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Middle Permian foraminifers of the Izuru and Nabeyama Formations in the Kuzu area, Tochigi Prefecture, Japan Part 1. Schwagerinid, neoschwagerinid, and verbeekinid fusulinoideans

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Abstract. **The Middle Permian Izuru and Nabeyama Formations in the Kuzu area, Tochigi Prefecture are composed of thick basaltic rocks and fossiliferous partly dolomitized limestone. Fusulinoidean biostratigraphy is first established in these two formations, and the stratigraphic distribution of the 30 species of fusulinoideans distinguished from 70 localities is shown. The Izuru and Nabeyama Formations are biostratigraphically subdivided into the lower *Parafusulina nakamigawai*, the middle *Parafusulina yabei*, and the upper *Parafusulina tochigiensis* zones. The first zone is correlated to the *Parafusulina nakamigawai* Zone of the basal part of the Akasaka Limestone. The middle part of the third zone corresponds to the upper part of the *Neoschwagerina craticulifera* Zone to the lower part of the *Neoschwagerina margaritae* Zone of the Akasaka Limestone based on the occurrence of *Gifuella amicula*. More precise correlation of the *Parafusulina yabei* and *Parafusulina tochigiensis* zones will be possible when biostratigraphic zonation by schwagerinids is made clear in relation to the stratigraphic range of neoschwagerinids in Middle Permian limestones of the Jurassic terrane of Japan. Seven species of *Parafusulina* including two new species, *P. shimotsukensis* and *P. tochigiensis*, and *Pseudodoliolina ozawai* and *Gifuella gifuensis* are described and discussed herein.**

Key words: biostratigraphy, fusulinoideans, Izuru and Nabeyama Formations, Kuzu area, Middle Permian

Introduction

The Nabeyama Formation in the Kuzu area, Tochigi Prefecture, is designated as the standard chronostratigraphic unit of the lower Middle Permian of Japan (Nabeyaman) on account of the abundant occurrence of well preserved fusulinoideans (Toriyama, 1967). Several species of *Parafusulina* were described from the lower part of the formation (Hanzawa, 1942; Morikawa and Takaoka, 1961; Igo, 1964; Chisaka and Fuse, 1973) and the underlying Izuru Formation (Morikawa and Horiguchi, 1956). However, the stratigraphic distribution of these parafusulinids and other fusulinoideans in these two formations has remained uncertain.

This paper shows the stratigraphic distribution of fusulinoideans in the formations, and discusses the faunal composition in the established three zones from lower to upper: *Parafusulina nakamigawai*, *P. yabei*, and *P. tochigiensis* zones. Nine species of schwagerinid, neoschwagerinid, and verbeekinid fusulinoideans, including two new species of *Parafusulina*, *P. shimotsukensis* and *P. tochigiensis*, are described. Many photographs of parafusulinids are illustrated so as to understand their wide morphologic variation. Schubertellid and ozawainellid fusulinoideans and non-fusulinoidean foraminifers of the Izuru and Nabeyama Formations will be described and discussed in future.

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

Stratigraphy

Jurassic accretionary complexes in the Ashio Mountains consist of tectonically repeated stratigraphic sequences of Triassic to Jurassic chert and Jurassic terrigenous clastic rocks, and contain huge blocks of Upper Paleozoic limestone and basaltic rocks in the

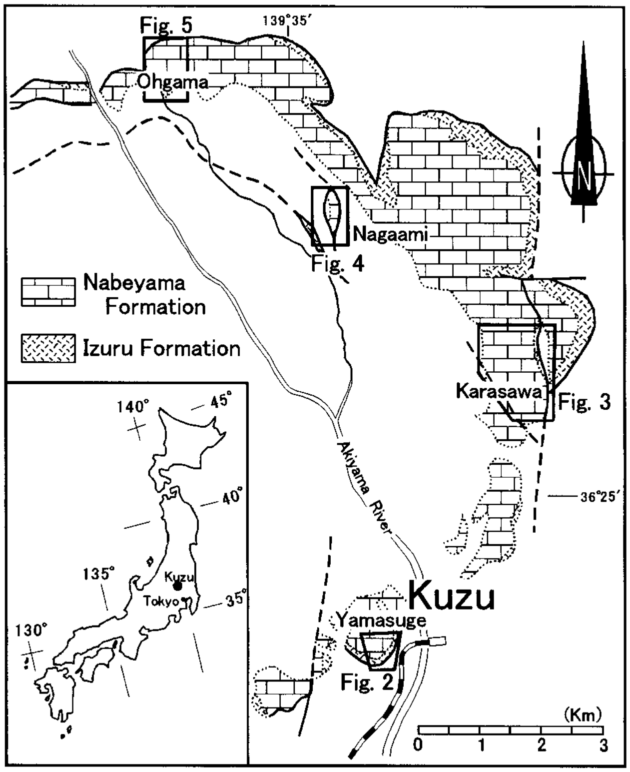

Figure 1. Index map showing the surveyed area and distribution of Nabeyama and Izuru Formations in the Kuzu area.

Kuzu area in the southern part of the mountains (e.g., Kamata, 1996; 1997). These rocks had been thought to be Permian by the end of 1960's, and were originally classified from lower to upper into the Aisawa, Nabeyama, Adoyama, Maki, and Mikagura formations in the Kuzu area (Yoshida, 1956; 1957). Fujimoto (1961) redefined the Nabeyama Formation by establishing the Izuru Formation and subdivided the newly defined Nabeyama Formation into three members, the lower Yamasuge Limestone, middle Hanezuru Dolostone, and upper Karasawa Limestone. The Izuru and Nabeyama formations are laterally traceable for more than 20 km, showing a horseshoe-shaped outline (Figure 1).

The Izuru Formation is about 400 m in its maximum thickness and is in thrust contact with the Jurassic siliciclastic rocks assiganble to the Aisawa Formation (Koike *et al.*, 1971). It consists mostly of basaltic pyroclastic rocks and lava. Lenticular limestones are intercalated within pyroclastic rocks in the upper part. They are dark gray, bedded, tuffaceous, and partly dolomitized. Many fossils such as crinoids, foraminifers, marine algae, sponges, brachiopods, and bryozoans are abundant in them. Some of these fossils also occur in pyroclastic rocks.

The Nabeyama Formation consists of limestone, dolomitic limestone, and dolostone of about 300 m thickness measured at Yamasuge (Figure 2), Karasawa (Figure 3), Nagaami (Figure 4), and Ohgama (Figure 5). Lenticular pyroclastic rocks are intercalated in its lower part. Although the formation is not lithostratigraphically subdivided, it is correlated on the basis of the stratigraphic boundary between the Izuru and Nabeyama Formations as done by Kobayashi (1979) (Figure 6).

Limestones of the lower part of the formation are mostly dark gray and bedded. They are partly laminated, interbedded with thin tuffaceous and calcareous argillaceous rocks, and contain nodular chert. These limestones consist of dominant packstone, wackestone, and lime-mudstone, and subordinate oncoidal boundstone/framestone and grainstone. Some of them are secondarily dolomitized, and the post-depositional dolomitization becomes conspicuous stratigraphically upwards (Kobayashi, 1979). The middle part of the Nabeyama Formation consists mostly of dolostone (Figure 6). The upper part of the Nabeyama Formation is composed mainly of light gray to dark gray massive limestones. They consist of dominant fusulinoidean packstone and accessary wackestone, lime-mudstone, grainstone, oncoidal boundstone/framestone, and cerioid coral boundstone.

Fossils are diversified and abundant in limestones of the Nabeyama Formation, such as foraminifers, especially large-sized fusulinoideans, marine algae, crinoids, sponges, hydrozoans, rugose corals, bryozoans, brachiopods, bivalves, gastropods, and ostracods. They are dolomitized variously in the lower part of the formation (Kobayashi, 1979). Fusulinoideans, crinoids, brachiopods, and other indeterminable fossils are nearly completely replaced by mosaic dolomite in the middle part of the formation.

The limestone conglomerate unconformably overlying the Nabeyama Formation consists of ill-sorted granules to boulders of limestone, dolomitic limestone, dolostone, and chert, which are packed within laminated, arenaceous to argillaceous limestone. Most of these lithic clasts were derived from the Nabeyama Formation. Pebbles to boulders of Middle to Late Permian limestone are also discriminated in this limestone conglomerate (Igo and Igo, 1977; Kobayashi, 1979). The laminated limestone originated from the karst deposits fills up the crevices of dolostone and limestone in the middle and upper parts of the formation, showing several millimeter- to centimeter-order depositional sequences with upward-fining successions

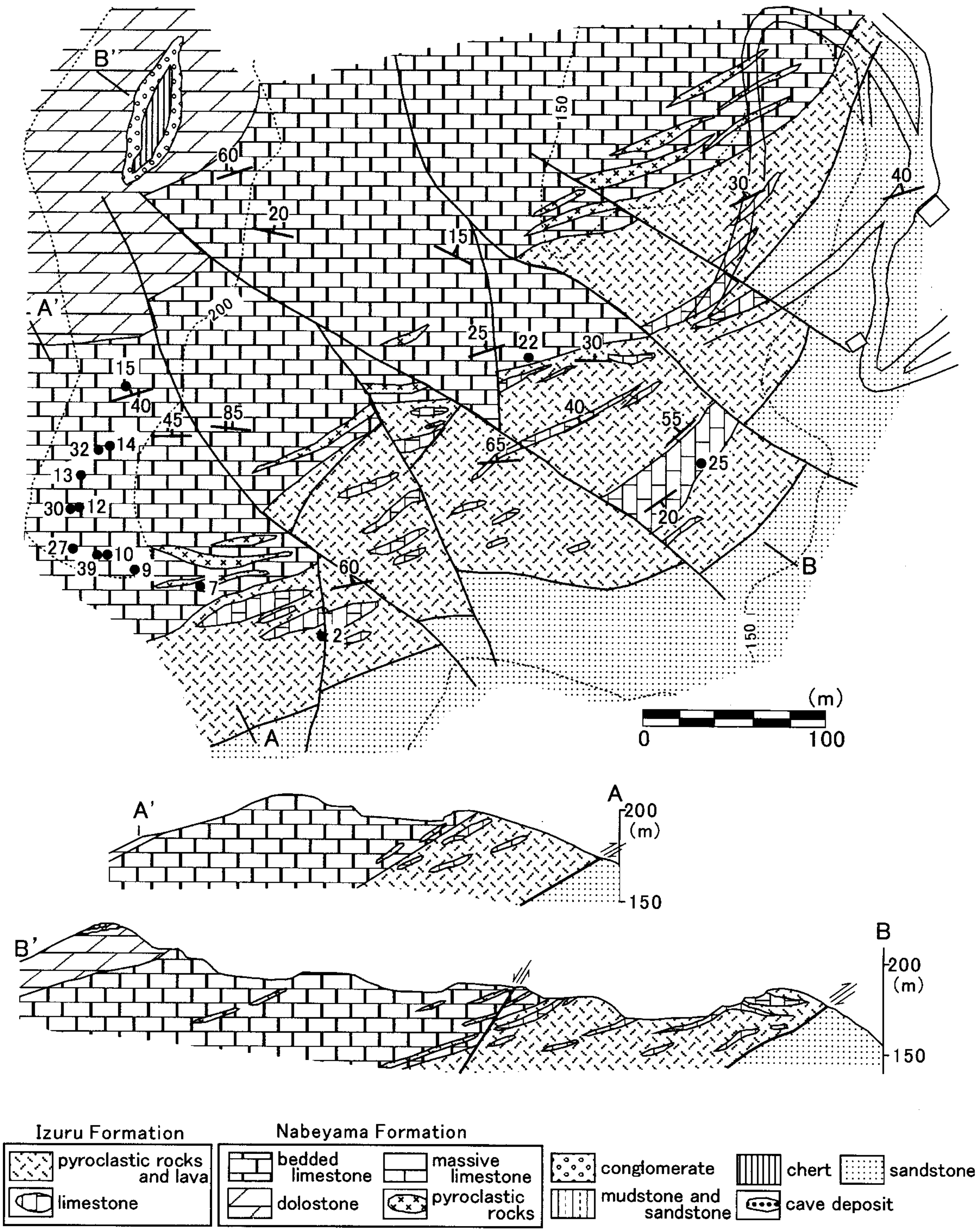

Figure 2. Geological map and sample localities in Yamasuge.

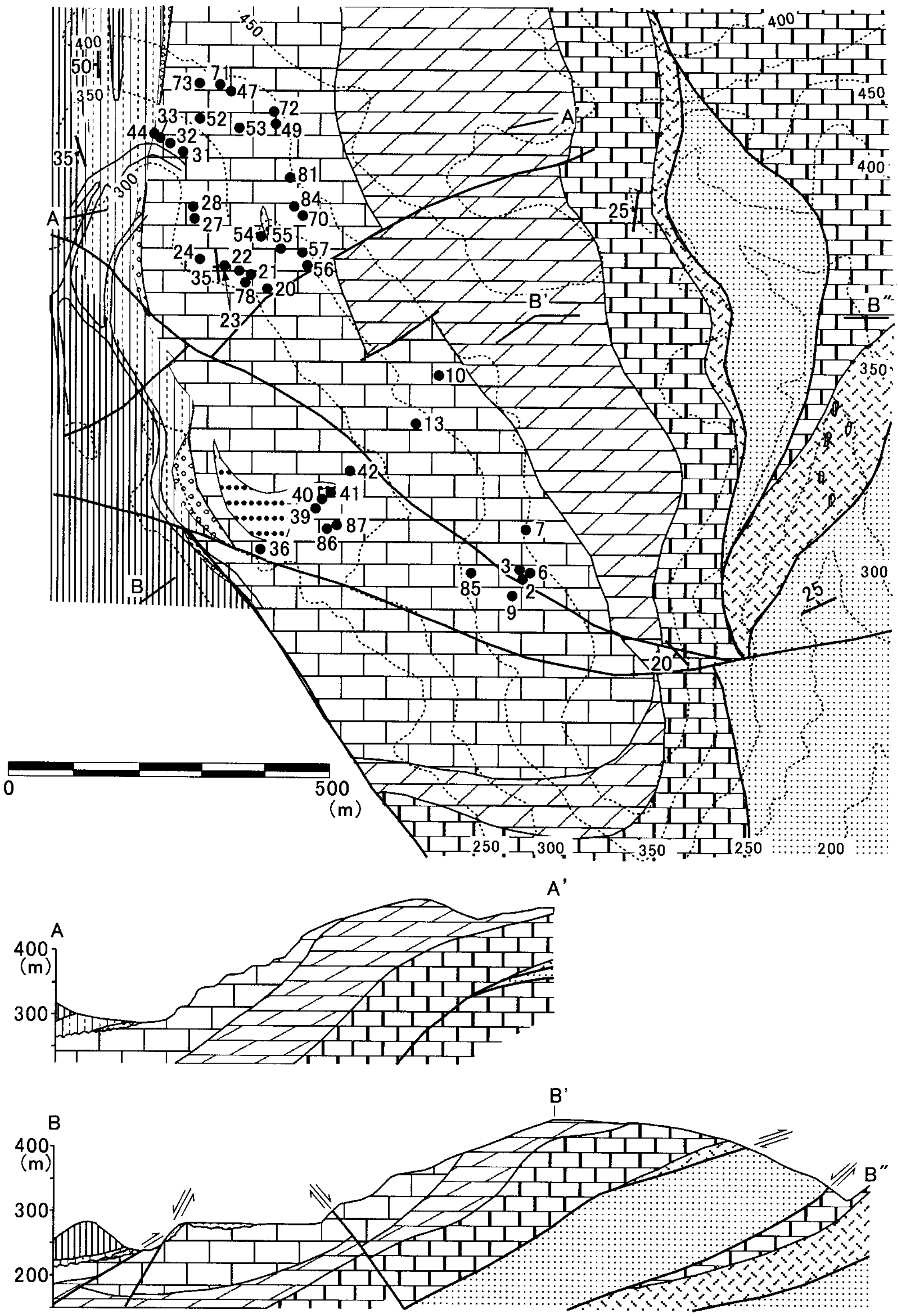

Figure 3. Geological map and sample localities in Karasawa. Legend of lithology is the same as in Figure 2.

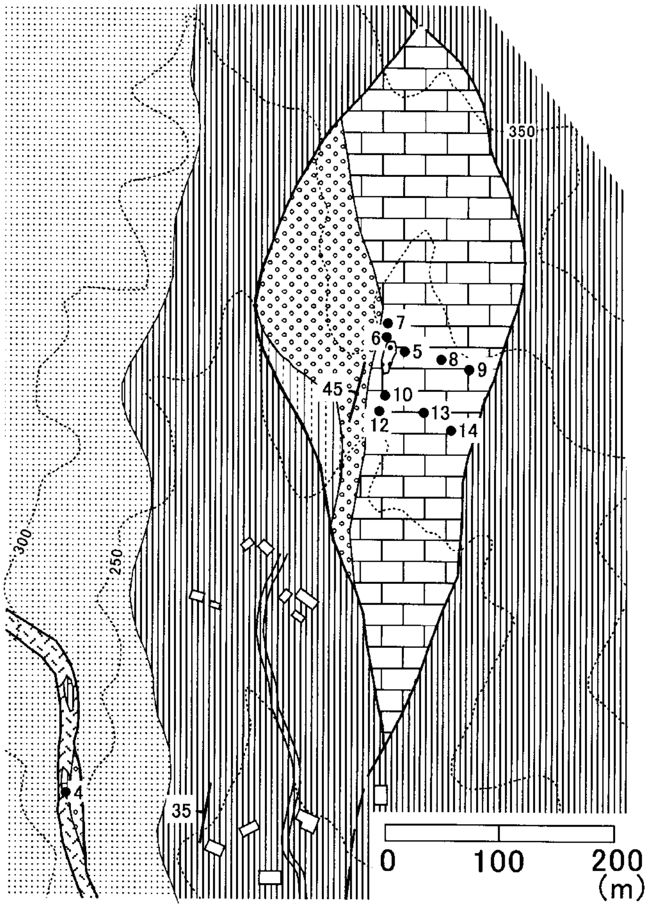

Figure 4. Geological map and sample localities in Nagaami. Legend of lithology is the same as in Figure 2.

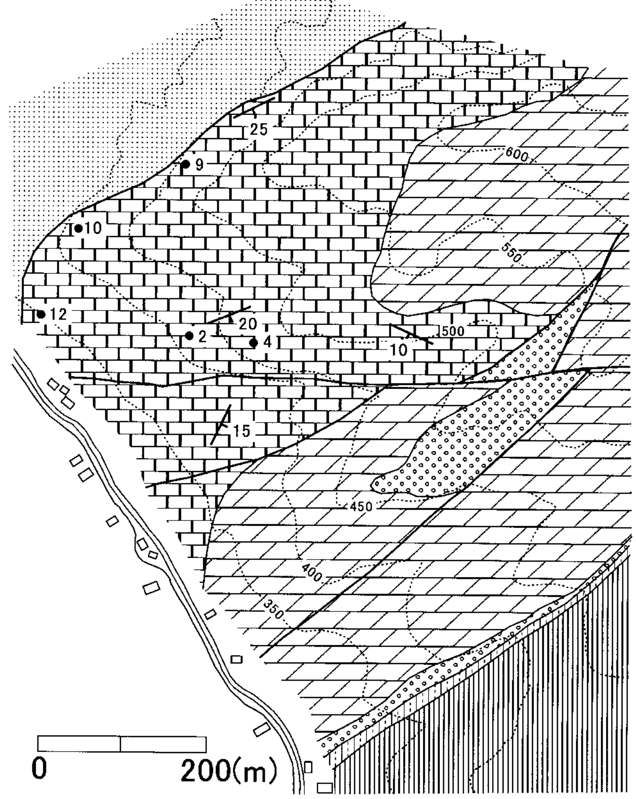

Figure 5. Geological map and sample localities in Ohgama. Legend of lithology is the same as in Figure 2.

(Kobayashi, 1979). A mixed fauna of late Olenekian to early Norian conodonts is reported from these laminated limestones (Koike *et al.*, 1974).

Biostratigraphy

Three fusulinoidean zones are distinguished from lower to upper: the *Parafusulina nakamigawai*, *Parafusulina yabei*, and *Parafusulina tochigiensis* zones, based on their stratigraphical distribution in the Izuru and Nabeyama Formations (Figure 6). Biostratigraphic subdivision by other foraminifers is inferior to these parafusulinids.

Parafusulina nakamigawai Morikawa and Horiguchi, 1956 is found only in impure limestone and pale green basaltic tuff at Loc. 4 in Nagaami (Figure 4) in association with *Parafusulina* sp., which occurs in two levels of the Izuru Formation in Yamasuge. The *Parafusulina nakamigawai* Zone is assigned to the Izuru Formation except for its uppermost part where *Parafusulina yabei* Hanzawa, 1942 first occurs. Other fusulinoideans such as *Dunbarula*? sp. and *Rauserella*? sp. are exceedingly rare in this zone.

The base of the *Parafusulina yabei* Zone is defined at Yamasuge by the first occurrence of *Parafusulina yabei* in the uppermost part of the Izuru Formation. The top of this zone corresponds to the level of the first occurrence of *Parafusulina tochigiensis* in Ohgama (Figure 6). This zone represents the bedded limestone of the lower part of the Nabeyama Formation. *Parafusulina yabei* is very characteristic and abundant in this zone along with *Parafusulina kuzuensis* Chisaka and Fuse, 1973. In addition to these two species of *Parafusulina*, *Rauserella ellipsoidalis* Sosnina, 1968, *R.* sp. A, *Dunbarula schubertellaeformis* Sheng, 1958, *D.* sp. A, *Codonofusiella* sp. B, *C.* sp. C and *Neofusulinella* sp. are discriminated in this zone. The occurrence of the latter two species is restricted to this zone. The former five species also occur in the *Parafusulina tochigiensis* Zone. Neither verbeekinid nor neoschwagerinid fusulinoideans are detected from this zone.

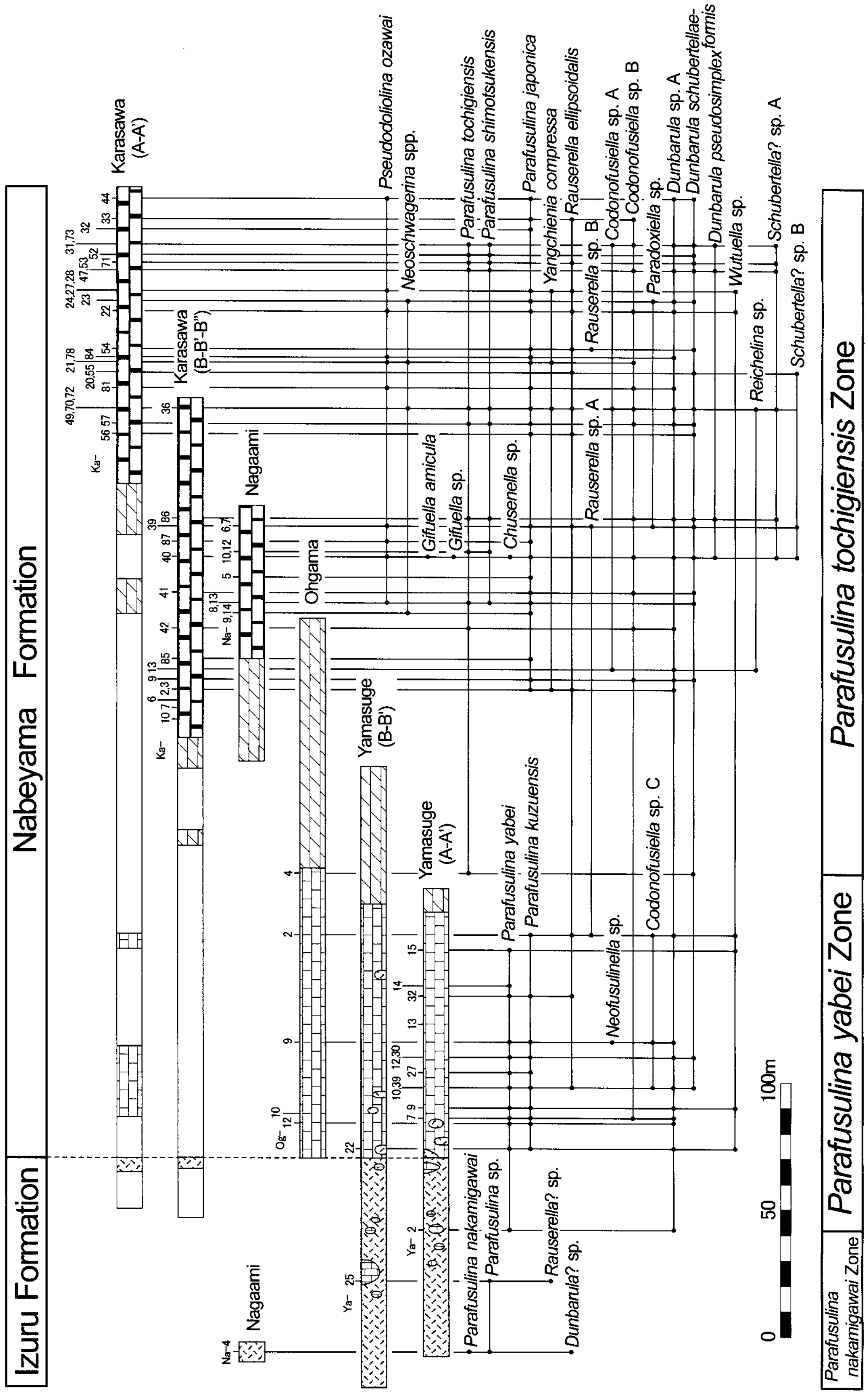

Figure 6. Stratigraphic columns (after Kobayashi, 1979), stratigraphic distribution of fusulinoideans, and biostratigraphic zonation in the Izuru and Nabeyama Formations. The locations of stratigraphic columns A-A′ and B-B′ in Yamasuge, and those of A-A′ and B-B′-B″ in Karasawa are shown in Figure 2 and 3, respectively.

The *Parafusulina tochigiensis* Zone corresponds to the middle and upper parts of the Nabeyama Formation. The zonal species first occurs in the level beneath thick dolostone of the middle part of the formation in Ohgama (Figure 6). Although specific identification of *Parafusulina* is impossible due to remarkable replacement by dolomite in the middle part of the formation, *Parafusulina yabei* and *Parafusulina kuzuensis* seem not to extend to this zone. *Parafusulina tochigiensis* co-exists with *Parafusulina shimotsukensis* in the middle and upper parts of this zone. *Parafusulina japonica* (Gümbel, 1874) occurs in more than twenty stratigraphic levels and its biostratigraphic range extends to the uppermost part of the Nabeyama Formation. *Gifuella amicula* Honjo, 1959, *Gifuella* sp., *Neoschwagerina* spp., and *Pseudodoliolina ozawai* Yabe and Hanzawa, 1932 are restricted to this zone, and occur in association with dominant *Parafusulina japonica*. Other fusulinoideans including *Chusenella* sp., *Yangchienia compressa* (Ozawa, 1927), and *Paradoxiella* sp. also exclusively occur in this zone.

Fusulinoidean fauna and its correlation

Taxonomic diversity of the *Parafusulina nakamigawai* Zone is very low. *Dunbarula*? sp., *Rauserella*? sp., and a palaeotextulariid of unknown affinity are rarely discriminated in addition to the zonal species and *Parafusulina* sp. (Figure 6). *Parafusulina nakamigawai* was described from the limestone intercalated within tuff, exposed in Nagaami, which was erroneously referred to the Adoyama Formation by Morikawa and Horiguchi (1956). This species is restricted to the basal part of the Akasaka Limestone and does not extend to the *Cancellina nipponica* Zone in the limestone (Ozawa and Nishiwaki, 1992) and the limestone immediately above the *Misellina claudiae* Zone of the Kozaki Formation of west Kyushu (Kanmera, 1963). The *Parafusulina nakamigawai* Zone of the Izuru Formation is correlated to the *P. nakamigawai* Zone of the Akasaka Limestone. This zone is thought to be probably equivalent to Kubergandian in age in the Tethyan standard scale based on the stratigraphic distribution of *Misellina* and *Cancellina* in Southeast Pamir (Leven, 1967) and Afghanistan (Leven, 1997), and the comparison of verbeekinid and neoschwagerinid faunas between Japan and outside Japan (Kobayashi, 1997a; 1997b). Low specific diversity of foraminifers in the *Parafusulina nakamigawai* Zone in Kuzu is common in the biostratigraphic range of the species in Akasaka and Kozaki.

Parafusulina yabei and *Parafusulina kuzuensis* are abundant in and restricted to the *Parafusulina yabei* Zone. This zone is surely younger than the Kubergandian *Parafusulina nakamigawai* Zone, and other fusulinoideans in this zone such as *Rauserella ellipsoidalis* and two unnamed species of *Codonofusiella*, *C.* sp. B and *C.* sp. C, suggest a Middle Permian age. More detailed age determination of the zone is, however, difficult due to complete absence of neoschwagerinids and verbeekinids in the Kuzu area.

Parafusulina yabei and its allied forms were reported from the Mino Terrane (Morikawa, 1958; Igo, 1959; Morikawa and Isomi, 1961) and Kozaki (Kanmera, 1963). Biostratigraphic and paleontologic data, however, are insufficient in them to discuss closely the age and correlation of the *Parafusulina yabei* fauna. On the other hand, as well as *Parafusulina nakamigawai*, complete absence of *Parafusulina yabei* in the Permian terranes of Japan is very significant paleobiogeographically and tectonically with respect to westward drifting of the Panthalassan seamount (Kobayashi, 1997b, 1999, 2004).

Species composition of foraminifers is more diversified in the *Parafusulina tochigiensis* Zone than in the *Parafusulina yabei* Zone, though it is unclear in the dolomitized lower part. More than twenty species of fusulinoideans are discriminated, and about half of them exclusively occur in this zone (Figure 6). Non-fusulinoidean foraminifers are also prolific and diversified. Among them, *Neodiscus padangensis* (Lange, 1925), *Climacammina valvulinoides* Lange, 1925, *Pachyphloia schwageri* Sellier de Civrieux and Dessauvagie, 1965, and *Tetrataxis* spp. are prevailing. However, detailed discussion on biostratigraphic correlation and age determination is not easy in this zone, because the zonal species and *Parafusulina shimotsukensis* are newly proposed herein, and a reliable biostratigraphic range for *Parafusulina japonica*, the most dominant species in this zone, cannot be determined exactly from the many previously published references (e.g., M. Kobayashi, 1957; Morikawa, 1958; Ozawa and Nishiwaki, 1992; F. Kobayashi, 1997b; 2005b).

The occurrence of *Gifuella amicula* is restricted to the upper part of the *Neoschwagerina craticulifera* Zone to the lower part of the *Neoschwagerina margaritae* Zone of the Akasaka Limestone (Honjo, 1959; Ozawa and Nishiwaki, 1992; Zaw Win, 1999). *Pseudodoliolina ozawai* is dominant in the *Pseudodoliolina ozawai* Zone between the lower *Cancellina nipponica* Zone and the upper *Neoschwagerina craticulifera* Zone in the Akasaka Limestone (Ozawa and Nishiwaki, 1992; Zaw Win, 1999), and ranges upward into the *Neoschwagerina craticulifera* Zone (Ozawa and Nishiwaki, 1992).

Biostratigraphic correlation between the Nabeyama

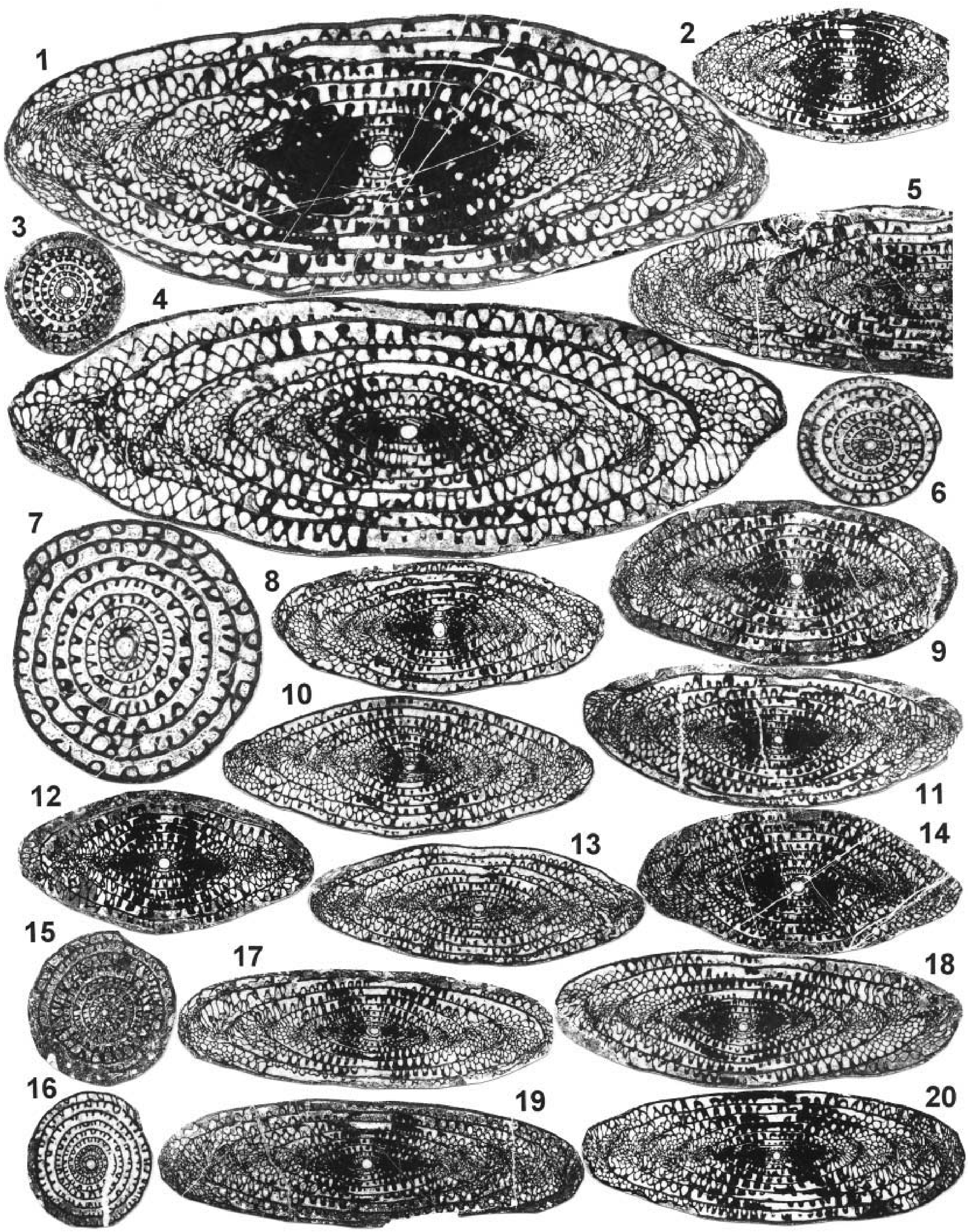

Figure 7.

Formation and the Akasaka Limestone shows that the middle part of the *Parafusulina tochigiensis* Zone with *Gifuella amicula* is probably correlative to the upper part of the *Neoschwagerina craticulifera* Zone to the lower part of the *Neoschwagerina margaritae* Zone. The Murgabian age of the *Neoschwagerina craticulifera* Zone is widely accepted among fusulinoidean paleontologists. On the other hand, there are unresolved problems concerning the age assignment of the *Neoschwagerina margaritae* Zone in relation to the species identification of "*Neoschwagerina margaritae* Deprat, 1913" by authors and the taxonomic validity of *Yabeina ozawai* Honjo, 1959 (Honjo, 1959; Leven, 1996), and the first appearance of *Yabeina* in the Tethyan regions especially in the Akasaka Limestone, based on which the Murgabian-Midian boundary is defined (Leven, 1993; 1996). Faunal correlation of the Middle Permian fusulinoideans in the Tethyan (Kobayashi, 1997a) and Circum-Pacific regions (Kobayashi, 1997b) suggests that the middle part of the *Parafusulina tochigiensis* Zone corresponds to the Murgabian or Wordian in age. The *Parafusulina tochigiensis* Zone does not exactly correspond to the stratigraphic range of *Pseudodoliolina ozawai* in the Nabeyama Formation. Other fusulinoideans exclusively found in this zone are also less useful and reliable for correlation.

The difficulty of correlation of the Nabeyama Formation by fusulinoidean biostratigraphy is obviously caused by and related to the absence of such marker species as *Cancellina nipponica* Ozawa, 1927, *Neoschwagerina simplex* Ozawa, 1927, *Neoschwagerina craticulifera* (Schwager, 1883), and *Neoschwagerina margaritae*, which have been used widely for the regional biostratigraphic correlation of the Japanese Middle Permian since Y. Ozawa (1927). More precise correlation and age determination of three fusulinoidean zones proposed herein are possible when biostratigraphic zonation by schwagerinids is made clear in relation to the stratigraphic range of neoschwagerinids in Middle Permian limestones of the Jurassic terrane of Japan.

Systematic paleontology

Superfamily Fusulinoidea von Möller, 1878
Family Schwagerinidae Dunbar and Henbest, 1930

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

Type species.—*Parafusulina wordensis* Dunbar and Skinner, 1931, p. 261–263, pl. 2, figs. 1–4.

Discussion.—Although typical species assigned to *Parafusulina* (*Skinnerella*) by Coogan (1960) are easily distinguished from those of *Parafusulina* (*Parafusulina*) by many test characters, there are some species uneasily determinable in their generic affinity to either *Parafusulina* (*Parafusulina*) or *Parafusulina* (*Skinnerella*) with respect to the form of outer and inner whorls, development of cuniculi and axial filling, and septal folds, as pointed out by Kanmera (1963) and Skinner (1971). On the other hand, the much larger test size of microspheric forms of *Parafusulina* (*Parafusulina*) than those of *Parafusulina* (*Skinnerella*) is very characteristic (Skinner, 1971). This difference in test size is thought to be closely related to the evolution of advanced forms of schwagerinids, in comparison with the marked difference of test size between megalospheric and microspheric forms of neoschwagerinids assignable to Neoschwagerininae Dunbar and Condra, 1927 and Lepidolininae A.D. Miklukho-Maklay, 1958.

Parafusulina yabei and *P. japonica*, characteristic in the Nabeyama Formation, were assigned to *Parafusulina* (*Skinnerella*) by Coogan (1960). Other species of *Parafusulina* from the formation have also some morphologic characters closer to *Parafusulina* (*Skinnerella*) than *Parafusulina* (*Parafusulina*). Certain authors such as Leven (1997), Kobayashi and Ishii (2003), and Leven and Mohaddam (2004) recognized the taxonomic validity of *Skinnerella* from characteristic features of septal fluting in their Afghan and Iranian materials. However, no microspheric forms of *Skinnerella* or *Parafusulina* were shown by them. Although Leven and Mohaddam (2004) suggested the gradual morphologic change of test characters from *Chalaroschwagerina* to *Skinnerella*, any differences between *Skinnerella* and *Parafusulina* were not pointed out by them.

In this paper, *Parafusulina* is not treated as a subgeneric rank, and species described below are all assigned to *Parafusulina* until taxonomic discussion on the basis of the ontogenetic and phylogenetic relationships or other paleontologic analysis of Middle Per-

← **Figure 7.** Schwagerinids of the lower part of the Nabeyama Formation (1). **1–20.** *Parafusulina yabei* Hanzawa. All from Yamasuge (Figure 2). 1, 4 and 7: ×10; others: ×5. 1: D2-006421, Loc. Ya-30; 2: D2-006439, Loc. Ya-30; 3: D2-006560, Loc. Ya-32; 4: D2-006448, Loc. Ya-30; 5: D2-006532, Loc. Ya-32; 6: D2-006502, Loc. Ya-30; 7: D2-006541, Loc. Ya-32; 8: D2-006454a, Loc. Ya-30; 9: D2-006572, Loc. Ya-32; 10: D2-006445, Loc. Ya-30; 11: D2-006531, Loc. Ya-32; 12: D2-006320, Loc. Ya-22; 13: D2-006437, Loc. Ya-30; 14: D2-006236, Loc. Ya-14; 15: D2-006623a, Loc. Ya-32; 16: D2-006497, Loc. Ya-30; 17: D2-006472, Loc. Ya-30; 18: D2-006441, Loc. Ya-30; 19: D2-006556, Loc. Ya-32; 20: D2-006374, Loc. Ya-27.

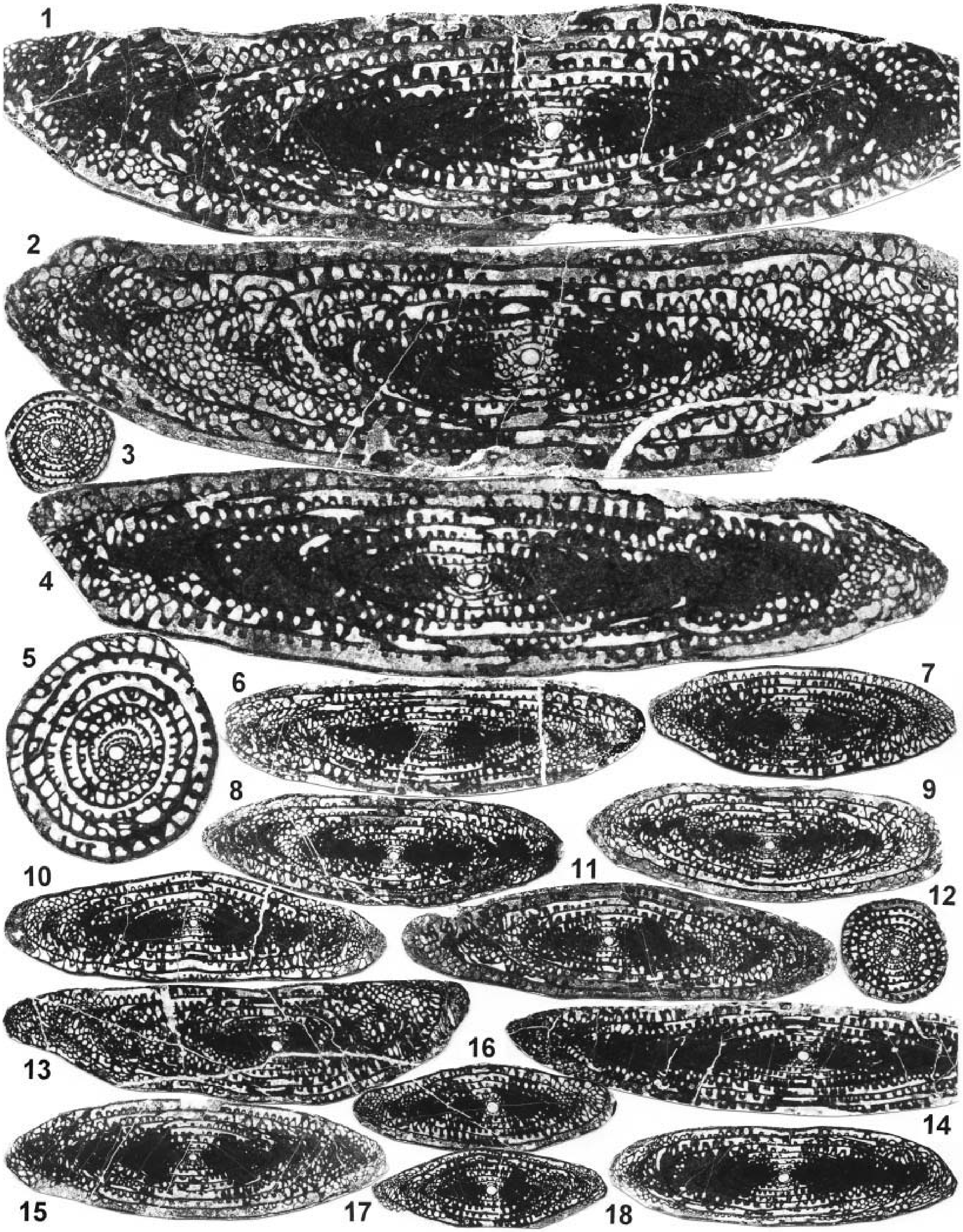

Figure 8.

mian schwagerinids is possible.

Parafusulina japonica (Gümbel, 1874)

Figures 12.1–12.25

Fusulina japonica Gümbel, 1874. p. 479.
Fusulina japonica Gümbel *in* Schwager, 1883, p. 121–124, pl. 15, figs. 1–11.

Material examined.—Illustrated twenty-five and other specimens.

Discussion.—According to T. Kobayashi (1980), Gümbel introduced "*Fusulina japonica*" in 1874 for a form having a shorter cylindrical test, and a greater number of and larger height of whorls in comparison with those of *Fusulina cylindrica* Fischer de Waldheim, 1829. Later, Schwager (1883) illustrated "*Fusulina japonica*" based on the original materials by Gümbel probably collected in the Akasaka Limestone.

The present materials are closely similar to the original ones from the Akasaka Limestone by Gümbel *in* Schwager (1883). Distinction of this species from immature specimens or fusiform forms of *Parafusulina tochigiensis* is not easy. Specific identification of either *P. japonica* or *P. tochigiensis* requires many well oriented mature specimens. The former has a larger proloculus, smaller form ratio of test and of corresponding whorls, and more arched periphery than the latter. *Parafusulina japonica* differs from *Parafusulina* sp. from the Izuru Formation in having a larger test, larger proloculus, and more strongly folded septa.

Parafusulina kuzuensis Chisaka and Fuse, 1973

Figures 8.1–8.18

Parafusulina (*Parafusulina*) *kuzuensis* Chisaka and Fuse, 1973, p. 184, 185, pl. 1, figs. 1–5.

Material examined.—Illustrated eighteen and other specimens.

Discussion.—Present specimens are variable in many characters such as size, form, and expansion of test, septal folds in tunnel and polar regions, and development of axial filling. All these differences from specimen to specimen are considered to merely represent the intraspecific variation of *Parafusulina kuzuensis* originally described from the lower part of the Nabeyama Formation by Chisaka and Fuse (1973). Smaller forms illustrated are thought to represent the immature stage or specimens whose outer whorls were abraded. Ten specimens named *Parafusulina kaerimizensis* in association with *Parafusulina yabei* by Igo (1964) from the lower part of the Nabeyama Formation may be referable to *Parafusulina kuzuensis* on account of the wide morphologic variation of this species.

The holotype of this species of Chisaka and Fuse (1973) attains an axial length of about 25 mm, which is the longest length recorded among *Parafusulina* described from Japan. The holotypes of *Parafusulina tomeganensis* from the Akasaka Limestone (Morikawa, 1958) and *Parafusulina iisakai* from the Funafuseyama Limestone (Igo and Ogawa, 1958) also have large and elongate tests. These three species may be conspecific. However, close comparison of the three species is difficult and is postponed until more specimens from the Akasaka and Funafuseyama limestones are accumulated.

Parafusulina nakamigawai Morikawa and Horiguchi, 1956

Figures 13.1, 13.8–13.12

Parafusulina nakamigawai Morikawa and Horiguchi, 1956, p. 262, 263, pl. 35, figs. 1–7.
non *Parafusulina nakamigawai* Morikawa and Horiguchi. Igo, 1964, p. 19, 20, pl. 10, figs. 1, 2.

Lectotype.—Specimen illustrated by Morikawa and Horiguchi (1956, pl. 35, fig. 1) designated by Kanmera (1963), kept in the Department of Earth Sciences, Saitama University (register number not indicated), probably from a small limestone intercalated in the Izuru Formation exposed at Nagaami, Kuzu Town, Sano City, Tochigi Prefecture.

Material examined.—Illustrated six and other specimens.

Discussion.—This species has a characteristic subcylindrical test with slightly concave periphery, slightly curved axis of coiling, and bluntly to broadly rounded poles. Present materials are safely identical to the original ones of Morikawa and Horiguchi (1956).

⬅ **Figure 8.** Schwagerinids of the lower part of the Nabeyama Formation (2). **1–18.** *Parafusulina kuzuensis* Chisaka and Fuse. 1–12, 15, 17, 18: from Yamasuge (Figure 2); others: from Ohgama (Figure 6). 1, 2, 4 and 5: ×10; others: ×5. 1: D2-006568, Loc. Ya-32; 2: D2-006479, Loc. Ya-30; 3: D2-006594, Loc. Ya-32; 4: D2-006370, Loc. Ya-27; 5: D2-006499, Loc. Ya-30; 6: D2-006494, Loc. Ya-30; 7: D2-006474, Loc. Ya-30; 8: D2-006581, Loc. Ya-32; 9: D2-006482, Loc. Ya-30; 10: D2-006550, Loc. Ya-32; 11: D2-006570, Loc. Ya-32; 12: D2-006548, Loc. Ya-32; 13: D2-008596, Loc. Og-12; 14: D2-008532, Loc. Og-2; 15: D2-006571, Loc. Ya-32; 16: D2-008575, Loc. Og-9; 17: D2-006473, Loc. Ya-30; 18: D2-006545, Loc. Ya-32.

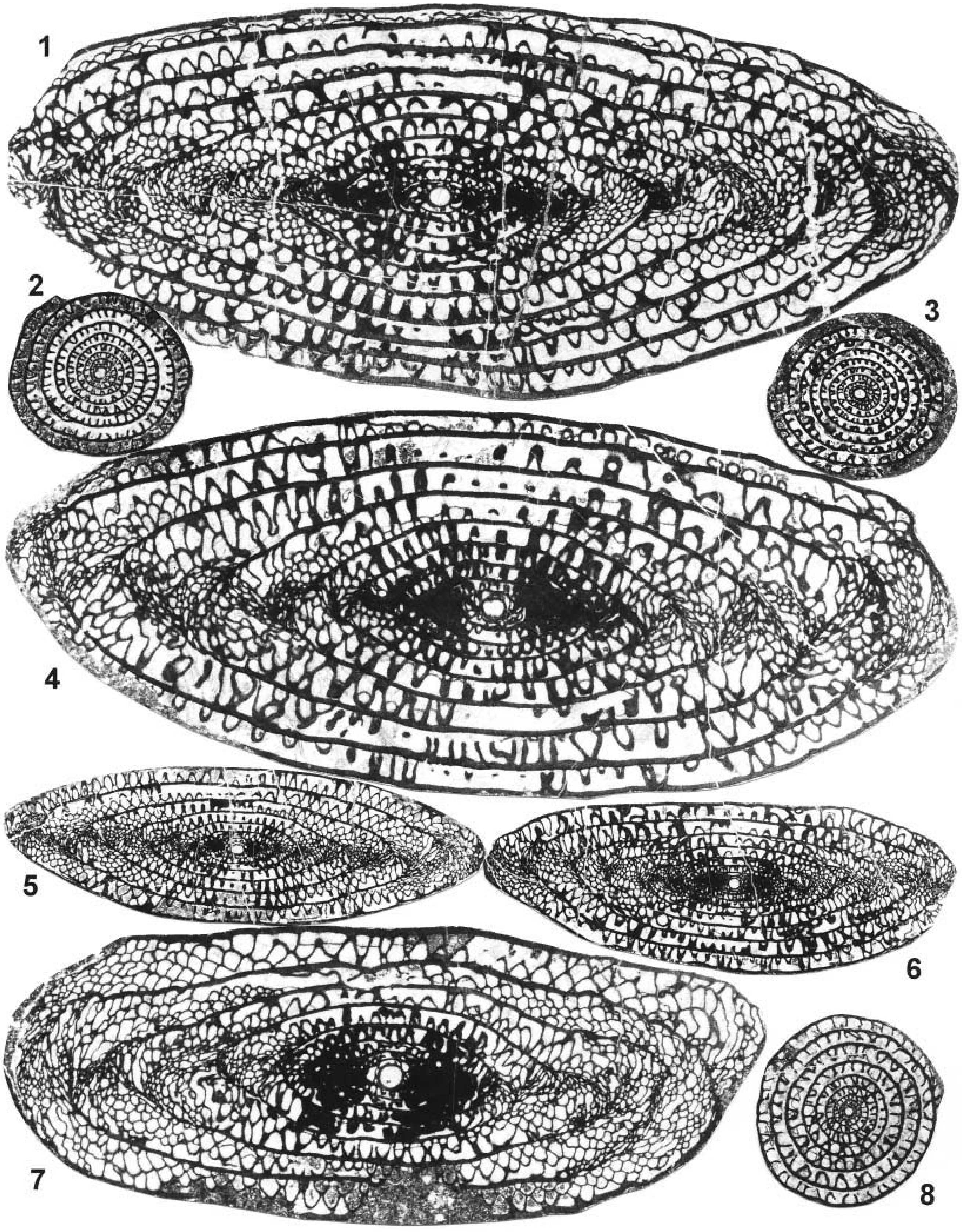

Figure 9. Schwagerinids of the upper part of the Nabeyama Formation (1). **1–8.** *Parafusulina shimotsukensis*, n. sp. All from Karasawa (Figure 3). 1, 4 and 7: ×10; others: ×5. 1: D2-007817, Loc. Ka-70; 2: D2-007789, Loc. Ka-70; 3: D2-007960, Loc. Ka-71; 4: D2-007774, Loc. Ka-70; 5: D2-007819, Loc. Ka-70; 6: D2-007775, Loc. Ka-70; 7: D2-007746, Loc. Ka-70; 8: D2-007796, Loc. Ka-70.

Two specimens described by Igo (1964) as *Parafusulina nakamigawai* from the lower part of the Nabeyama Formation are associated with *Parafusulina yabei*. They appear to be more similar to *P. nakamigawai* than to the original specimens of *P. yabei* of Hanzawa (1942), as discussed later. However, my examination of more than one hundred free specimens which came from the same locality as Igo's, about 300 m west of Kuzu Railway Station, shows that the two specimens of Igo (1964) represent intraspecific variation in *P. yabei* and are referable to *Parafusulina yabei* rather than to *Parafusulina nakamigawai*.

Parafusulina shimotsukensis n. sp.

Figures 9.1–9.8, Figures 10.1–10.13

Derivation of name.—Ancient geographic name, Shimotsuke, for the present Tochigi Prefecture.

Type specimens.—Holotype D2-007817 (axial section, Fig. 9.1). Paratypes D2-007789 (sagittal section, Fig. 9.2), D2-007960 (sagittal section, Fig. 9.3), D2-007774 (axial section, Fig. 9.4), D2-007819 (axial section, Fig. 9.5), D2-007775 (axial section, Fig. 9.6), D2-007746 (axial section, Fig. 9.7), D2-007796 (sagittal section, Fig. 9.8), D2-008353 (axial section, Fig. 10.1), D2-008344a (sagittal section, Fig. 10.2), D2-007440 (sagittal section, Fig. 10.3), D2-007777 (axial section, Fig. 10.4), D2-008179 (axial section, Fig. 10.5), D2-007437 (axial section, Fig. 10.6), D2-007453 (axial section, Fig. 10.7), D2-007751 (tangential section, Fig. 10.8), D2-007577 (axial section, Fig. 10.9), D2-007761 (axial section, Fig. 10.10), D2-007809 (sagittal section, Fig. 10.11), D2-007787 (sagittal section, Fig. 10.12), D2-008186 (sagittal section, Fig. 10.13).

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

Diagnosis.—Large-sized *Parafusulina*, showing very wide morphologic variation in many characters, represented by strongly and rather irregularly fluted septa throughout test so as to produce indistinct cuniculi, and numerous chamberlets on and above chamber floor.

Description.—Test inflated to elongate fusiform with broadly arched periphery, straight to slightly convex lateral slopes, rounded to bluntly pointed poles, and straight axis of coiling. Mature test with eight to ten whorls, more than 15 mm in length, about 6 to 7 mm in width, and about 1.9 to 3.2 in form ratio. Proloculus nearly spherical, 0.36–0.61 mm in outer diameter. Test gradually increasing in length and height, but last whorl of fully mature specimens less high than preceeding whorl.

Septa thin for large test, strongly fluted throughout test. Septal folds commonly more than half as high as chambers, and commonly reach the top of chambers. Combination of strongly folded adjacent septa results in numerous, various-sized, various-shaped chamberlets on and above the chamber floor, especially in polar regions. Rather irregular folds of adjacent septa, however, not producing distinct cuniculi except for the median part of test in outer whorls. Phrenotheca developed in middle to outer part of test in most specimens. Septal counts 11–13, 17–22, 24–29, 32–38, 34–40, 39–47, 43–50, 47–53, and 59 (?) in the first to the ninth whorl in the illustrated eight paratypes. Wall thin in comparison with test size, 0.072–0.106 mm in the last whorl, consisting of tectum and fine alveolar keriotheca. Rudimentary chomata present only on the proloculus. Tunnel low, not well defined due to strongly fluted septa even in median part of test. Axial filling developed in axial region and both sides of tunnel of inner whorls, but obscure in specimens.

Material examined.—Twenty-one types and other specimens.

Discussion.—This new species is of particular interest because it apparently represents a highly specialized group and the largest known form of inflated *Parafusulina*. Its test is larger in volume and shorter in axial length than elongate forms of *Parafusulina* commonly over 2 cm reported from North America including Coahuila, Mexico (Dunbar *et al.*, 1935), west Texas (Dunbar and Skinner, 1937), northern California (Coogan, 1960; Skinner and Wilde, 1965), and Washington (Mills and Davis, 1962; Skinner and Wilde, 1966). Except for having large tests in common, no similar or related test characters can be recognized between *Parafusulina shimotsukensis* and these North American *Parafusulina*. They are thought to be quite different phylogenetically.

As to septal folds, development of phrenotheca, and indistinct cuniculi, this new species is more similar to forms assignable to *Parafusulina* (*Skinnerella*) proposed by Coogan (1960) and emended by Skinner (1971). *Parafusulina shimotsukensis* is not like any described species outside Japan. It is closest to *Parafusulina yabei* in strongly and rather irregularly fluted septa, development of indistinct cuniculi and axial filling, and numerous chamberlets on and above the chamber floor. *Parafusulina shimotsukensis*, however, has a larger test, larger proloculus, and larger height and width in the corresponding whorls than *Parafusulina yabei*. This new species is considered to be the direct descendant of *Parafusulina yabei* based on those test characters that are intimately related phylogenetically, and its occurrence higher than *P. yabei* in the

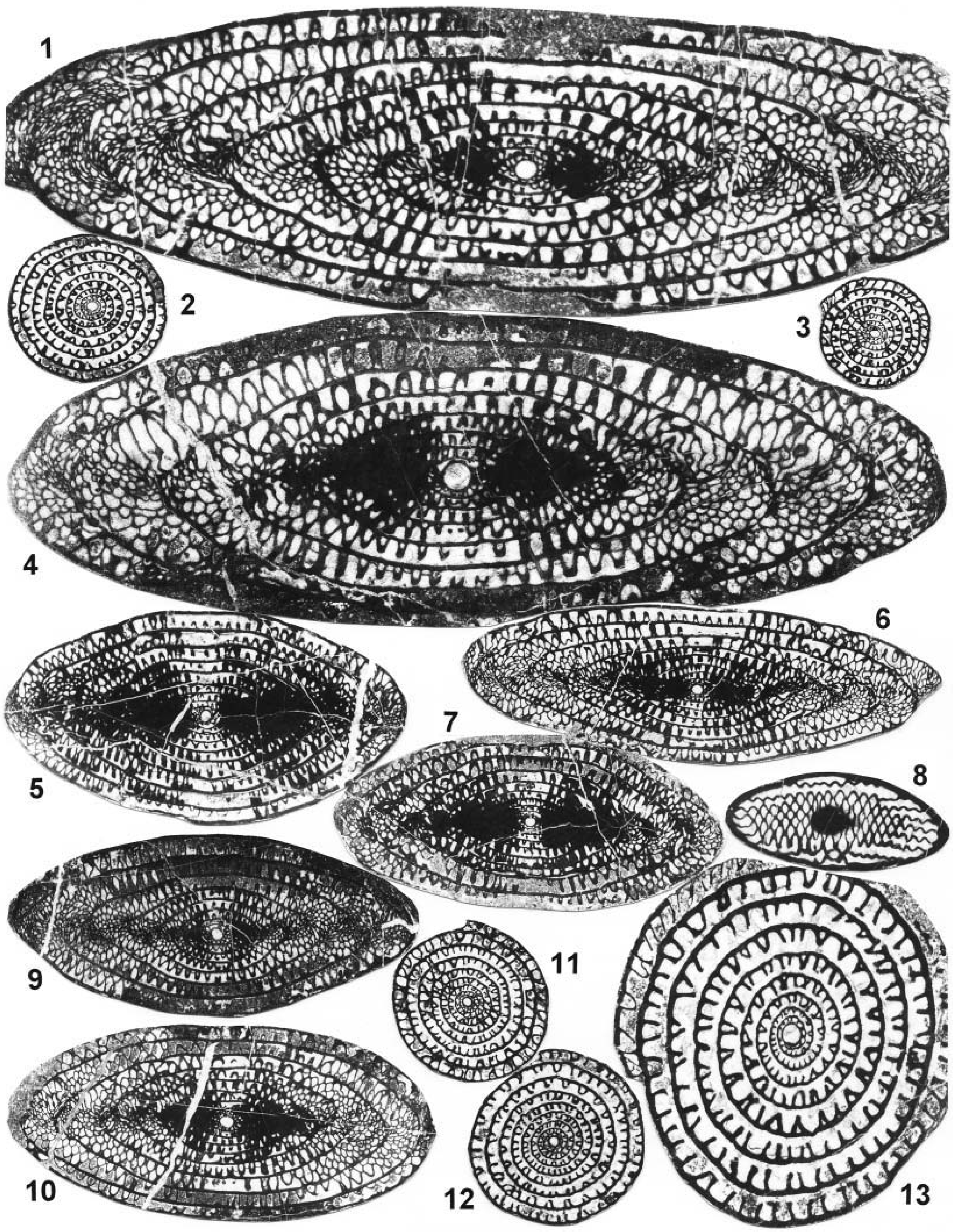

Figure 10.

Nabeyama Formation.

Parafusulina tochigiensis n. sp.

Figures 11.1–11.20

Derivation of name.—Prefectural name Tochigi.

Type specimens.—Holotype D2-007864 (axial section, Fig. 11.1). Paratypes D2-007443 (axial section, Fig. 11.2), D2-007449 (sagittal section, Fig. 11.3), D2-007450 (sagittal section, Fig. 11.4), D2-007852b (sagittal section, Fig. 11.5), D2-007447 (sagittal section, Fig. 11.6), D2-007853 (sagittal section, Fig. 11.7), D2-007849 (sagittal section, Fig. 11.8), D2-007855 (sagittal section, Fig. 11.9), D2-007828 (axial section, Fig. 11.10), D2-008209 (sagittal section, Fig. 11.11), D2-007441 (axial section, Fig. 11.12), D2-007827 (axial section, Fig. 11.13), D2-007442 (axial section, Fig. 11.14), D2-007860 (axial section, Fig. 11.15), D2-007824 (axial section, Fig. 11.16), D2-007863 (axial section, Fig. 11.17), D2-008561 (tangential section, Fig. 11.18), D2-008554 (axial section, Fig. 11.19), D2-007902 (sagittal section, Fig. 11.20).

Type locality.—Ohgama (two paratypes, D2-008561 and D2-008554) and Karasawa (holotype and other seventeen paratypes), Kuzu Town, Sano City, Tochigi Prefecture.

Diagnosis.—Large, elongate fusiform to subcylindrical *Parafusulina*, having small proloculus for large test and for the genus, strongly folded septa, and not so well developed cuniculi for the genus, and thought to belong to the *P. japonica* species group.

Description.—Test elongate fusiform to subcylindrical with nearly straight to broadly arched periphery, straight to slightly convex lateral slopes and bluntly pointed poles. Axis of coiling nearly straight, slightly oscillating in specimens. Mature test with eight to nine whorls, 14 to 19 mm in length, about 4.5 to 6 mm in width, and about 2.7 to 3.9 in form ratio. Length reaches more than 20 mm in the holotype. Proloculus nearly spherical to subspherical, 0.28–0.52 mm in longer outer diameter. Test tightly coiled in inner one to two whorls, then gradually increasing in length and height in the succeeding two to four whorls, with the rate of increase finally becoming nearly steady or slightly decreasing.

Septa strongly fluted throughout test, especially in polar regions. Septal folds generally high, some reaching the top of the chamber. Combination of strongly folded adjacent septa forms numerous chamberlets on and above the chamber floor. Cuniculi, low, narrow, and not so well developed as in typical *Parafusulina*. Weak phrenotheca present in outer whorls of some specimens. Septal counts 8–13, 18–23, 22–28, 24–32, 27–36, 31–41, 34–45, and 43 (?)–44 in the first to the eighth whorl in the illustrated eight paratypes. Wall thin in comparison with test size, 0.031–0.074 mm in the last whorl, consisting of tectum and fine alveolar keriotheca. Rudimentary chomata present only on the proloculus. Tunnel low, rather narrow, and indistinct in its path. Axial filling developed in the axial region, but not in outer few whorls.

Material examined.—Twenty types and other specimens.

Discussion.—This new species closely resembles and appears to be conspecific with *Parafusulina kuzuensis* due to their many similarities, such as large and elongate fusiform to subcylindrical test, proloculus size, mode of septal folds, and development of axial filling and indistinct cuniculi. These test characters are highly variable in specimens. On the other hand, careful examination of a few hundred axial and sagittal sections of these two forms reveals that the former has more septa and a greater width in the corresponding whorl, and a larger test volume than the latter. These differences suggest the taxonomic independence of these two forms, and *P. tochigiensis* is thought to be the direct descendant of *P. kuzuensis* based on more advanced test characters of the former and their stratigraphic distribution in the Nabeyama Formation.

Parafusulina tochigiensis is, moreover, similar to many other species of *Parafusulina* described from the Middle Permian limestones of Japan, such as *Parafusulina japonica* (Gümbel), *P. gigantojaponica* Kobayashi, 1957, *P. japonica kinshoensis* Morikawa, 1958, and *P. kawaii* Morikawa, 1958. All of them are thought to belong to a species group around *Parafusulina japonica*, and it is difficult to strictly separate them from *P. japonica*. However, *Parafusulina tochigiensis* seems to be distinguished from others in the *P. japonica* species group by its larger and slenderer test in the mature stage, more whorls, and relatively smaller proloculus in comparison with a large test.

← **Figure 10.** Schwagerinids of the upper part of the Nabeyama Formation (2). **1–13.** *Parafusulina shimotsukensis*, n. sp. All from Karasawa (Figure 3). 1, 4 and 13: ×10; others: ×5. 1: D2-008353, Loc. Ka-86; 2: D2-008344a, Loc. Ka-86; 3: D2-007440, Loc. Ka-47; 4: D2-007777, Loc. Ka-70; 5: D2-008179, Loc. Ka-73; 6: D2-007437, Loc. Ka-47; 7: D2-007453, Loc. Ka-47; 8: D2-007751, Loc. Ka-70; 9: D2-007577, Loc. Ka-57; 10: D2-007761, Loc. Ka-70; 11: D2-007809, Loc. Ka-70; 12: D2-007787, Loc. Ka-70; 13: D2-008186, Loc. Ka-73.

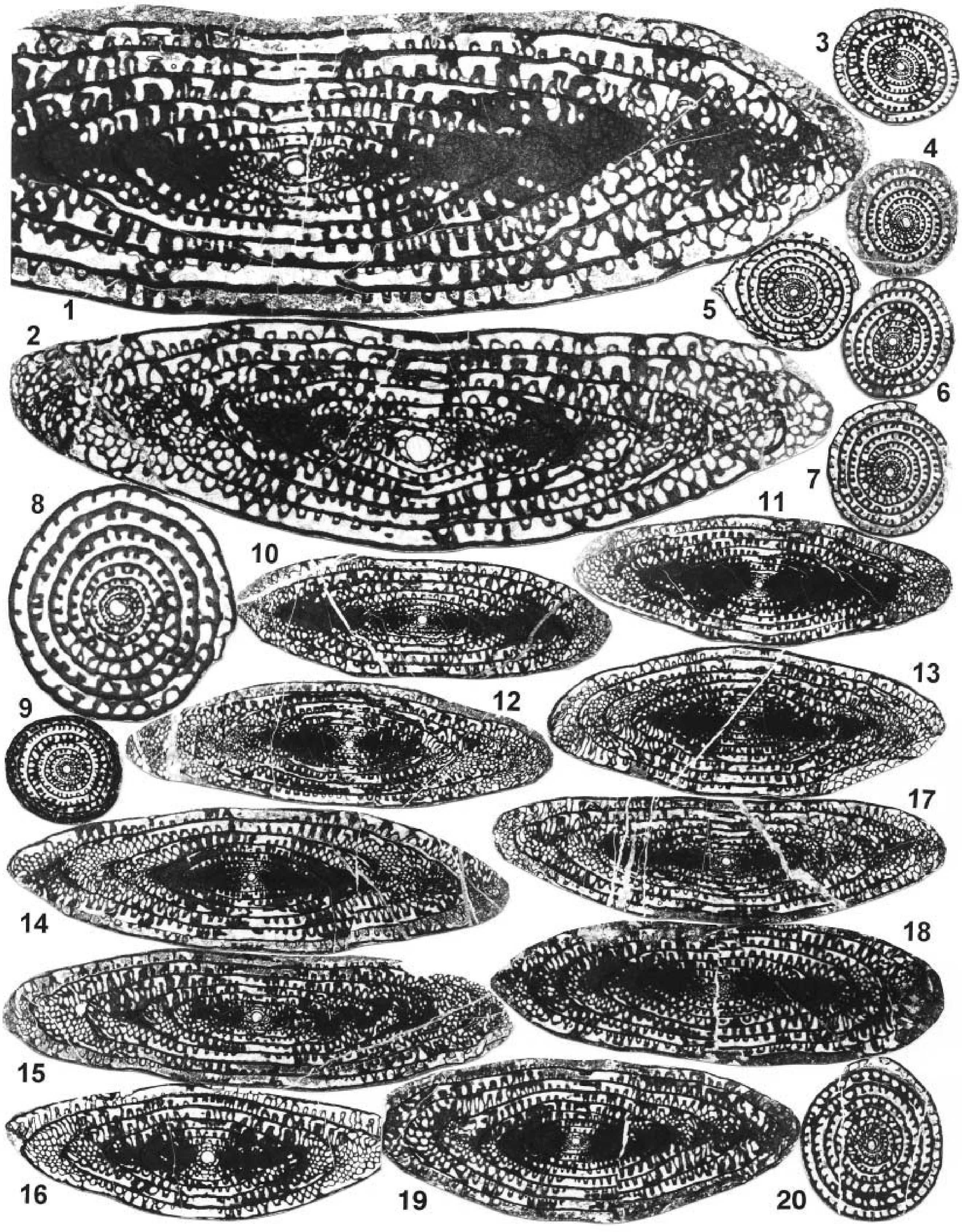

Figure 11.

Parafusulina yabei Hanzawa, 1942

Figures 7.1–7.20

Parafusulina yabei Hanzawa 1942, p. 127–130, pl. 13, figs. 1–4; pl. 14, figs. 1–5.
Schwagerina yabei (Hanzawa), Igo, 1959, p. 248, pl. 2, fig. 8.
Parafusulina nabeyamensis Morikawa and Takaoka 1961, p. 37, pl. 8, figs. 1–9.
Parafusulina tomuroensis Morikawa and Takaoka 1961, p. 36, 37, pl. 7, figs. 1–7.
Parafusulina (*Skinnerella*) *figueroai* (Thompson and Miller), Kanmera, 1963, p. 96–98, pl. 16, figs. 1–5.
Parafusulina yabei yabei Hanzawa, Igo, 1964, p. 14, 15, pl. 1, fig. 4; pl. 2, figs. 1–4; pl. 3, figs. 1–3; pl. 4, figs. 1–4.
Parafusulina yabei nabeyamensis Morikawa and Takaoka, Igo, 1964, p. 15, 16, pl. 1, figs. 1–3.
Parafusulina yabei tomuroensis Morikawa and Takaoka, Igo, 1964, p. 16, 17, pl. 5, figs. 1–4; pl. 6, figs. 1–4.
Parafusulina yabei hanzawae Igo, 1964, p. 17, 18, pl. 7, figs. 1–4.
Parafusulina nakamigawai Morikawa and Horiguchi, Igo, 1964, p. 19, 20, pl. 10, figs. 1, 2.

Lectotype.—Here designated as the specimen illustrated by Hanzawa (1942, pl. 14, fig. 1), I.G.P.S.J. Coll. No. 22321, from the lower part of the Nabeyama Formation exposed at Tomuro, a few km SW of Yamasuge, Tanuma Town, Sano City, Tochigi Prefecture.

Material examined.—Illustrated twenty and other specimens.

Discussion.—Original description by Hanzawa (1942) is based on free specimens with short subcylindrical to short fusiform test and axial filling in inner whorls. Species or subspecies names of *nabeyamensis*, *tomuroensis*, and *hanzawae* were given by later authors for forms with a more inflated test, more elongate test and weaker axial filling, and larger test than *P. yabei sensu stricto*. All the material of Hanzawa (1942), Morikawa and Takaoka (1961), and Igo (1964) are from the lower part of the Nabeyama Formation. These morphologic differences in thin sections can be ascribed to intraspecific variation in *Parafusulina yabei*, because my close examination of more than one hundred axial sections from the same limestone sample reveals that the differences are gradual from specimen to specimen. The same morphologic variation as in this sample is recognized in other samples from lower and higher stratigraphic levels in the lower part of the Nabeyama Formation.

Also thought only to represent intraspecific variation of this species are two specimens named *Parafusulina nakamigawai* by Igo (1964), which were described from the same locality as were the four subspecies of *Parafusulina yabei* by Igo (1964). *Schwagerina kinosakii* proposed by Morikawa (1958) from the Akasaka Limestone may be synonymous with *Parafusulina yabei*, as Igo (1964) indicated. Also possibly identical with this species are some specimens named *Parafusulina iwasensis* Morikawa and Isomi, 1961 from a limestone block east of Lake Biwa. However, detailed comparison between *P. iwasensis* and *P. yabei* is impossible, because no axial section of *P. iwasensis* was shown by Morikawa and Isomi (1961). Although not pointed out by Kanmera (1963), *Parafusulina* (*Skinnerella*) *figueroai* described from the Kozaki Formation is more closely similar to this species in many points of test morphology than to *Schwagerina figueroai* Thompson and Miller, 1944 from the La Vainilla Limestone (Wolfcampian to Leonardian) of southern Chiapas, southernmost Mexico.

This species was thought to be one of the typical examples assignable to *Skinnerella* proposed as a subgenus of *Parafusulina* by Coogan (1960). Skinner (1971) emended Coogan's original definition and insisted on its subgeneric validity on the basis of diagnostic characters such as well developed phrenotheca, low and narrow cuniculi that present invariably in the outer whorls of the middle part of the test, septal folds showing a mushroomshape in axial sections, and other features. These characters are well represented by *Parafusulina yabei*, but are lacking or not common in typical *Parafusulina*. However, this species, as well as *Parafusulina shimotsukensis*, *P. tochigiensis*, and others, is tentatively assigned to *Parafusulina* until further discussion is possible on the basis of stratigraphic distribution and phylogenetic relationships of Middle Permian schwagerinids.

Parafusulina sp.

Figures 13.2–13.7

Material examined.—Illustrated six and other specimens.

⬅ **Figure 11.** Schwagerinids of the upper part of the Nabeyama Formation (3). **1–20.** *Parafusulina tochigiensis*, n. sp. All from Karasawa (Figure 3) except for 18 and 19 from Ohgama (Figure 6). 1, 2 and 8: ×10; others: ×5. 1: D2-007864, Loc. Ka-70; 2: D2-007443, Loc. Ka-47; 3: D2-007449, Loc. Ka-47; 4: D2-007450, Loc. Ka-47; 5: D2-007852b, Loc. Ka-70; 6: D2-007447, Loc. Ka-47; 7: D2-007853, Loc. Ka-70; 8: D2-007849, Loc. Ka-70; 9: D2-007855, Loc. Ka-70; 10: D2-007828, Loc. Ka-70; 11: D2-008209, Loc. Ka-73; 12: D2-007441, Loc. Ka-47; 13: D2-007827, Loc. Ka-70. 14: D2-007442, Loc. Ka-47; 15: D2-007860, Loc. Ka-70; 16: D2-007824, Loc. Ka-70; 17: D2-007863, Loc. Ka-70; 18: D2-008561, Loc. Og-4; 19: D2-008554, Loc. Og-4; 20: D2-007902, Loc. Ka-70.

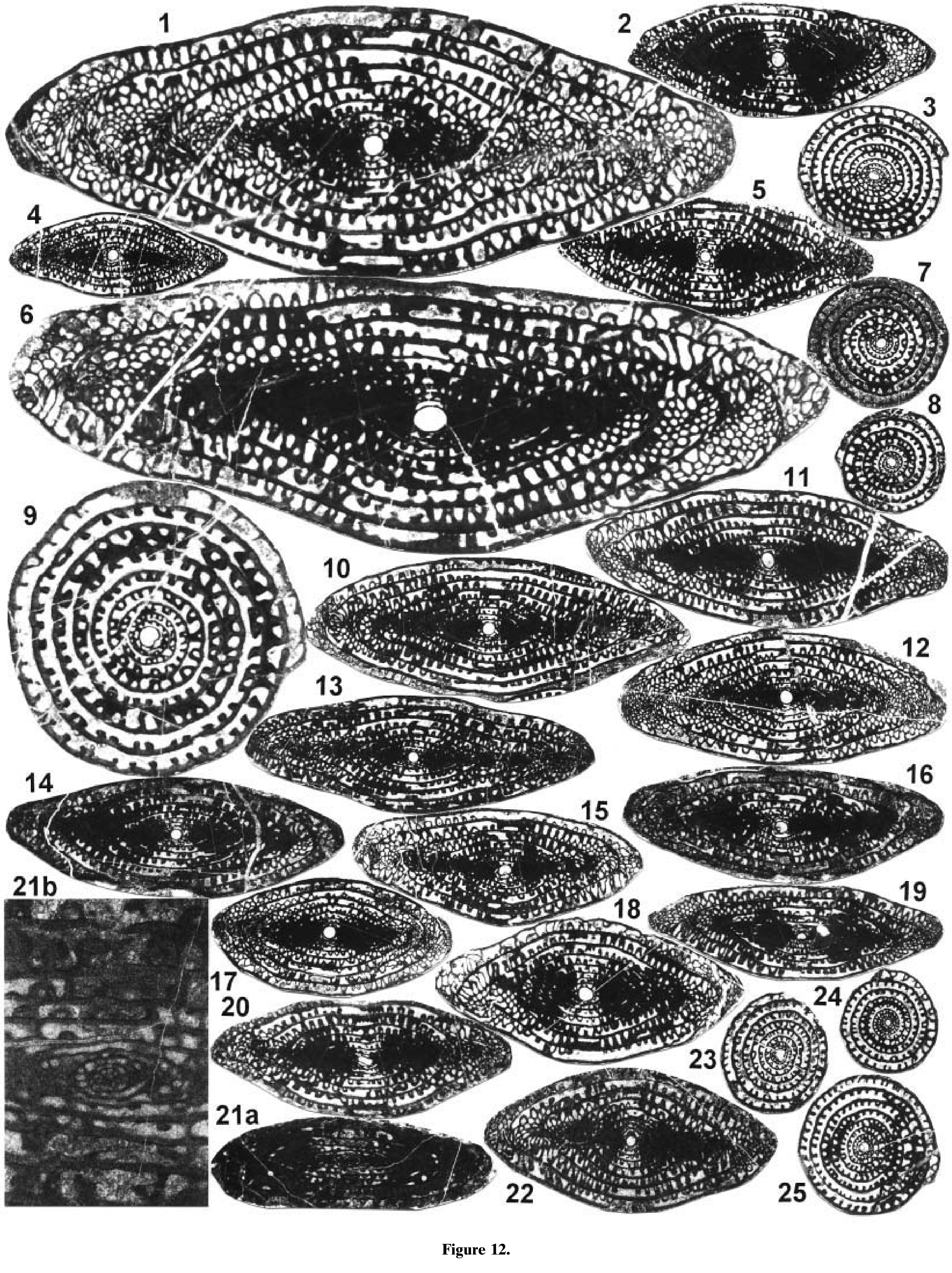

Figure 12.

Discussion.—Schwagerinids found in the Izuru Formation are more or less deformed and their outer whorls are mostly abraded or destroyed. Although this unnamed species of *Parafusulina* is found in association with *Parafusulina nakamigawai* in Nagaami, they are quite different morphologically. *Parafusulina* sp. is probably distinguished from *P. kuzuensis* restricted to the lower part of the Nabeyama Formation by its smaller test. Detailed comparison with *Parafusulina japonica* is difficult because of insufficient preservation and small number of well oriented specimens of this unnamed species.

Family Verbeekinidae Staff and Wedekind, 1910
Genus ***Pseudodoliolina*** Yabe and Hanzawa, 1932
Pseudodoliolina ozawai Yabe and Hanzawa, 1932

Figures 13.20–13.29

Pseudodoliolina ozawai Yabe and Hanzawa, 1932, p. 40–42.

Material examined.—Illustrated ten and other specimens.

Discussion.—This species was proposed by Yabe and Hanzawa (1932) for the specimens named *Doliolina lepida* Schwager, 1883 by Deprat (1914) and Ozawa (1927) from the Akasaka Limestone, based on a difference of wall structure. Thompson and Foster (1937) made clear the taxonomic validity of *Pseudodoliolina* and *Pseudodoliolina ozawai* through their historical review and examination of topotype materials. *Pseudodoliolina ozawai* first occurs above the *Cancellina nipponica* Zone and ranges up to the *Neoschwagerina craticulifera* Zone in the Akasaka Limestone, and shows gradual morphologic changes with increasing test size and number of whorls from lower to upper in the limestone.

The Kuzu specimens were obtained from several stratigraphic levels in the upper part of the *Parafusulina tochigiensis* Zone. They are larger and more advanced morphologically than *Pseudodoliolina ozawai* that are crowded in a few horizons above the *Cancellina nipponica* Zone in the Akasaka Limestone. The present specimens are, on the other hand, similar to topotype specimens shown by Thompson and Foster (1937) except for more parachomata in the corresponding whorls, and different from *Pseudodoliolina pseudolepida* (Deprat, 1912), a direct descendent species of *P. ozawai*, in their subcylindrical and smaller test, smaller proloculus, and fewer whorls. The Kuzu materials are confidently identifiable as *Pseudodoliolina ozawai* based on these morphological features.

Family Neoschwagerinidae Dunbar and Condra, 1927
Genus ***Gifuella*** Honjo, 1959
Gifuella amicula Honjo, 1959

Figures 13.16–13.18

Gifuella amicula Honjo, 1959, p. 136, 137, pl. 6, fig. 2; pl. 9, figs. 1, 2, 4.

Material examined.—Illustrated three specimens.

Discussion.—*Gifuella*, proposed by Honjo (1959) from the lower part of the *Neoschwagerina margaritae* Zone in the Akasaka Limestone, has been regarded as a junior synonym of *Neoschwagerina* (Morikawa and Suzuki, 1961; Zaw Win, 1999) or *Colania* (Ozawa, 1970; Ozawa and Nishiwaki, 1992).

The most diagnostic character of *Gifuella* is the nearly complete lack of secondary transverse septula even in large specimens of the type species more than 1 cm in axial length (Kobayashi, 2005a). *Gifuella* is easily distinguished from *Neoschwagerina* by its larger proloculus and slenderer septula, and from *Colania* by its smaller proloculus, not clearly defined secondary transverse septula, and easily distinguishable microspheric forms of *Colania*. By these characters, *Gifuella* is considered to be taxonomically independent from *Neoschwagerina* and *Colania*, as discussed by Kobayashi (2005a). *Gifuella amicula*, *Gifuella gifuensis* Honjo, 1959, and allied species such as *Gifuella larga* (Morikawa and Suzuki, 1961) occur from the upper part of the *Neoschwagerina craticulifera* Zone to the lower part of the *Yabeina globosa* Zone in the Akasaka Limestone (Morikawa and Suzuki, 1961; Ozawa and Nishiwaki, 1992; Zaw Win, 1999).

Specific identification of most neoschwagerinids in the Nabeyama Formation is difficult because of exceedingly rare occurrence and insufficient preservation. The three specimens illustrated here, however, are most reasonably identified as *Gifuella amicula* by

⬅ **Figure 12.** Schwagerinids of the upper part of the Nabeyama Formation (4). **1–25.** *Parafusulina japonica* (Gümbel). All from Karasawa (Figure 3). 1, 6, 9: ×10; 21b: ×20; others: ×5. 1: D2-006765, Loc. Ka-2; 2: D2-008128, Loc. Ka-72; 3: D2-007119, Loc. Ka-28; 4: D2-007204, Loc. Ka-33; 5: D2-008273, Loc. Ka-85; 6: D2-007140, Loc. Ka-28; 7: D2-007269, Loc. Ka-36; 8: D2-008357, Loc. Ka-87; 9: D2-007561, Loc. Ka-56; 10: D2-006767, Loc. Ka-2; 11: D2-007156, Loc. Ka-28; 12: D2-007120, Loc. Ka-28; 13: D2-007118, Loc. Ka-28. 14: D2-007283, Loc. Ka-36; 15: D2-007565, Loc. Ka-56; 16: D2-007267, Loc. Ka-36; 17: D2-007153, Loc. Ka-28; 18: D2-007114, Loc. Ka-28; 19: D2-007130, Loc. Ka-28; 20: D2-007117, Loc. Ka-28. 21: D2-008214, Loc. Ka-78; 22: D2-007546, Loc. Ka-54; 23: D2-007385, Loc. Ka-42; 24: D2-007202, Loc. Ka-33; 25: D2-006763, Loc. Ka-2.

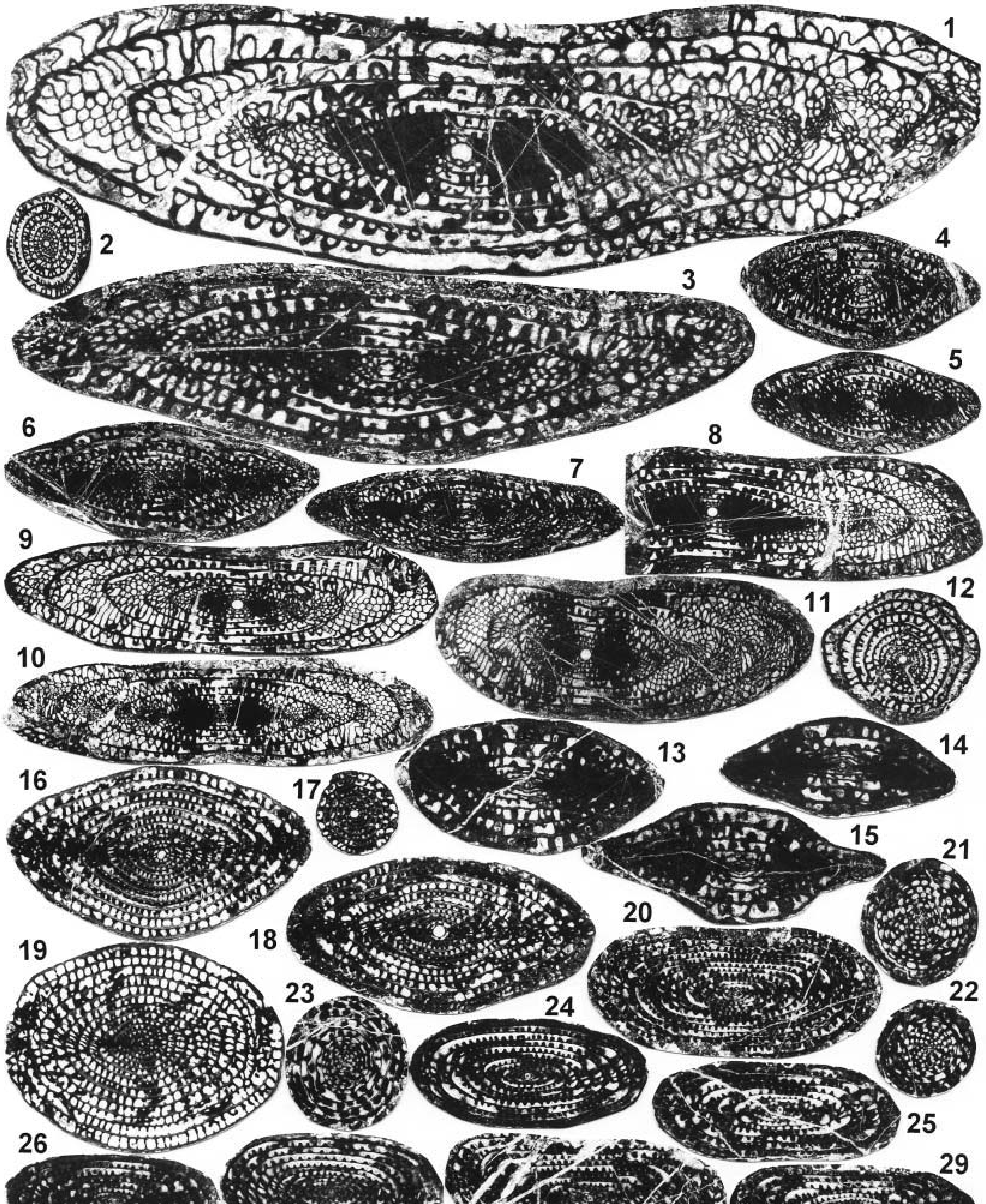

Figure 13.

having a larger proloculus and less distinct axial septula than contemporaneous *Neoschwagerina*, and by having a smaller proloculus and test than *Colania*. They are considerably different from *Gifuella* sp. in this paper by their stouter transverse septula and more massive parachomata.

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← **Figure 13.** Schwagerinids of the Izuru Formation, and schwagerinids, neoschwagerinids, and verbeekinids of the upper part of the Nabeyama Formation. **1, 8–12.** *Parafusulina nakamigawai* Morikawa and Horiguchi. All from Loc. Na-4 in Nagaami (Figure 4). 1: ×10; others: ×5. 1: D2-008462, 8: D2-008468, 9: D2-008464, 10: D2-008465, 11: D2-008474, 12: D2-008463. **2–7.** *Parafusulina* sp. Fig. 2 from Loc. Na-4 in Nagaami, and others from Loc. Ya-25 in Yamasuge (Figure 2). 3: ×10, and others: ×5. 2: D2-008473, 3: D2-006342. 4: D2-006340, 5: D2-006341, 6: D2-006345, 7: D2-006358. **13–15.** *Chusenella* sp. All from Karasawa (Figure 3), ×10. 13: D2-006883, Loc. Ka-14; 14: D2-007347, Loc. Ka-40; 15: D2-006880, Loc. Ka-14. **16–18.** *Gifuella amicula* Honjo. All from Loc. Ka-40 in Karasawa, ×10. 16: D2-007360, 17: D2-007343, 18: D2-007344a. **19.** *Gifuella* sp., D2-007344b, Loc. Ka-40 in Karasawa, ×10. **20–29.** *Pseudodoliolina ozawai* Yabe and Hanzawa. All from Karasawa, ×10. 20: D2-007419, Loc. Ka-47. 21: D2-007325, Loc. Ka-40; 22: D2-008242, Loc. Ka-84; 23: D2-008232, Loc. Ka-81; 24: D2-007320, Loc. Ka-40; 25: D2-008355, Loc. Ka-87; 26: D2-007324, Loc. Ka-40; 27: D2-007323, Loc. Ka-40; 28: D2-008228, Loc. Ka-81; 29: D2-008246, Loc. Ka-84.

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