

Middle Permian foraminifers of the Izuru and Nabeyama Formations in the Kuzu area, central Japan

Part 2. Schubertellid and ozawainellid fusulinoideans, and non-fusulinoidean foraminifers

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Abstract. Middle Permian Izuru and Nabeyama Formations in the Kuzu area, central Japan are divisible into three zones based on the stratigraphic distribution of larger fusulinoideans: the lower *Parafusulina nakamigawai* Zone, the middle *Parafusulina yabei* Zone, and the upper *Parafusulina tochigiensis* Zone. Although schubertellid and ozawainellid fusulinoideans and non-fusulinoidean foraminifers are accessory in comparison with dominant schwagerinid fusulinoideans, 56 species assignable to 25 genera and a few more indeterminate genera are distinguished in these three zones. Their taxonomic diversity is very low in the lower zone, and becomes higher in the middle zone and highest in the upper zone. The difference of their variety well agrees with lithologic change of limestone in these three zones. There are no remarkable differences in the faunal composition of schubertellid and ozawainellid fusulinoideans and non-fusulinoidean foraminifers between the Izuru and Nabeyama Formations and other contemporaneous limestones of Japan. The similar faunal composition of these groups shows a striking contrast to the provinciality of the schwagerinids and neoschwagerinids of the Izuru and Nabeyama Formations. Six species of schubertellid fusulinoideans newly proposed herein are systematically described and discussed. They are *Schubertella? karasawensis*, *Schubertella? minutisphaera*, *Codonofusiella ashioensis*, *Codonofusiella elongata*, *Codonofusiella nabeyamensis*, and *Dunbarula oviformis*.

Key words: foraminifers, Middle Permian, taxonomic diversity, Izuru and Nabeyama Formations, Kuzu area

Introduction

Huge blocks of Upper Paleozoic limestone and basaltic rocks in the Jurassic accretionary complexes are distributed in the Kuzu area, southern part of the Ashio Mountains, showing a horseshoe-shaped outline more than 20 km long (Figure 1). They originated in the Panthalassan seamount (Kobayashi, 1999; 2005), and are divided into the lower Izuru and the upper Nabeyama Formations (Kobayashi, 1979). The Izuru Formation is about 400 m thick, and consists of basaltic pyroclastic rocks and lava intercalating with lenticular limestones in the upper part. The conformably overlying Nabeyama Formation of 300 m thickness is composed of bedded limestone partly dolomitized in the lower part, mainly dolostone in the middle part, and massive limestone in the upper part (Kobayashi, 1979). Fossils such as foraminifers, especially larger fusulinoideans, marine algae, crinoids, sponges, hy-

drozoans, rugose corals, bryozoans, brachiopods, bivalves, gastropods, and ostracods are abundant and diversified.

Kobayashi (2006) showed that the Izuru and Nabeyama Formations are biostratigraphically subdivided into three zones, the lower *Parafusulina nakamigawai* Zone, the middle *P. yabei* Zone, and the upper *P. tochigiensis* Zone, based on the stratigraphic distribution of the 30 species of fusulinoideans distinguished from 70 localities (Figure 2). The first zone corresponds to the *Parafusulina nakamigawai* Zone of the basal part of the Akasaka Limestone, and is Kuber-gandian in age in the Tethyan standard scale. The third zone is correlated to the *Neoschwagerina craticulifera* Zone to the *Neoschwagerina margaritae* Zone of the Akasaka Limestone, and is Murgabian in age in the Tethyan standard and Wordian in age in the international standard (Kobayashi, 2006).

Schubertellid and ozawainellid fusulinoideans and

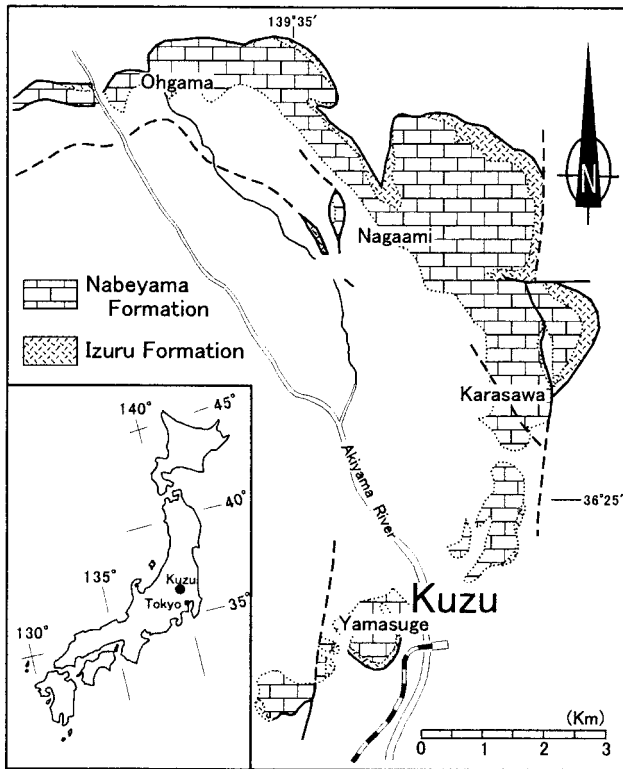


Figure 1. Index map showing the distribution of Nabeyama and Izuru Formations in the Kuzu area.

non-fusulinoidean foraminifers have not heretofore been described in the Izuru and Nabeyama Formations. Many microphotographs of them are shown so as to understand all aspects of these foraminifers in the two formations and to compare them with contemporaneous Tethyan faunas and other Panthalas- san ones. Six species of schubertellid fusulinoideans are newly proposed herein: *Schubertella? karasawensis*, *Schubertella? minutisphaera*, *Codonofusiella ashioensis*, *Codonofusiella elongata*, *Codonofusiella nabeyamensis*, and *Dunbarula oviformis*.

The stratigraphic range of the recognized 18 species belonging to 8 genera of schubertellid and ozawainellid fusulinoideans are shown in Figure 2, along with 12 species of schwagerinid, neoschwagerinid, and verbeekinid genera described and discussed in Kobayashi (2006). The occurrence of 38 species assignable to 17 genera and a few more indeterminate genera of non-fusulinoidean foraminifers are shown in Table 1. Fossil localities of these foraminifers in the Izuru and Nabeyama Formations are shown in figures 3 to 6 of Kobayashi (2006). All limestone thin sections are registered and stored in the collection of Museum of Nature and Human Activities, Hyogo (Fumio Kobayashi Collection).

Table 1. Occurrences of foraminifers except for fusulinoideans in the *Parafusulina nakamigawai*, *P. yabei*, and *P. tochiensis* zones.

	<i>Parafusulina nakamigawai</i> Zone	<i>Parafusulina yabei</i> Zone	<i>Parafusulina tochiensis</i> Zone
<i>Glomospira</i> sp. A		X	X
<i>Glomospira</i> sp. B		X	X
<i>Glomospira?</i> spp.			X
<i>Palaeonubecularia?</i> sp.			X
<i>Pseudoammodiscus</i> sp. A			X
<i>Pseudoammodiscus</i> sp. B		X	
<i>Lunucamina?</i> sp.			X
<i>Geinitzina</i> <i>postcarbonica</i> Spandel		X	X
<i>Geinitzina</i> sp. A		X	X
<i>Geinitzina</i> sp. B			X
<i>Geinitzina</i> sp. C			X
<i>Pachyphloia</i> spp.		X	X
<i>Climacammina</i> <i>valvulinoides</i> Lange		X	X
<i>Deckerella</i> sp.		X(?)	X
Palaeotextulariidae gen. and sp. indet.	X	X	X
<i>Globivalvulina</i> <i>cyprica</i> Reichel		X	X
<i>Globivalvulina</i> spp.			X
<i>Endothyra?</i> sp.		X	
<i>Neoendothyra</i> spp.		X	X
<i>Tetrataxis</i> sp. A		X	
<i>Tetrataxis</i> sp. B			X
<i>Tetrataxis</i> spp.		X	X
<i>Abadehella</i> <i>coniformis</i> Okimura and Ishii			X
<i>Abadehella</i> sp.			X
<i>Agathammina</i> spp.		X	X
<i>Neodiscus</i> <i>padangensis</i> (Lange)		X	X
<i>Neodiscus</i> sp. A			X
<i>Neodiscus</i> sp. B			X
<i>Neodiscus</i> sp. C			X
<i>Neodiscus?</i> sp.			X
<i>Protonodosaria</i> sp.		X	X
<i>Vervilleina</i> sp.			X
<i>Nodosinellioides?</i> sp. A			X
<i>Nodosinellioides?</i> sp. B			X
Ichthyolariidae gen. and sp. indet. A			X
Ichthyolariidae gen. and sp. indet. B			X
Ichthyolariidae gen. and sp. indet. C			X

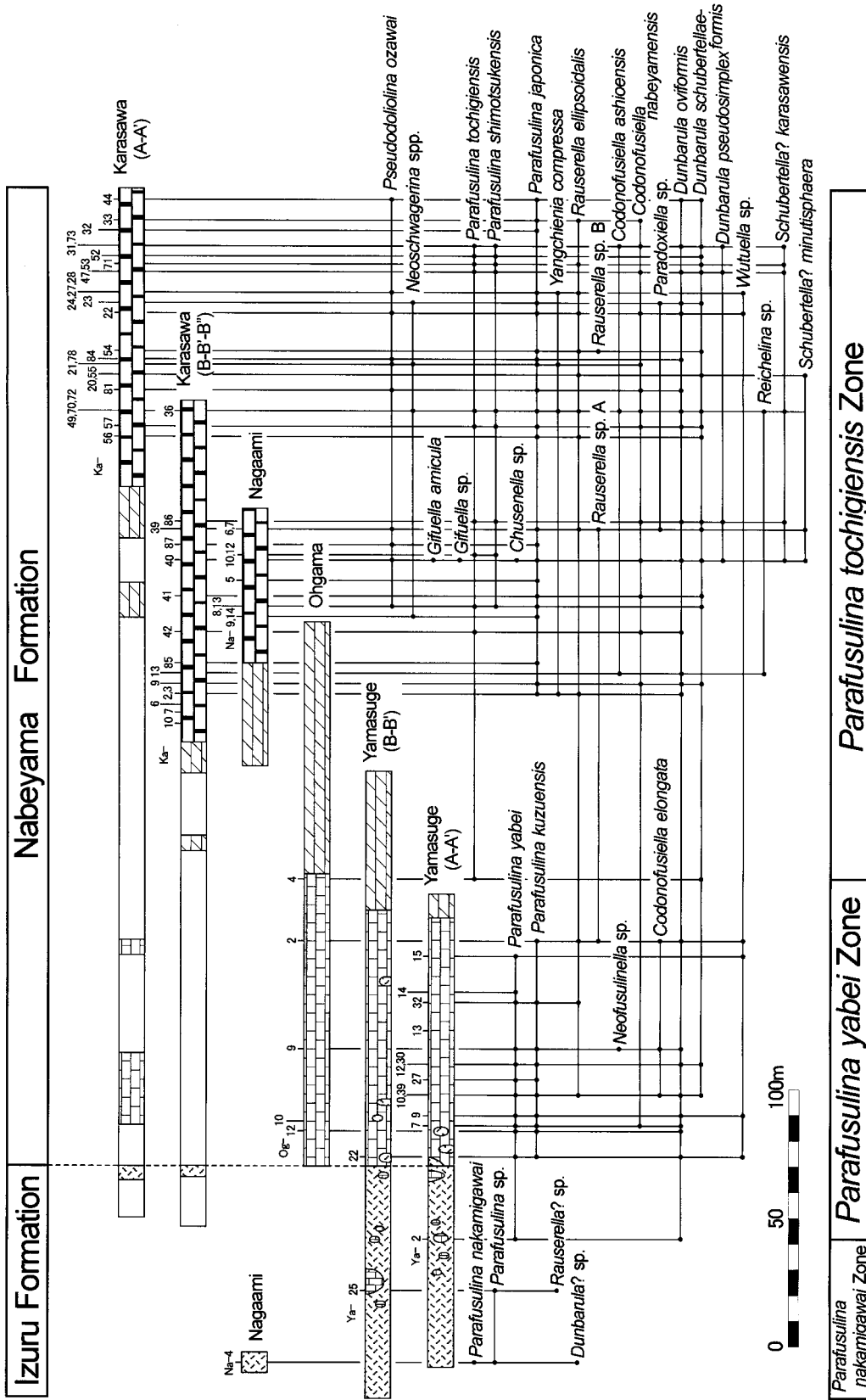


Figure 2. Stratigraphic distribution of fusulinoids in the Izuru and Nabeyama formations.

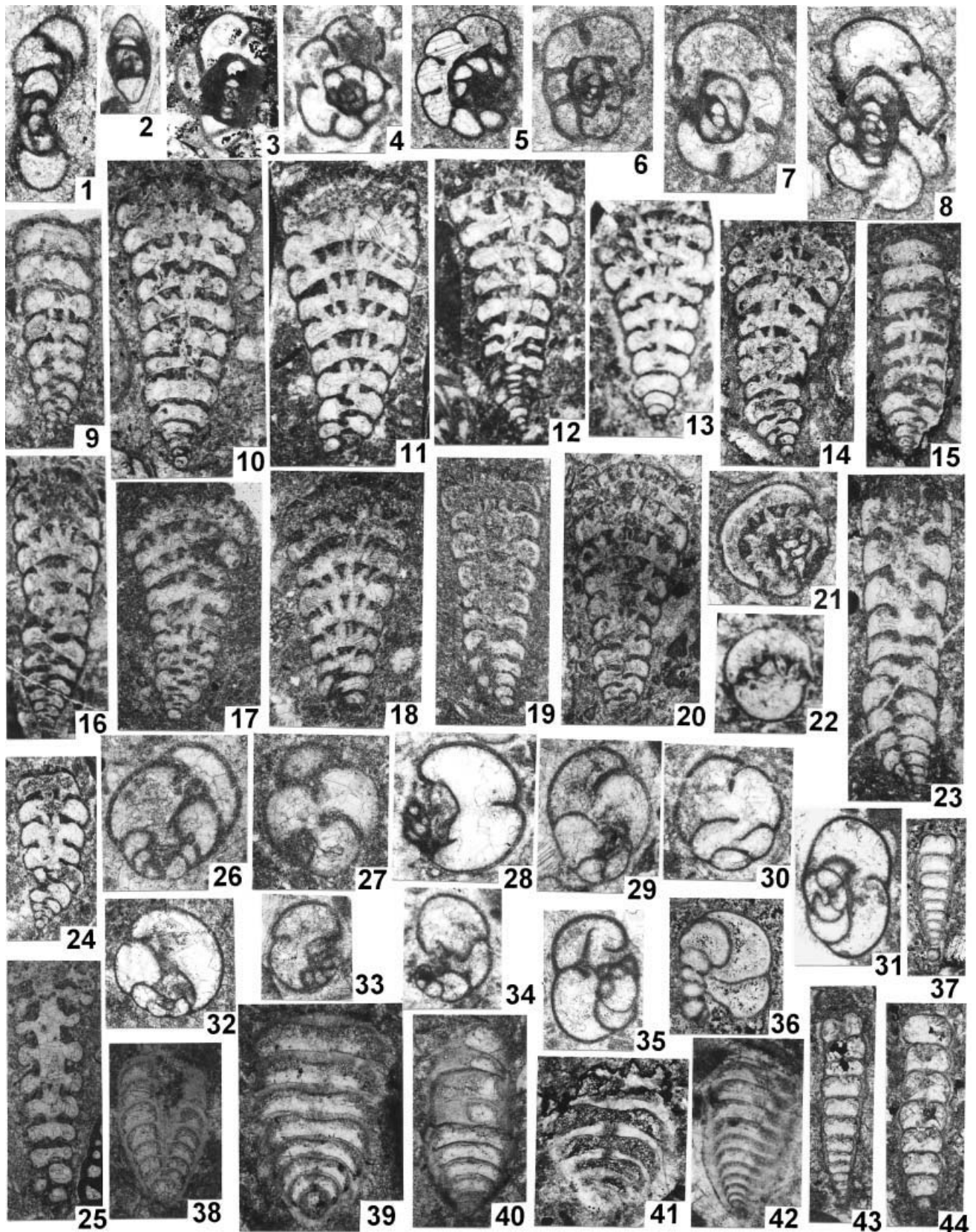


Figure 3.

Foraminifer fauna

Number of individuals and taxonomic diversity of schubertellid and ozawainellid fusulinoideans, and non-fusulinoidean foraminifers are largely different in three fusulinoidean zones of the Izuru and Nabeyama Formations (Figure 2, Table 1). Biostratigraphic zonation of the two formations based on the stratigraphic range of these small-sized foraminifers is, however, difficult and less reliable, because, in comparison with parafusulinid fusulinoideans, most of them are less dominant and less widely distributed in the formations.

Few occurrences and very low taxonomic diversity are conspicuous in the *Parafusulina nakamigawai* Zone that is distinguished in the Izuru Formation except for its uppermost part. Among small-sized foraminifers, only one individual of *Rausserella?* sp. is recognized in Yamasuge where *Parafusulina* sp. abundantly occurs. A fragment of Palaeotextulariidae and of *Dunbarula?* sp. is found in Nagaami where *Parafusulina nakamigawai* Morikawa and Horiguchi, 1956 is abundant. Foraminifers are nearly absent in other fossiliferous limestones assignable to the zone in Yamasuge. All these fossiliferous limestones in the *Parafusulina nakamigawai* Zone contain tuffaceous materials. Other fossils are less diversified as well as foraminifers. Abundant schwagerinid fusulinoideans and rare small-sized foraminifers in the Kubergandian *Parafusulina nakamigawai* Zone are common in the Izuru Formation and the basal part of the Akasaka Limestone (Kobayashi, 2006).

Although two species of *Parafusulina* are the same as in the underlying *Parafusulina nakamigawai* Zone, eight species of schubertellid and ozawainellid fusulinoideans, and seventeen species of non-fusulinoidean foraminifers are discriminated in the *Parafusulina yabei* Zone (Figure 2, Table 1). Among them, *Neofusulinella* sp. and *Codonofusiella elongata* Kobayashi, n. sp. are restricted to this zone, and other schubertellid and ozawainellid fusulinoideans range upwards to the

Parafusulina tochiensis Zone. Complete absence of Neoschwagerinidae and Verbeekinidae is important faunistically in this zone, because these two families are very common throughout the Middle Permian limestone of Japan.

The most striking phenomenon in the Murgabian *Parafusulina tochiensis* Zone is the occurrence of highly dominant *Parafusulina*, extremely rare Neoschwagerinidae, and rare Verbeekinidae. Although this zone is correlated to the *Neoschwagerina craticulifera* Zone to the *Neoschwagerina margaritae* Zone of the Akasaka Limestone (Kobayashi, 2006), these two zonal species, widespread in East and Southeast Asia, have not been discriminated in the Nabeyama Formation. Schubertellid fusulinoideans are much more variable in the *Parafusulina tochiensis* Zone than in the underlying *Parafusulina yabei* Zone. Among them, *Dunbarula schubertellaeformis* Sheng, 1958 and *Dunbarula oviformis*, n. sp. are most common in this zone. There are many genera and species of schubertellid and ozawainellid fusulinoideans the occurrences of which seem to be limited to this zone, such as *Yangchienia compressa* (Ozawa, 1927), *Reichelina* sp., *Rausserella* sp. B, *Codonofusiella ashioensis*, n. sp., *Dunbarula pseudosimplex* (Sheng, 1958), *Paradoxiella* sp., *Schubertella? karasawensis*, n. sp., and *Schubertella? minutisphaera*, n. sp. (Figure 2).

Non-fusulinoidean foraminifers are also more diversified in the *Parafusulina tochiensis* Zone than in the *Parafusulina yabei* Zone. Although the specific identification of most of them is difficult, 34 species are distinguished in the *Parafusulina tochiensis* Zone (Table 1, Figures 3–6). *Abadehella coniformis* Okimura and Ishii in Okimura et al., 1975, *Abadehella* sp., and many others occur exclusively in this zone. *Neodiscus padangensis* (Lange, 1925) is very characteristic, and *Climacamina valvulinoides* Lange, 1925, *Pachyphloia schwageri* Sellier de Civrieux and Des-sauvage, 1965, and *Tetrataxis* spp. are also prevalent in this zone.

◀ **Figure 3.** 1. *Endothyra?* sp., D2-006481, Loc. Ya-30, ×80. 2–8. *Endothyra* spp., 2: D2-008532, Loc. Og-2; 3: D2-006218, Loc. Ya-12; 4: D2-007307b, Loc. Ka-39; 5: D2-008171, Loc. Ka-73; 6: D2-007109, Loc. Ka-27; 7: D2-008497, Loc. Na-8; 8: D2-006806, Loc. Ka-6, all ×40. 9–24. *Climacamina valvulinoides* Lange, 1925, 9: D2-008203, Loc. Ka-73; 10: D2-006209a, Loc. Ya-10; 11: D2-007660, Loc. Ka-70; 12: D2-007048, Loc. Ka-21; 13: D2-007696a, Loc. Ka-70; 14: D2-006209b, Loc. Ya-10; 15: D2-006549, Loc. Ya-32; 16: D2-007374b, Loc. Ka-41; 17: D2-008146, Loc. Ka-73; 18: D2-008208, Loc. Ka-73; 19: D2-007026, Loc. Ka-21; 20: D2-007374a, Loc. Ka-41; 21: D2-007110a, Loc. Ka-27; 22: D2-007696b, Loc. Ka-70; 23: D2-007205, Loc. Ka-33; 24: D2-007643, Loc. Ka-70, all ×20. 25. *Deckerella* sp., D2-007844, Loc. Ka-70, ×20. 26, 27. *Globivalvulina cyprica* Reichel, 1945, 26: D2-007553, Loc. Ka-54; 27: D2-008035, Loc. Ka-71; both ×40. 28–36. *Globivalvulina* sp. A, 28: D2-007357, Ka-40; 29: D2-008536b, Loc. Og-2; 30: D2-007271, Loc. Ka-36; 31: D2-007350b, Loc. Ka-40; 32: D2-007472a, Loc. Ka-49; 33: D2-008535, Loc. Og-2; 34: D2-007302, Loc. Ka-39; 35: D2-007376b, Loc. Ka-41; 36: D2-006623, Loc. Ya-32, 36: ×30; others: ×40. 37, 43, 44. *Nodosinelloides?* sp. C, 37: D2-006630, Loc. Ya-32; 43: D2-006454, Loc. Ya-30; 44: D2-006544, Loc. Ya-32, all ×40. 38. *Geinitzina?* sp., D2-007780, Loc. Ka-70, ×40. 39–41. *Geinitzina postcarbonica* Spandel, 1901, 39: D2-006207, Loc. Ya-10; 40: D2-008293, Loc. Ka-86; 41: D2-006193, Ya-7, all ×40. 42. *Geinitzina* sp. A, D2-007306, Loc. Ka-39, ×40.

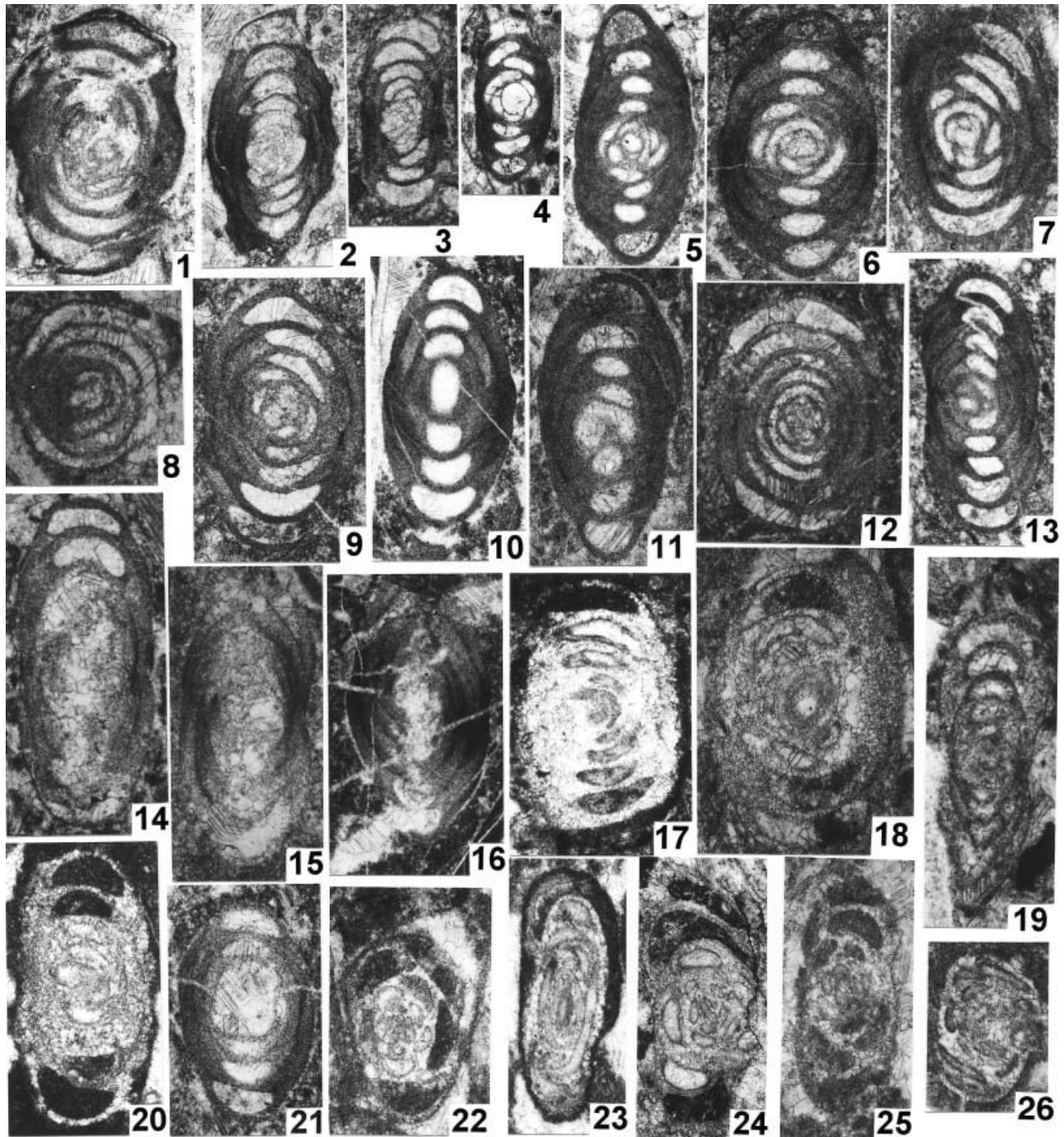


Figure 4. 1–13, 21. *Neodiscus padangensis* (Lange, 1925), 1: D2-008538a, Loc. Og-2; 2: D2-008536a, Loc. Og-2; 3: D2-007070, Loc. Ka-24; 4: D2-008591, Loc. Og-10; 5: D2-008588, Loc. Og-10; 6: D2-008496a, Loc. Na-8; 7: D2-008496b, Loc. Na-8; 8: D2-007065, Loc. Ka-23; 9: D2-008142, Loc. Ka-73; 10: D2-007843, Loc. Ka-70; 11: D2-007615, Loc. Ka-57; 12: D2-006812, Loc. Ka-7; 13: D2-008180a, Loc. Ka-73; 21: D2-008190, Loc. Ka-73, 1, 4–6, 11: $\times 40$; others: $\times 30$. 14–16. *Multidiscus?* sp. A, 14: Da-007559a, Loc. Ka-55, $\times 30$; 15: D2-007452, Loc. Ka-47, $\times 40$; 16: D2-007747, Loc. Ka-70, $\times 30$. 17, 18. *Neodiscus* sp. A, 17: D2-007340b, Loc. Ka-40; 18: D2-007195, Loc. Ka-31, both $\times 30$. 19. *Multidiscus?* sp. B, D2-007540, Loc. Ka-53, $\times 30$. 20. *Neodiscus* sp. B, D2-007190, Loc. Ka-31, $\times 40$. 22–26. *Agathammina* spp., 22: D2-007185, Loc. Ka-31; 23: D2-007199, Loc. Ka-31; 24: D2-008583a, Loc. Og-9; 25: D2-007187, Loc. Ka-31; 26: D2-008149, Loc. Ka-73; 23: $\times 30$, others: $\times 40$.

In regard to the generic and species composition of Schwagerinidae, Neoschwagerinidae, and Verbeekiniidae and their relative dominance there, the Izuru and Nabeyama Formations are largely different from Middle Permian limestones in the Akiyoshi Terrane (Kobayashi, 1997a; 2005; 2006), and somewhat dissimilar to other limestones in the Jurassic terranes of Japan (Kobayashi, 2005; 2006). On the other hand, no remarkable differences are recognized in the faunal composition of schubertellid and ozawainellid fusulinoideans and non-fusulinoidean foraminifers between the Izuru and Nabeyama Formations and other contemporaneous limestones of Japan.

Systematic paleontology

Superfamily Tetrataxioidea Galloway, 1933
 Family Abadehellidae Loeblich and Tappan, 1984
 Genus *Abadehella* Okimura and Ishii in Okimura
et al., 1975

Abadehella sp.

Figures 6.22, 6.23

Material examined.—Illustrated two specimens.

Discussion.—Only two specimens of large-sized *Abadehella* were recognized under the microscopic observation of more than 2,500 limestone thin sections from the Izuru and Nabeyama Formations. Although they are not well-oriented, they are easily distinguished not only from *Abadehella coniformis* Okimura and Ishii in Okimura *et al.*, 1975 but also from most Middle Permian forms of *Abadehella* (Kobayashi, 1996) by their clearly defined secondary platy partitions and large test.

Abadehella sp. is possibly as large as some forms of *Abadehella* of Late Permian age such as *A. iwaiensis* Kobayashi, 1997 described from the limestone pebbles of the Iwai-Kanyo area, Japan (Kobayashi, 1997b) and *A. cf. coniformis* illustrated from the Takhabulak Formation of Southeast Pamir by Kotljar *et al.* (1983). However, the internal reticulate structure of the test, which is produced by the combination of chamber floor and primary and secondary platy partitions, is simpler in the former than in the Late Permian forms.

Superfamily Fusulinoidea von Möller, 1878
 Family Ozawainellidae Thompson and Foster, 1937
 Genus *Rauserella* Dunbar, 1944

*Rauserella ellipsoidal*s Sosnina, 1968

Figures 6.1–6.12

*Rauserella ellipsoidal*s Sosnina, 1968, p. 116, 117, pl. 29, fig. 8.

Material examined.—Illustrated twelve and other specimens.

Discussion.—This species was proposed from the lower Midian *Metadoliolina lepida* Zone of Sikhote-Alin by Sosnina (1968). Although Sosnina pointed out morphologic differences such as size and shape of test and juvenile whorls, and expansion of test between *R. ellipsoidal*s and *R. breviscula* Sosnina, 1968, these differences are not clear in her description and the four specimens she illustrated. The latter also known from the *Metadoliolina lepida* Zone of Sikhote-Alin seems to only represent an incomplete form of the former.

Although the morphologic variation of *Rauserella ellipsoidal*s from Sikhote-Alin is unknown, the Kuzu material is thought to be highly similar to the original material. The Kuzu material shows wide morphologic variation in the number and shape of juvenile whorls, expansion of later whorls, and shape of periphery and lateral sides of the test. By these characters especially of juvenile whorls, this species is easily distinguished from the type species of *Rauserella*, *R. erratica* Dunbar, 1944, described from the Middle Permian of Coahuila, Mexico by Dunbar (1944).

*Rauserella ellipsoidal*s is similar to *Rauserella fuji-motoi* Kobayashi, 1956 proposed by Kobayashi (1956) from the Middle Permian of the Ibukiyama Limestone, but, the former is possibly distinguished from the latter by less tightly coiled juvenile whorls, larger proloculus, and more loosely spaced septa in outer whorls. *Rauserella* sp. A in this paper is tentatively separated from this species by its larger test and more rapidly expanding outer whorls.

Family Schubertellidae Skinner, 1931
 Subfamily Schubertellinae Skinner, 1931
 Genus *Schubertella* Staff and Wedekind, 1910
Schubertella? karasawensis Kobayashi n. sp.

Figures 8.16–8.25

Derivation of name.—From local geographic name, Karasawa, about 4 km NNE of Kuzu, where the upper part of the Nabeyama Formation is well exposed.

Type specimens.—Holotype D2-007350a (axial section, Fig. 8-21). Paratypes D2-007455c (oblique section, Fig. 8-16), D2-007808a (sagittal section, Fig. 8-17), D2-008162b (axial section, Fig. 8-18), D2-008338 (axial section, Fig. 8-19), D2-007875 (axial section, Fig. 8-20), D2-007818 (oblique section, Fig. 8-22), D2-007805b (sagittal section, Fig. 8-23), D2-007874 (tangential section, Fig. 8-24), D2-007958 (oblique section, Fig. 8-25).

Type locality.—Karasawa, Kuzu Town, Sano City, Tochigi Prefecture.

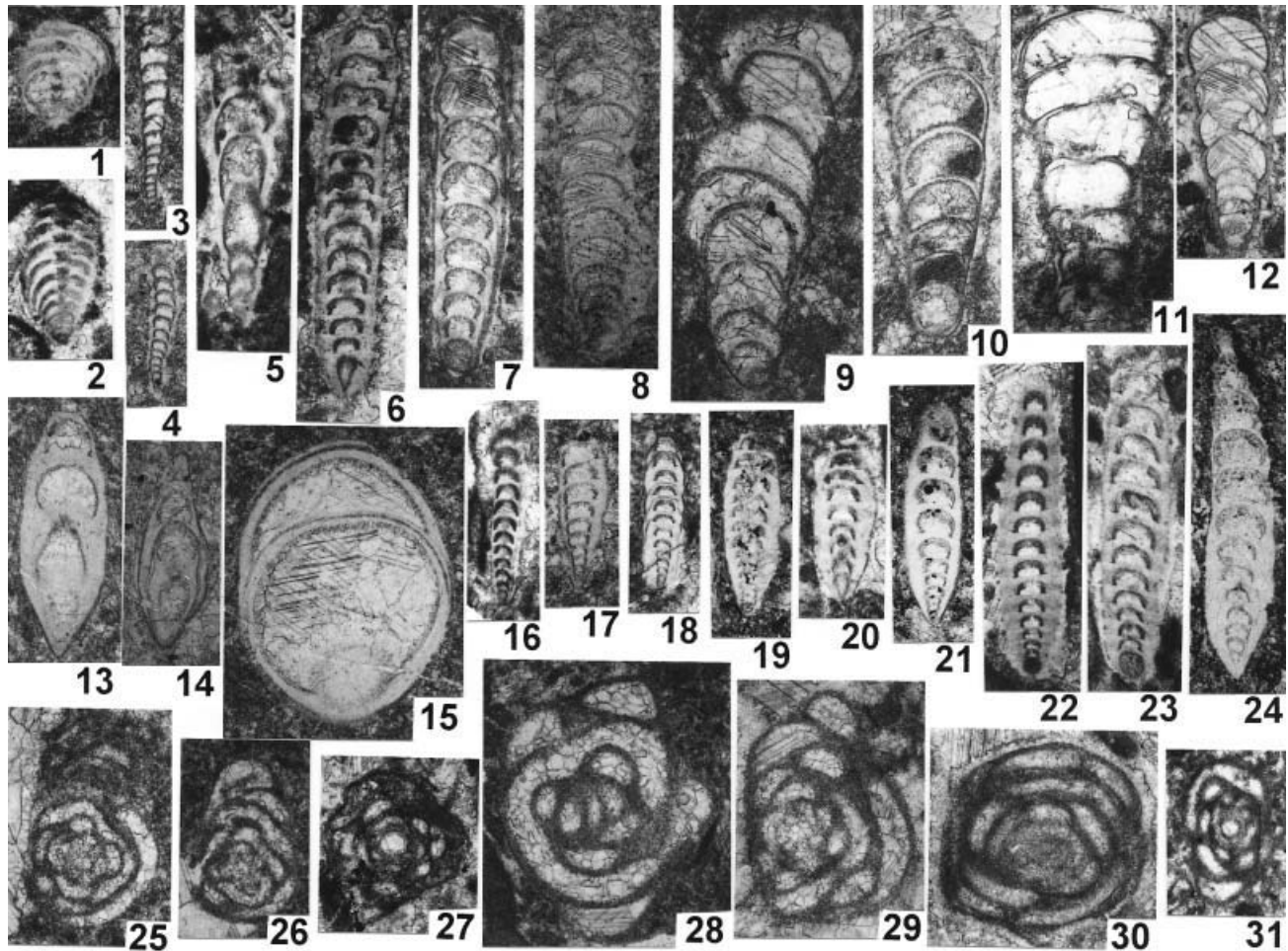


Figure 5. 1, 2. *Geinitzina* sp. B, 1: D2-008194, Loc. Ka-73; 2: D2-007348a, Loc. Ka-40, both $\times 40$. 3, 4. *Nodosinelloides* sp., 3: D2-008309, Loc. Ka-86; 4: D2-006235, Loc. Ya-13, both $\times 40$. 5. *Vervilleina* sp., D2-007323b, Loc. Ka-40, $\times 40$. 6. *Nodosinelloides*? sp. A, D2-007332, Loc. Ka-40, $\times 40$. 7, 8. *Nodosinelloides*? sp. B, 7: D2-007085, Loc. Ka-24; 8: D2-008167, Loc. Ka-73, both $\times 40$. 9–12. Ichthyolariidae? gen. and sp. indet., 9: D2-008331, Loc. Ka-86; 10: D2-007193, Loc. Ka-31; 11: D2-008308, Loc. Ka-86; 12: D2-007808b, Loc. Ka-70, all $\times 40$. 13, 14. Ichthyolariidae gen. and sp. indet., 13: D2-008141, Loc. Ka-73; 14: D2-008289, Loc. Ka-86, both $\times 40$. 15. *Langella*? sp., D2-008189, Loc. Ka-73, $\times 40$. 16–24. *Pachyphloia schwageri* Sellier de Civrieux and Dessauvagie, 1965, 16: D2-007323a, Loc. Ka-40; 17: D2-008186, Loc. Ka-73; 18: D2-007269, Loc. Ka-36; 19: D2-006561, Loc. Ya-32; 20: D2-007366, Loc. Ka-40; 21: D2-006367, Loc. Ka-27; 22: D2-007318, Loc. Ka-40; 23: D2-007310, Loc. Ka-39; 24: D2-006588, Loc. Ya-32, all $\times 40$. 25–27, 31. *Glomospira* sp. A, 25: D2-008495a, Loc. Na-8; 26: D2-007681, Loc. Ka-70; 27: D2-008605, Loc. Og-12; 31: D2-008587, Loc. Og-10, all $\times 40$. 28–30. *Glomospira* sp. B, 28: D2-007745, Loc. Ka-70; 29: D2-007600, Loc. Ka-57; 30: D2-008542, Loc. Og-2, all $\times 40$.

→ **Figure 6.** 1–12. *Rauserella ellipsoidalis* Sosnina, 1968, 1: D2-007301c, Loc. Ka-39; 2: D2-007301d, Loc. Ka-39; 3: D2-007805a, Loc. Ka-70; 4: D2-006210, Loc. Ya-10; 5: D2-007439, Loc. Ka-47; 6: D2-006565, Loc. Ya-32; 7: D2-007880, Loc. Ka-70; 8: D2-007057, Loc. Ka-22; 9: D2-007564a, Loc. Ka-56; 10: D2-007559b, Loc. Ka-55; 11: D2-008540b, Loc. Og-2; 12: D2-006790, Loc. Ka-3, 6–8: $\times 30$; others: $\times 40$. 13. *Rauserella* sp. B, D2-007073, Loc. Ka-24, $\times 30$. 14. *Cornuspira*? sp. A, D2-007686, Loc. Ka-70, $\times 80$. 15, 16. *Cornuspira*? sp. B, 15: D2-006188a, Loc. Ya-7; 16: D2-008579b, Loc. Og-9, both $\times 80$. 17–19. *Abadehella coniformis* Okimura and Ishii in Okimura *et al.*, 1975, 17: D2-008288, Loc. Ka-86; 18: D2-008290, Loc. Ka-86; 19: D2-006792, Loc. Ka-3, all $\times 40$. 20, 21. *Palaeonubecularia*? sp., 20: D2-008209a, Loc. Ka-73, $\times 20$; 21: D2-006209c, Loc. Ka-10, $\times 40$. 22, 23. *Abadehella* sp., 22: D2-007321, Loc. Ka-40; 23: D2-007557a, Loc. Ka-55, both $\times 30$. 24, 44. *Tetrataxis* sp. A, 24: D2-006430, Loc. Ya-30; 44: D2-008583b, Loc. Og-9, both $\times 40$. 25. *Tetrataxis* sp. B, D2-007278, Loc. Ka-36, $\times 20$. 26–43. *Tetrataxis* spp., 26: D2-007346, Loc. Ka-40; 27: D2-007375a, Loc. Ka-41; 28: D2-007367, Loc. Ka-40; 29: D2-006414, Loc. Ya-30; 30: D2-008121, Loc. Ka-72; 31: D2-007110b, Loc. Ka-27; 32: D2-007376a, Loc. Ka-41; 33: D2-007721, Loc. Ka-70; 34: D2-007702, Loc. Ka-70; 35: D2-006163, Loc. Ya-2; 36: D2-007368a, Loc. Ka-40; 37: D2-007368b, Loc. Ka-40; 38: D2-007650, Loc. Ka-70; 39: D2-008557, Loc. Og-4; 40: D2-008106, Loc. Ka-72; 41: D2-008162a, Loc. Ka-73; 42: D2-008107, Loc. Ka-72; 43: D2-008495b, Loc. Na-8; 26, 28, 31, 33, 34: $\times 30$; others: $\times 40$.

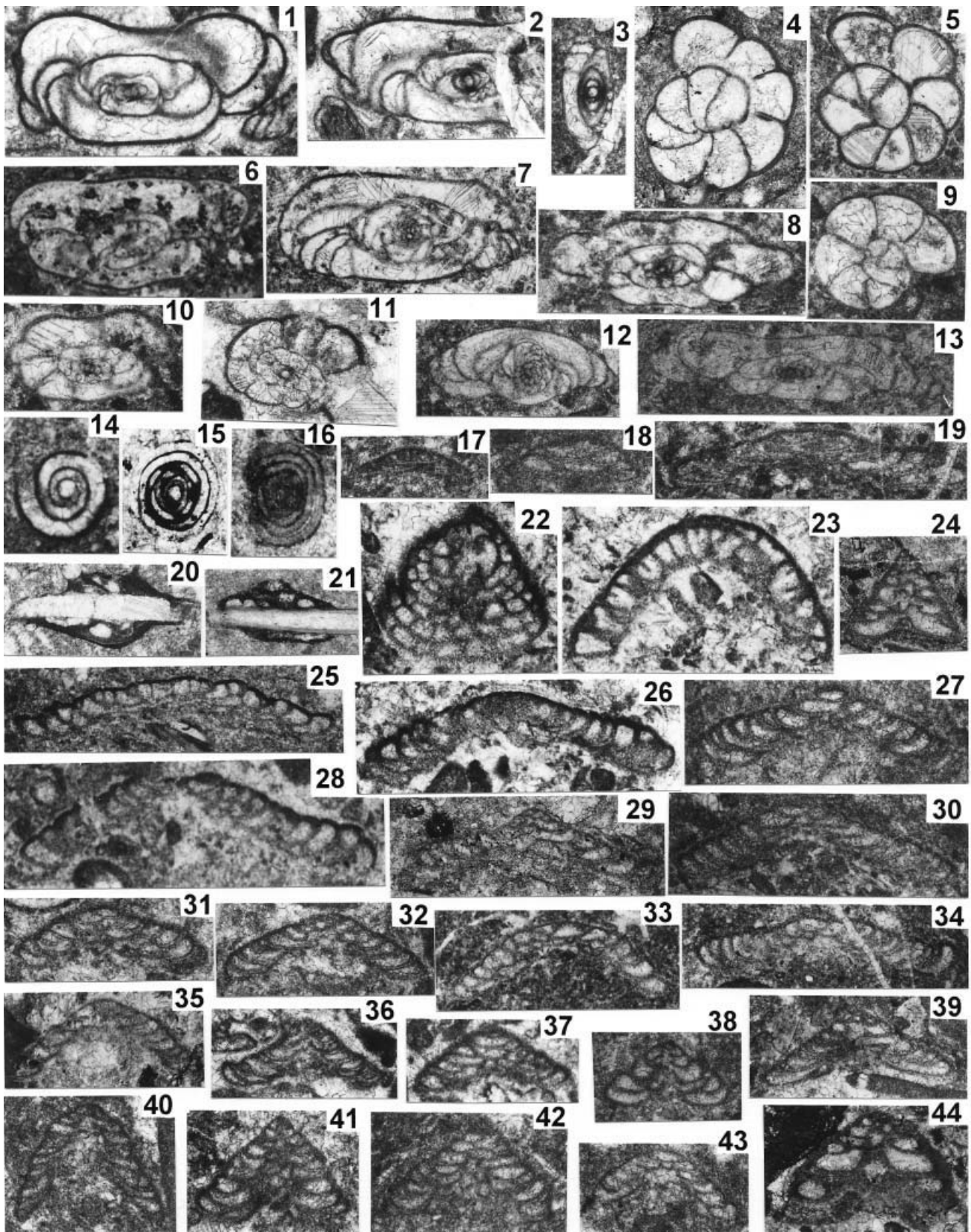


Figure 6.

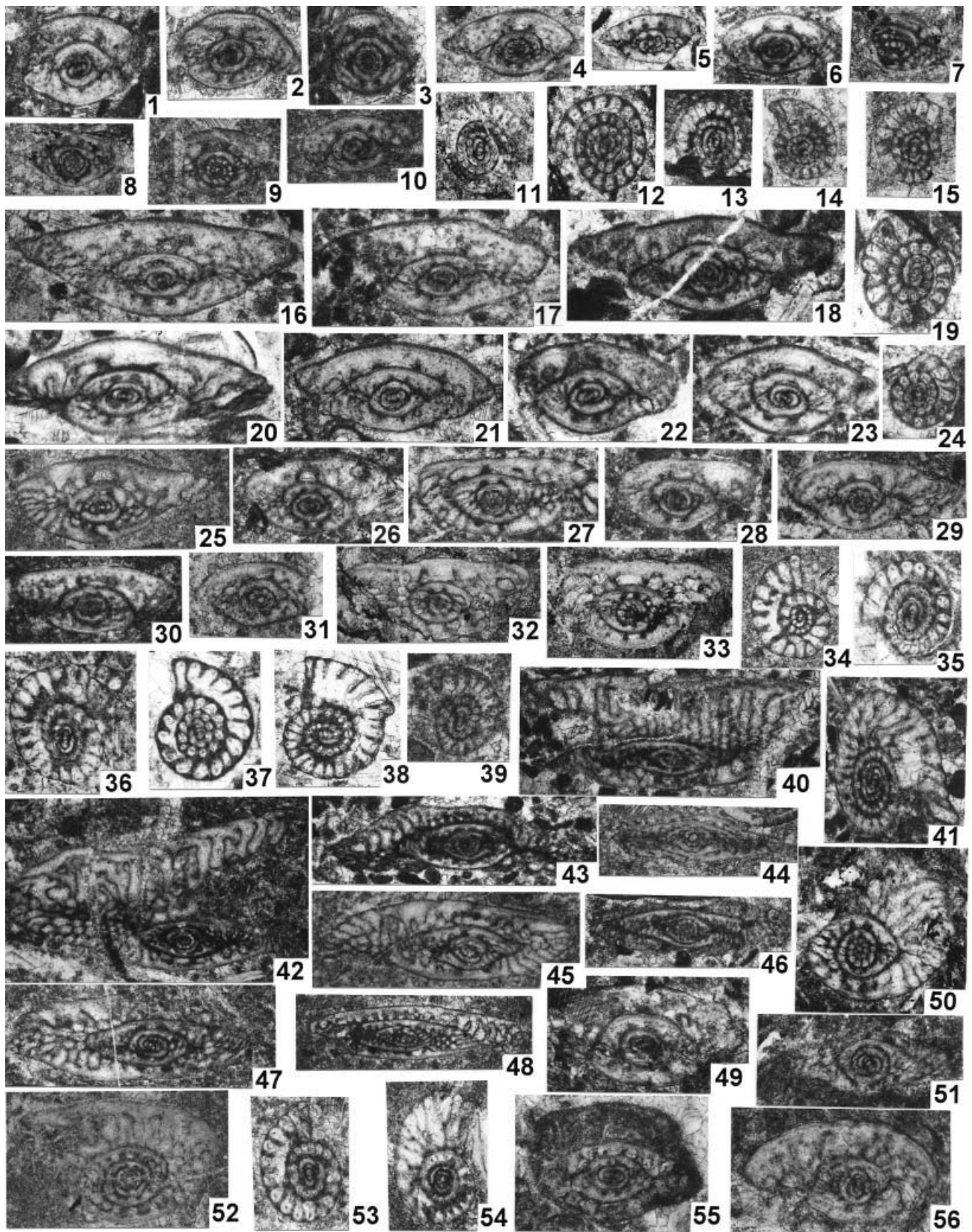


Figure 7.

Diagnosis.—Small schubertellid questionably assignable to *Schubertella* having subspherical test, large proloculus in comparison with small test, thin wall consisting of very thin tectum and protheca-like layer, and massive chomata in outer whorls.

Description.—Test small, subspherical with three to three and a half whorls and shallow umbilical depressions in both sides, about 0.35 to 0.41 mm in length and about 0.30 to 0.35 mm in width, giving an approximate form ratio of 1.0 to 1.3. Proloculus spherical to subspherical, 0.041–0.083 mm in outside diameter. Endothyroid inner one to two whorls followed by planispirally coiled outer subspherical whorls with an abrupt change of axis of coiling.

Wall thin, less than 0.014 mm in its thickest part, and composed of very thin tectum and lower, thicker, less dense layer comparable to protheca in outer whorls. Thickness and development of protheca-like layer are variable in specimens. Septa plane and not fluted throughout test. Septal count in the last whorl about 16. Chomata poorly developed in the endothyroid whorls, becoming massive and well developed in outer whorls. Tunnel narrow, and its path rather irregular.

Material examined.—Illustrated ten and other specimens.

Discussion.—This new species is quite different from the type species and many other species of *Schubertella* known from the Upper Carboniferous to Middle Permian especially in its small subspherical test, fewer whorls, and large proloculus. Although a new generic designation may be possible for this new species, it is assigned questionably to *Schubertella*, because its phylogenetic position cannot be reliably discussed, and the general appearance of the test and inner test structures are most like *Schubertella* among known genera.

Size and construction of the test of this species are much closer to *Neoschubertella* proposed by Saurin

(1962) from the Midian Sisophon Limestone of Cambodia than to typical *Schubertella*. However, points of the generic diagnosis presented by Saurin (1962) such as “acuminate poles” and “very finely porous keriotheca” are not easily recognized in his description and the three specimens he illustrated. It seems to be questionable whether the partly pointed lateral side of the terminal whorl in the specimen shown in pl. 1, fig. 16 of Saurin (1962) is common to most forms of *Neoschubertella*. *Neoschubertella* is thought to be possibly a junior synonym of *Dunbarula* from its chamber arrangement, closely spaced septa with septal pores, and other features.

Schubertella australis Thompson and Miller, 1949, from the Lower Permian of the Maracaibo Basin (Thompson and Miller, 1949) and Slovenia (Ramovš and Kochansky-Devidé, 1965), is closely similar to this species in its small test, large proloculus, and chamber arrangement. The present new species, however, has a distinct protheca-like layer which is absent in the wall of *Schubertella australis*, and a larger test, more whorls, and stouter chomata than does *Schubertella australis*.

***Schubertella? minutisphaera* Kobayashi n. sp.**

Figures 8.26–8.29

Derivation of name.—From the small spherical test of this species, corresponding to Latin combination *minutus* and *sphaera*.

Type specimens.—Holotype D2-007348b (axial section, Fig. 8-26). Paratypes D2-007301b (tangential section, Fig. 8-27), D2-007556c (axial section, Fig. 8-28), D2-007357 (oblique section, Fig. 8-29).

Type locality.—Karasawa, Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Very small spherical schubertellid questionably assigned to *Schubertella* with very thin wall of which differentiation is obscure, tightly coiled

◆ **Figure 7. 1–15.** *Dunbarula oviformis*, n. sp., 1: D2-006783, Loc. Ka-3; 2: D2-008541, Loc. Og-2; 3: D2-008270, Loc. Ka-84; 4: D2-008539, Loc. Og-2; 5: D2-008579a, Loc. Og-9; 6: D2-008136, Loc. Ka-73; 7: D2-006188b, Loc. Ya-7; 8: D2-006491, Loc. Ya-30; 9: D2-007455b, Loc. Ka-47; 10: D2-008290, Loc. Ka-86; 11: D2-006755a, Loc. Ya-10; 12: D2-008584, Loc. Og-9; 13: D2-007868, Loc. Ka-70; 14: D2-008538b, Loc. Og-2; 15: D2-006492, Loc. Ya-30, all $\times 40$. **16–39.** *Dunbarula schubertellaeformis* Sheng, 1958, 16: D2-007558b, Loc. Ka-55; 17: D2-007556b, Loc. Ka-55; 18: D2-007333, Loc. Ka-40; 19: D2-007312, Loc. Ka-40; 20: D2-007307a, Loc. Ka-39; 21: D2-007349, Loc. Ka-40; 22: D2-007338, Loc. Ka-40; 23: D2-007341, Loc. Ka-40; 24: D2-007329b, Loc. Ka-40; 25: D2-007511, Loc. Ka-52; 26: D2-008555, Loc. Og-4; 27: D2-007870, Loc. Ka-70; 28: D2-007564b, Loc. Ka-56; 29: D2-007558c, Loc. Ka-55; 30: D2-006965, Loc. Ka-20; 31: D2-007558a, Loc. Ka-55; 32: D2-006493, Loc. Ya-30; 33: D2-006755b, Loc. Ya-10; 34: D2-007849, Loc. Ka-71; 35: D2-007175, Loc. Ka-31; 36: D2-007557b, Loc. Ka-55; 37: D2-007340a, Loc. Ka-40; 38: D2-007556a, Loc. Ka-55; 39: D2-007175, Loc. Ka-31, all $\times 40$. **40–48.** *Codonofusiella ashioensis*, n. sp., 40: D2-006861a, Loc. Ka-13; 41: D2-006861b, Loc. Ka-13; 42: D2-008180b, Loc. Ka-73; 43: D2-006871a, Loc. Ka-13; 44: D2-007879, Loc. Ka-70; 45: D2-007806, Loc. Ka-70; 46: D2-006871b, Loc. Ka-13; 47: D2-007814, Loc. Ka-70; 48: D2-007802, Loc. Ka-70, 45: $\times 30$; others: $\times 40$. **49–56.** *Codonofusiella nabeyamensis*, n. sp., 49: D2-008163, Loc. Ka-73; 50: D2-006754, Loc. Ya-7; 51: D2-008214, Loc. Ka-78; 52: D2-007455a, Loc. Ka-47; 53: D2-007374c, Loc. Ka-41; 54: D2-007472b, Loc. Ka-49; 55: D2-007329a, Loc. Ka-40; 56: D2-007204, Loc. Ka-33, all $\times 40$.

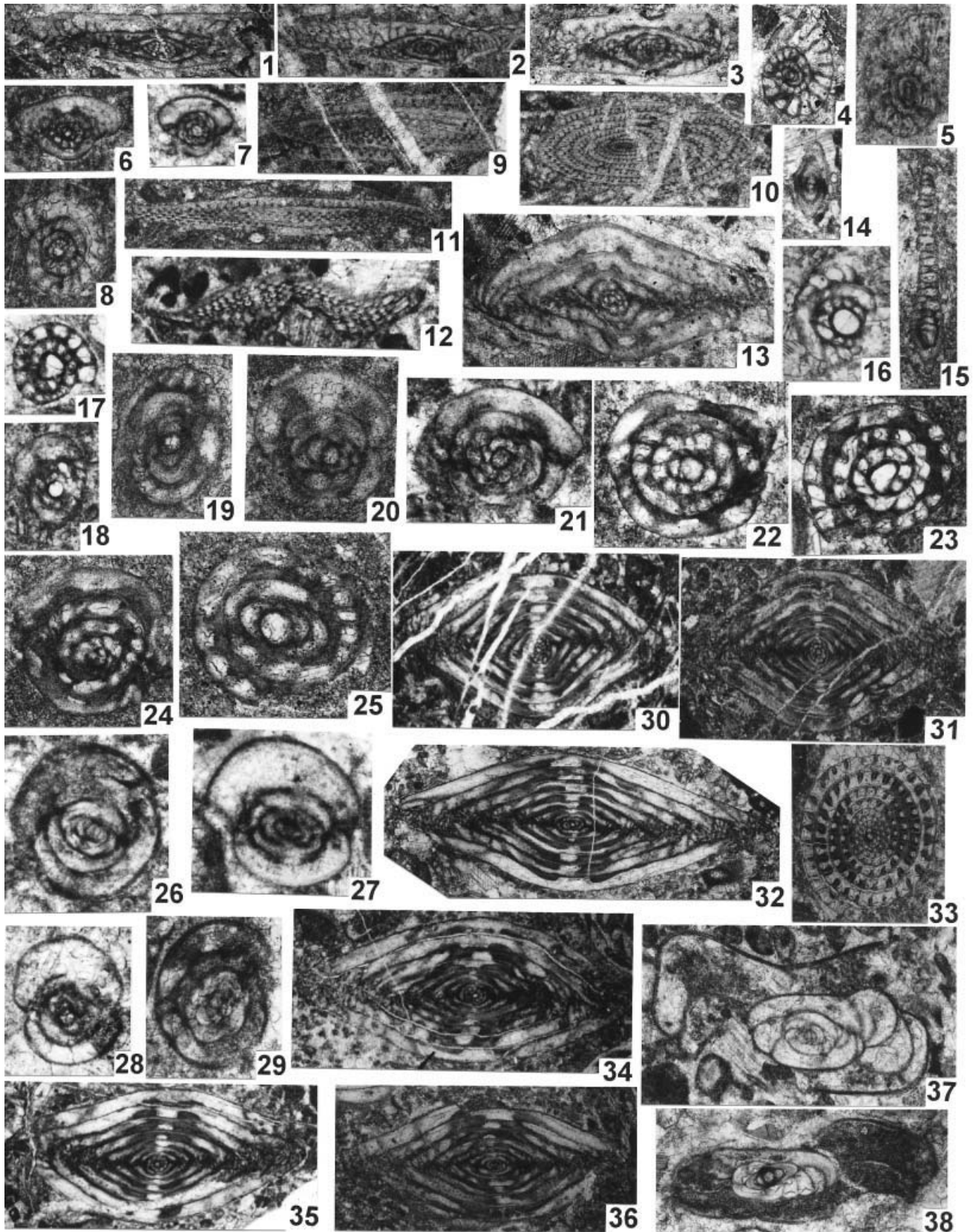


Figure 8.

endothyroid whorls succeeded by loosely coiled nearly spherical whorls, and rudimentary chomata.

Description.—Test very small, nearly spherical, shallowly umbilicated in both sides, consisting of four whorls, about 0.35 mm in length and width. Proloculus spherical, 0.032–0.043 mm in outside diameter. Tightly coiled inner one to two endothyroid whorls followed by rapidly expanding, planispirally coiled, nearly spherical outer whorls with a change of axis of coiling. Wall very thin, less than 0.008 mm in the last whorl, undifferentiated in inner whorls, and composed of very thin tectum and indistinct, lower less dense layer possibly referable to lower tectorium in outer whorls. Septa plane and not fluted. Chomata rudimentary, and discontinuously developed.

Material examined.—Illustrated four specimens.

Discussion.—*Schubertella? minutisphaera* is not similar to any other described species. This new species probably belongs to Schubertellinae based on the ontogenetic development of the test and wall structure, and is thought to be questionably assigned to *Schubertella*. It might be morphologically allied to inflated forms of *Eoschubertella* from simple test construction including small number of whorls and wall structure. Although a new generic designation for the present new species might be possible, it is postponed as in the case of *Schubertella? karasawensis*.

Subfamily Boultoninae Skinner and Wilde, 1954
Genus *Codonofusiella* Dunbar and Skinner, 1937
Codonofusiella ashioensis Kobayashi n. sp.

Figures 7.40–7.48

Derivation of name.—From the Ashio Mountains, where the southern part the Kuzu area is located.

Type specimens.—Holotype D2-008180b (axial section, Fig. 7-42). Paratypes D2-006861a (tangential section, Fig. 7-40), D2-006861b (oblique section, Fig. 7-41), D2-006871a (axial section, Fig. 7-43), D2-007879 (axial section, Fig. 7-44), D2-007806 (tangential section, Fig. 7-45), D2-006871b (axial section, Fig. 7-46),

D2-007814 (axial section, Fig. 7-47), D2-007802 (tangential section, Fig. 7-48).

Type locality.—Karasawa, Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Medium-sized *Codonofusiella* having strongly fluted septa reaching the top of the chamber, and rapidly expanding last whorl, the uncoiled terminal portion of which becomes rectilinear and is larger than inner coiled whorls.

Description.—Test small, up to about 1.4 mm in length. Proloculus minute. First one to two whorls with short axis of coiling, tightly and planispirally coiled, then followed by two to three elongate fusiform whorls with a sharp change of axis of coiling. Outermost whorl rapidly increasing its length and width, finally becoming uncoiled and rectilinear. Uncoiled flaring portion larger than inner coiled whorls.

Wall thin, undifferentiated in early whorls, consisting of thin tectum and thicker less dense translucent layer referable to protheca in later whorls. Septa thin and strongly fluted, septal folds usually reaching top of chamber in outer fusiform whorls, and in contact with top of chamber in uncoiled part. Chomata present but not always distinct. Narrow tunnel well defined in fusiform whorls.

Material examined.—Illustrated nine and other specimens.

Discussion.—*Codonofusiella paradoxica* Dunbar and Skinner, 1937 originally described from the Capitan Limestone of west Texas (Dunbar and Skinner, 1937) most resembles this new species in expansion of test and septal fluting in both coiled and uncoiled whorls. However, the latter differs by the presence of chomata and larger form ratio in the fusiform whorls. This new species resembles *Codonofusiella tenuissima* Sheng, 1956, proposed from the Wuchiapingian Limestone of Shaanxi by Sheng (1956), in having larger uncoiled terminal whorl and mode of septal fluting, but the former has a larger test and more whorls than the latter.

By its more loosely spaced, less strongly, and less

◆ **Figure 8.** 1–5. *Codonofusiella elongata*, n. sp., 1: D2-008578, Loc. Og-9; 2: D2-006661, Loc. Ya-39; 3: D2-006666, Loc. Ya-39; 4: D2-008575, Loc. Og-9; 5: D2-008534a, Loc. Og-2, all $\times 40$. 6–8. *Dunbarula pseudosimplex* (Sheng, 1958), 6: D2-007422, Loc. Ka-47; 7: D2-007351, Loc. Ka-40; 8: D2-008168b, Loc. Ka-73, all $\times 50$. 9–11. *Wutuella* sp., 9: D2-006202, Loc. Ya-9, 40; 10: D2-006756, Loc. Ya-15, $\times 20$; 11: D2-007054, Loc. Ka-22, $\times 30$. 12. *Paradoxiella* sp., D2-007301a, Loc. Ka-39, $\times 30$. 13. *Neofusulinella* sp., D2-008580, Loc. Og-9, $\times 40$. 14, 15. *Reichelina* sp., 14: D2-006861c, Loc. Ka-13; 15: D2-007816, Loc. Ka-70, both $\times 50$. 16–25. *Schubertella? karasawensis*, n. sp., 16: D2-007455c, Loc. Ka-47; 17: D2-007808a, Loc. Ka-70; 18: D2-008162b, Loc. Ka-73; 19: D2-008338, Loc. Ka-86; 20: D2-007875, Loc. Ka-70; 21: D2-007350a, Loc. Ka-40; 22: D2-007818, Loc. Ka-70; 23: D2-007805b, Loc. Ka-70; 24: D2-007874, Loc. Ka-70; 25: D2-007958, Loc. Ka-71, all $\times 80$. 26–29. *Schubertella? minutisphaera*, n. sp., 26: D2-007348b, Loc. Ka-40; 27: D2-007301b, Loc. Ka-39; 28: D2-007556c, Loc. Ka-55; 29: D2-007357, Loc. Ka-40, all $\times 80$. 30–36. *Yangchienia compressa* (Ozawa, 1927), 30: D2-006788; 31: D2-007001; 32: D2-006988; 33: D2-007052; 34: D2-006984; 35: D2-006983; 36: D2-006989, 30: Loc. Ka-3; others: Loc. Ka-21, all $\times 20$. 37, 38. *Rausserella* sp. A, 37: D2-007304, Loc. Ka-39, $\times 30$; 38: D2-008536c, Loc. Og-2, $\times 40$.

regularly fluted septa and smaller test, *Codonofusiella ashioensis* is easily distinguished from forms described from the upper Guadalupian (Midian) of Japan, such as *Codonofusiella cuniculata* Kanmera, 1954 from the Kuma Formation (Kanmera, 1954), *Paraboultonia inuboensis* Chisaka, 1960 from Choshi (Chisaka, 1960), and *Codonofusiella inuboensis* (Chisaka) from Southern Kitakami (Choi, 1970). These three forms are thought to be assignable to *Lantschichites* Tuman-skaya, 1953, and the latter two are junior synonyms of *Lantschichites cuniculata* (Kanmera), as discussed by Kobayashi (2001).

***Codonofusiella elongata* Kobayashi n. sp.**

Figures 8.1–8.5

Derivation of name.—From the elongated test of this species.

Type specimens.—Holotype D2-008578 (axial section, Fig. 8-1). Paratypes D2-006661 (axial section, Fig. 8-2), D2-006666 (axial section, Fig. 8-3), D2-008575 (sagittal section, Fig. 8-4), D2-008534a (sagittal section, Fig. 8-5).

Type locality.—Ohgama, Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Primitive species of *Codonofusiella* with elongate test, very thin wall, not so strongly fluted septa, and poorly developed uncoiled terminal part of the last whorl.

Description.—Test small, elongate fusiform to sub-cylindrical, more than 1.2 mm in length, 0.55 mm or more in width in the uncoiled part, and about 0.32 mm in width in the coiled part. Proloculus minute, inner one to two whorls tightly coiled with short axis of coiling. After a sharp change of axis of coiling, the following whorls become fusiform, abruptly increasing their form ratio. Height of whorls rapidly increasing in the last whorl, and finally becoming uncoiled in its terminal part in specimens.

Wall very thin, obscure in its differentiation, appears to be of a single dense layer in most specimens. Thin translucent layer partly accompanied by dense layer in some specimens. Septa also very thin and strongly fluted in polar regions, weakly fluted or plane in tunnel regions. Septal folds sometimes reaching top of chamber in polar regions of last whorl. Irregular narrow tunnel bordered by indistinct low chomata.

Material examined.—Illustrated five and other specimens.

Discussion.—Because of poor development of an uncoiled terminal whorl, this new species appears to be allied to *Boultonia* Lee, 1927 or an elongate form of *Dunbarula* Ciry, 1948 in thin sections cut away

from the uncoiled part of the last whorl. Although some *Codonofusiella elongata* also seem to be related to a form of *Codonofusiella ashioensis* lacking an outermost uncoiled whorl, these two new species are distinguished by the thinner wall, more weakly and irregularly fluted septa, and less distinct uncoiled terminal part of the last whorl in the former.

Codonofusiella elongata is thought to be a primitive representative of *Codonofusiella* based on its indistinct uncoiled last whorl and relatively weakly fluted septa in comparison with most species of the genus. Specimens definitely identical with this new species occur only in the lower part of the Nabeyama Formation.

***Codonofusiella nabeyamensis* Kobayashi n. sp.**

Figures 7.49–7.56

Derivation of name.—From the local geographic name Nabeyama in the Kuzu area. The name is also applicable to the formation name.

Type specimens.—Holotype D2-007329a (axial section, Fig. 7-55). Paratypes D2-008163 (axial section, Fig. 7-49), D2-006754 (oblique section, Fig. 7-50), D2-008214 (axial section, Fig. 7-51), D2-007455a (axial section, Fig. 7-52), D2-007374c (sagittal section, Fig. 7-53), D2-007472b (sagittal section, Fig. 7-54), D2-007204 (axial section, Fig. 7-56).

Type locality.—Karasawa, Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Elongate nautiloid to oval *Codonofusiella*, having strongly and rather regularly fluted septa commonly reaching the top of the chamber in the outermost uncoiled whorl, without which this new species is similar to and not easily distinguishable from an oval *Dunbarula*.

Description.—Test small, elongate nautiloid to oval, more than 0.9 mm in length, more than 0.6 mm in width, and consisting of five whorls. Proloculus minute, about 0.04 mm in outside diameter. Inner two whorls tightly coiled with short axis of coiling, and, by a sharp change of axis of coiling, the succeeding two whorls become fusiform and gradually increase their height and width. Height of whorl rapidly increasing in the last one, and becoming uncoiled in its terminal part.

Wall thin, consisting of thin tectum and lower, thicker less dense translucent layer in fusiform and uncoiled whorls. Septa thin and strongly and rather regularly fluted. Septal folds commonly reach the top of the chamber in the terminal whorl. Tunnel narrow, bordered by chomata in fusiform whorls.

Discussion.—Identification with this new species

needs more thin sections and more careful microscopic observation than with other species of *Codonofusiella* in the Nabeyama Formation, because it may be erroneously assignable to *Dunbarula* on account of the indistinct flaring tip of the terminal whorl, septal fold of fusiform whorls closely similar to *Dunbarula*, and inflated fusiform to elliptic outline in sections cut away from the uncoiled part of this new species.

Among the described species, the present new species most resembles *Dunbarula schubertellaeformis* Sheng, 1958 originally described from the Maokou Limestone of Qinghai (Sheng, 1958) in many respects. Differences are not easily recognized between some axial sections of this new species lacking the terminal whorl and *D. schubertellaeformis* having a rapidly expanding terminal whorl and showing an inflated fusiform outline. In addition to the uncoiled terminal whorl, *Codonofusiella nabeyamensis* might be distinguished from *D. schubertellaeformis* by its more strongly fluted septal folds that commonly reach the roof of the chamber in the terminal whorl.

Genus *Dunbarula* Ciry, 1948
Dunbarula oviformis Kobayashi n. sp.

Figures 7.1–7.15

Derivation of name.—From the egg-shaped test of this species.

Type specimens.—Holotype D2-006783 (axial section, Fig. 7-1). Paratypes D2-008541 (axial section, Fig. 7-2), D2-008270 (axial section, Fig. 7-3), D2-008539 (axial section, Fig. 7-4), D2-008579a (axial section, Fig. 7-5), D2-008136 (axial section, Fig. 7-6), D2-006188b (axial section, Fig. 7-7), D2-006491 (axial section, Fig. 7-8), D2-007455b (axial section, Fig. 7-9), D2-008290 (axial section, Fig. 7-10), D2-006755a (sagittal section, Fig. 7-11), D2-008584 (sagittal section, Fig. 7-12), D2-007868 (sagittal section, Fig. 7-13), D2-008538b (sagittal section, Fig. 7-14), D2-006492 (sagittal section, Fig. 7-15).

Type locality.—Karasawa, Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Small, egg-shaped *Dunbarula* with minute initial one to two whorls succeeded by rapidly expanding inflated fusiform whorls, very thin wall and septa, septal pore in outer whorls, and weakly fluted septa in polar regions.

Description.—Test small, less than 0.65 mm in length, less than 0.42 mm in width, broadly arched periphery, convex to nearly straight lateral sides, and rounded poles, and consisting of four whorls. Proloculus minute, 0.028 to 0.036 mm in its outside diame-

ter. Tightly coiled inner one to two whorls succeeded, with a sharp change of axis of coiling, by rapidly expanding inflated fusiform whorls, the outermost of which is roughly as high as the inner three ones.

Wall less than 0.01 mm in its thickest part, consisting of tectum and lower less dense translucent layer referable to protheca in outer whorls. Septa very thin, weakly fluted in polar regions of the last whorl, and plane and not fluted in median part of test. Septal pore well developed in outer whorls. Number of septa 17 to 19 in the last whorl. Tunnel narrow, bordered by distinct to rudimentary chomata in fusiform whorls.

Discussion.—*Dunbarula oviformis* is the closest to *Dunbarula nana* originally described from Slovenia (Kochansky-Devidé and Ramovš, 1955) in its small test, test form, weakly fluted septa in polar regions, and other features. The former, however, has a smaller test, more rapidly expanding outer whorls, and thinner wall than the latter. It is different from *Dunbarula simplex* (Lange, 1925) and *Dunbarula pseudosimplex*, originally described from the Middle Permian limestone of Padang in Sumatra (Lange, 1925) and Qinghai in northwest China (Sheng, 1958), respectively, by its more distinctly fluted septa and more rapidly expanding test.

Inner whorls of *Dunbarula oviformis* and *D. schubertellaeformis* are closely similar to each other, and they are not strictly distinguishable in the Nabeyama Formation when their outer whorls are not preserved. However, *D. schubertellaeformis* has a larger form ratio in the corresponding whorls, and a more rapidly expanding length and width than *D. oviformis*. Based on these differences, *Dunbarula oviformis* is proposed as a new species of *Dunbarula* herein.

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