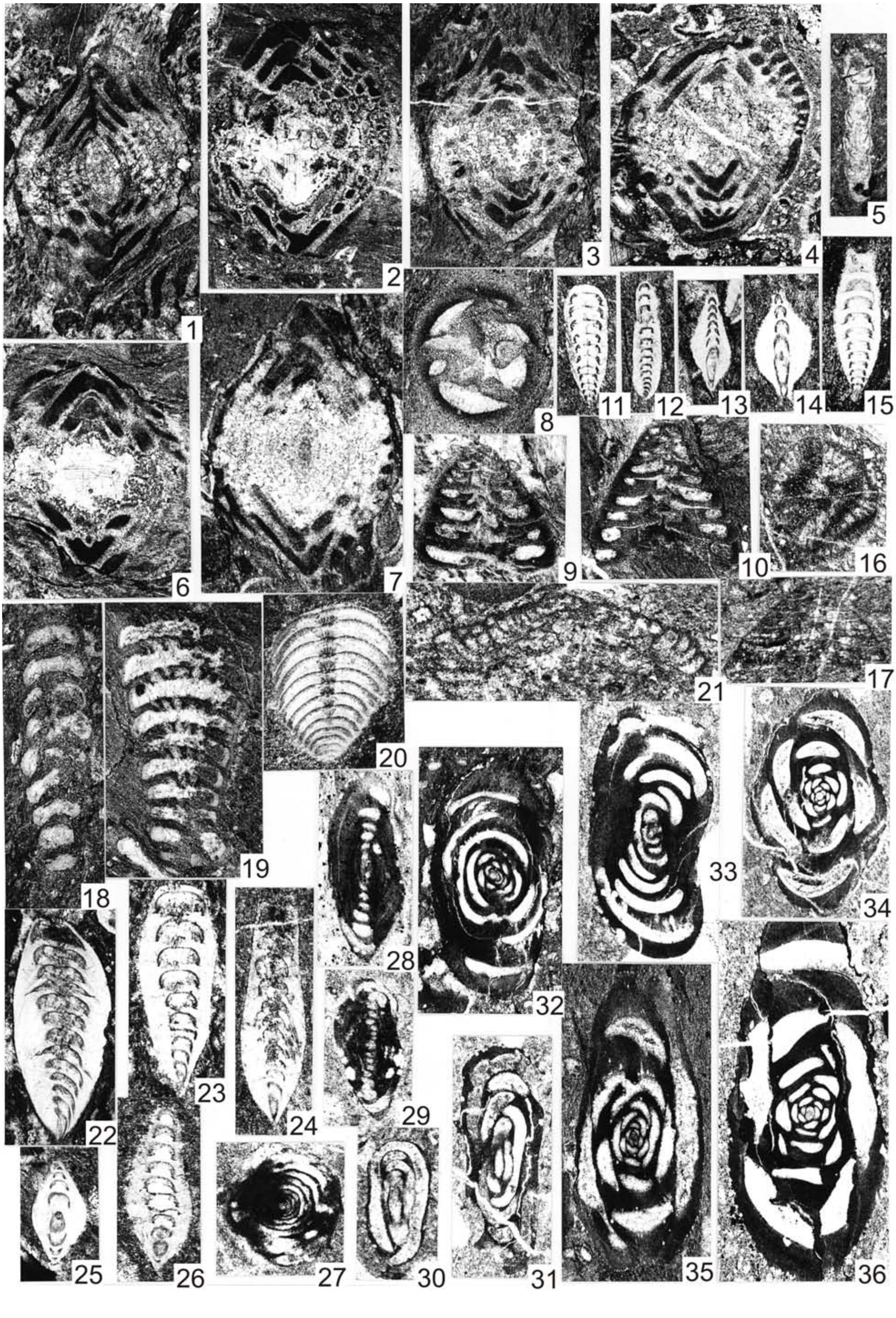


Plate 3


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36