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Moscovian (middle Pennsylvanian) foraminifers and biostratigraphy of the Ichinotani Formation, Hida Marginal Terrane, Japan

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Abstract. The Moscovian part of the Ichinotani Formation is subdivided into six fusuline zones from lower to upper, *Fusulinella kamitakarensis*, *Fusulina*? sp., *Fusulinella hanzawai*–*Fusulina kamensis*, *Fusulinella rhomboidalis*–*Protriticites ovatus*, *Beedeina lanceolata*, and *Fusulinella rhomboidalis*–*Fusulinella soligalichi*. The strata underlying the first zone, previously assigned to the Moscovian, are reassigned to the upper part of the Bashkirian. Age-diagnostic species are scarce in the possibly Kashirian *F. kamitakarensis* Zone and are absent in the *F.*? sp. Zone. The third to the sixth zones are correlated to the Podolskian, Myachkovian, Podolskian, and Myachkovian of the stratotypes in the Russian Platform, respectively. The fourth zone is inferred to be fault bounded with the fifth zone. The sixth zone is overlain by the lower part of the Kasimovian *Protriticites variabilis* Zone. Twenty species of fusulines and five species of non-fusuline foraminifers are described. Newly proposed herein are *Pseudojanischewskina titanica*, *Bradyinelloides paranautiliformis*, and *Fusulinella igoi*.

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Introduction

The Carboniferous Ichinotani Formation in the Fukuji area, Hida Marginal Terrane, is notable in its lithologic composition of shallow-water limestone interbedded with reddish mudstone and sharpstone conglomerate (Igo, 1956, 1957). The Ichinotani Formation is conformably overlain by the "Lower Permian" Mizuyagadani Formation (*Pseudoschwagerina* Zone) and was divided lithostratigraphically into Lower, Middle, and Upper members by Adachi (1985), and biostratigraphically into the *Millerella*, *Profusulinella*, *Fusulinella*, *Fusulina*, and *Triticites* zones from lower to upper by Igo (1957). Igo's (1957) biostratigraphic zonation and correlation, and fusuline taxonomy were reexamined by Niikawa (1978, 1980) and Igo *et al*. (1984). The *Pseudoschwagerina* Zone assigned to the Asselian (lowest Cisuralian) by these workers was reassigned to the Gzhelian (uppermost Pennsylvanian) by Watanabe (1991).

Kobayashi *et al*. (2022) subdivided the Lower Member of the Ichinotani Formation into the *Eostaffella kanmerai*, *Pseudostaffella antiqua*, *Pseudostaffella kanumai*, *Profusulinella fukujiensis*, and *Profusulinella dagmarae* zones from lower to upper. They made clear (1) a remarkable faunal transition between the *E. kanmerai* Zone and the *P. antiqua* Zone, and (2) strata with late Bashkirian *Pseudostaffella*-*Profusulinella* assemblages recognizable both in the upper part of the Lower Member and the lower part of the Middle Member. Moreover, Kobayashi (2022) revealed that the upper part of the Upper Member of the formation contains strata with Moscovian faunal elements in addition to the Kasimovian and Gzhelian, suggesting a more complicated geological structure of the formation than previously presumed.

As a continuation of my recent studies in the Fukuji area, the fusuline biostratigraphy, faunal composition, and correlation of the main part of the Moscovian strata in the Ichinotani Formation are reviewed in this paper. A significantly different interpretation from the previous works of the main part of the Moscovian is supported by the fault-bounded relationship between the seemingly lowerlying Myachkovian strata and seemingly upperlying Podolskian strata in the lower part of the Upper Member. Described herein are 20 species of fusulines including

Fusulinella igoi sp. nov., and five species of non-fusuline foraminifers including *Pseudojanischewskina titanica* sp. nov. and *Bradyinelloides paranautiliformis* sp. nov. Limestone thin sections of foraminifers used in this paper are stored in the collection of Museum of Nature and Human Activities, Hyogo (Fumio Kobayashi Collection, MNHAH).

Stratigrapic setting

The Ichinotani Formation, trending ENE to WSW and dipping steeply to almost vertically, is typically exposed along the middle reaches of the Ichinotani Valley, Fukuji area (Figure 1). The thickness of the formation is estimated as about 350 meters in the type section. The strata of the formation are in fault bounded contact with the strata of the Devonian Fukuji Formation, and overlain by strata of the Lower Permian Mizuyagadani Formation (Kamei, 1952; Igo, 1956), the lower part of which was revised to the uppermost Pennsylvanian by Watanabe (1991).

The Ichinotani Formation is lithostratigraphically divided into Lower, Middle, and Upper members, and further subdivided into 4 units in the Lower Member, 24 units in the Middle Member, and 33 units in the Upper Member accoding to Adachi (1985). The lithostratigraphic division of the main part of the Moscovian in this paper fundamentally follows that of Adachi (1985). The middle to upper part of the Middle Member corresponds to Adachi's units 17 to 28, and the lower to middle part of the Upper Member to units 29 to 51 (Figure 2). Adachi's units from 5 to 16 in lower part of the Middle Member are reassigned to the upper Bashkirian (Tashatinian to Asatausian) according to Kobayashi *et al*. (2022). That is, late Bashkirian *Pseudostaffella–Profusulinella* assemblages occur not only in the upper part of the Lower Member, but also in the lower part of the Middle Member. The fault-bounded relationship is inferred between Adachi's (1985) units 16 and 17 through the intrusion of dyke rocks, as well as the relationship between units 36 and 37 (between the Myachkovian *Fusulinella rhomboidalis–Protriticites ovatus* Zone and the Podolskian *Beedeina lanceolata* Zone) in the lower part of the Uppper Member (Figure 2), as discussed in the next section.

Adachi's (1985) unit 51 is overlain by the unit 52 referable to the lower Kasimovian that contains *Protriticites variabilis* Bensh, 1972 (Kobayashi, 2022). Several meters thick Moscovian limestones with *Beedeina*, *Fusulinella*, *Ozawainella*, and others are also distinguished at least in two horizons in the upper part of the Upper Member of the formation, which is treated as the *Triticites* Zone by Niikawa (1978) or the *Triticites exculptus–T. hidensis* Zone by Igo *et al*. (1984). These Moscovian limestones, not distinguished by previous workers, are in fault bounded contact with the upper Kasimovian to lower Gzhelian limestones (Kobayashi, 2022).

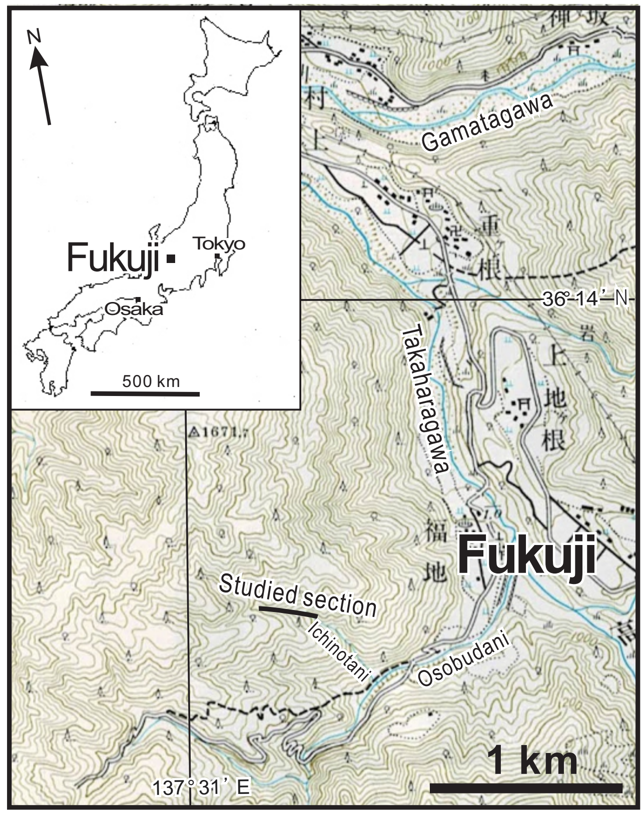

Figure 1. Map showing the location of the studied section of the Ichinotani Formation in the middle reaches of the Ichinotani valley. Topographic map is from 1:50,000 maps "Kamikochi" published by the Geospatial Information Authority of Japan.

Biostratigraphy

Based on the stratigraphic distribution of fusulines, the main part of the Moscovian is subdivided into six zones, from lower to upper: (1) *Fusulinella kamitakarensis* Zone, (2) *Fusulina*? sp. Zone, (3) *Fusulinella hanzawai-Fusulina kamensis* Zone, (4) *Fusulinella rhomboidalis-Protriticites ovatus* Zone, (5) *Beedeina lanceolata* Zone, and (6) *Fusulinella rhomboidalis–Fusulinella soligalichi* Zone (Figure 2). More than 40 species of non-fusuline foraminifers were distinguished in these six zones, although all of them are not shown in Figure 2. The appropriate zonation, however, could not be established on the basis of biostratigraphic ranges of them in this paper. Adachi (1985) distinguished 148 species of non-fusuline foraminifers from the Ichinotani Formation, although no biostratigraphic zonation based on them was presented. For

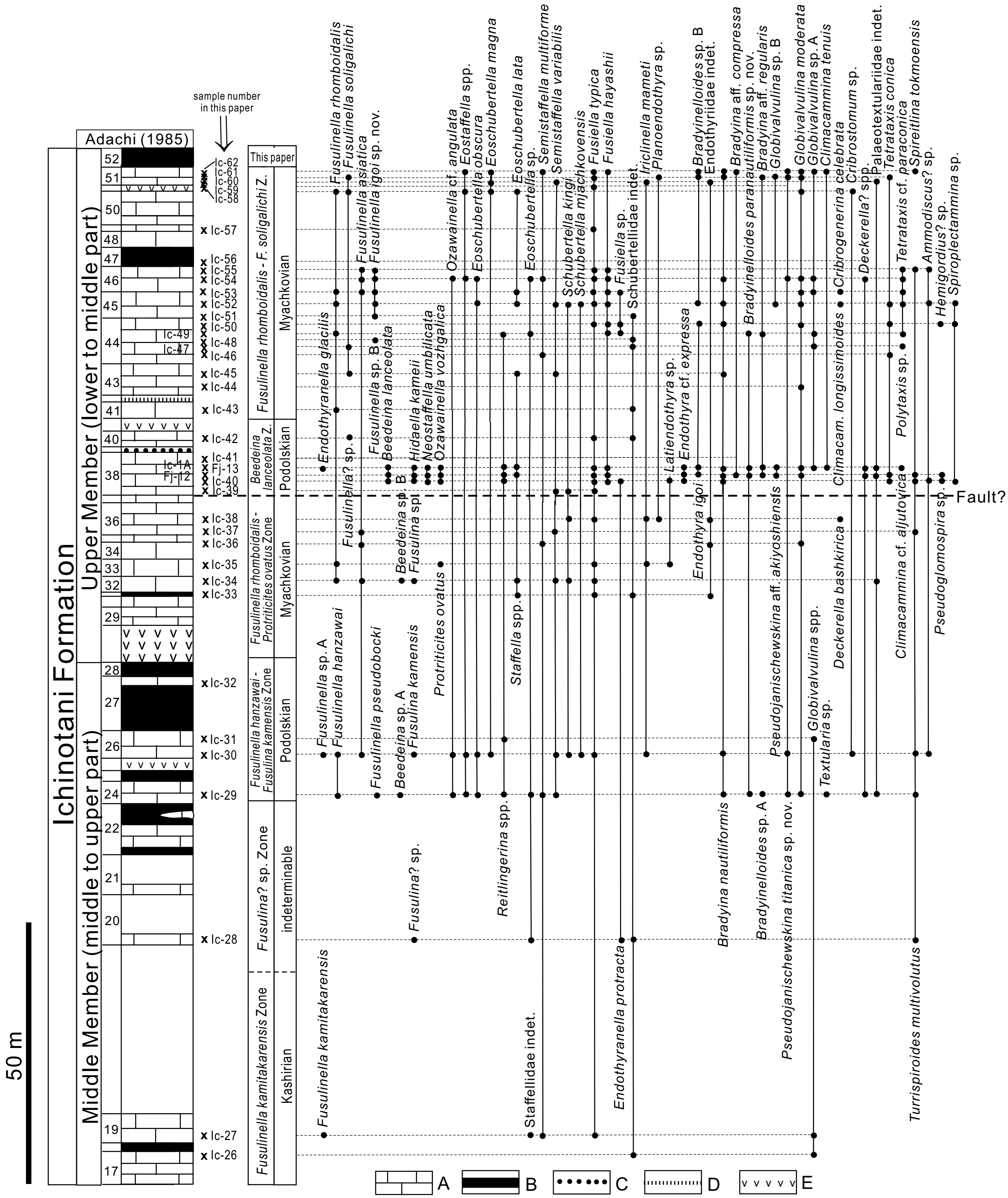

Figure 2. Columnar section of the middle part of the Ichinotani Formation (modified from Adachi, 1985, fig. 4), stratigraphic level of samples, stratigraphic distribution of foraminifers and biostratigraphic zonation (this paper). Roman numerals shown in the left side of the column correspond to the unit numbers used in Adachi (1985). A: limestone, B: mudstone, C: sandstone, D: tuff, E: dyke rocks.

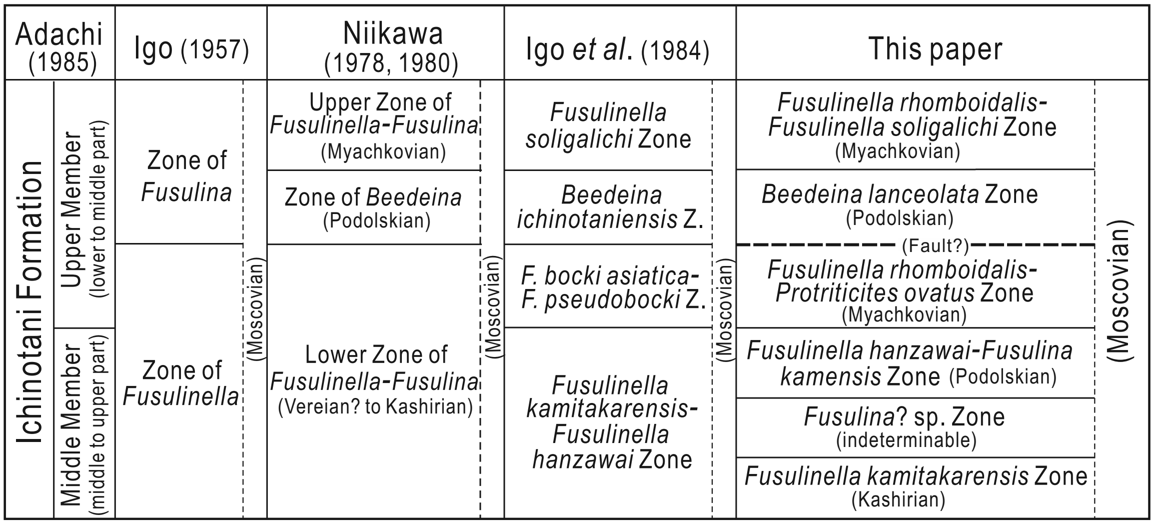

Figure 3. Biostratigraphic correlation of the middle part of Ichinotani Formation.

the sake of convenience to understand where and how the previous works are modified in this paper, the fusuline zonation and correlation of the Moscovian are tabulated in Figure 3.

The *Fusulinella kamitakarensis* Zone is named for oolitic limestone and wackestone/lime-mudstone in the middle part of the Middle Member of the Ichinotani Formation. Fine-grained, ooid wackestone of sample Ic-27 yields commonly *F. kamitakarensis* Igo, 1957, and rarely *Fusiella typica* Lee and Chen in Lee *et al*., 1930 and *Semistaffella multiforme* (Villa in Villa and Merino-Tomé, 2016). The first species is confined to this zone, and the second and third species extend to the uppermost part of the lower part of the Upper Member. The third species was proposed from the Bashkirian/Moscovian of the Cantabrian Mountains (NW Spain). Though uncertain in their details due to insufficient description, Igo *et al*. (1984) showed the occurrence of *Fusulina* sp. A in association with *Fusulinella kamitakarensis*, *Fusulinella simplicata* Toriyama, 1958, *Aljutovella*? sp., *Ozawainella vozhgalica* Safonova in Rauzer-Chernousova *et al*., 1951, and others from the units 17 and 19. However, detailed morphologic comparison of these species to the present materials is difficult. This is because almost all specimens illustrated in eight figures of Igo *et al*. (1984) are only one per species and all are drawn by hand and with no magnification.

The *Fusulinella kamitakarensis* Zone is in fault bounded contact with strata of the lowerlying upper Bashkirian in the lower part of the Middle Member (Kobayashi *et al*., 2022). Foraminifers suggesting the Vereian and biostratigraphically correlatable to the *Akiyoshiella ozawai* Zone in the Akiyoshi Terrane (Kobayashi, 2017) have not been discovered in the Ichinotani Formation. This zone is assumed to be possibly assignable to the Kashirian in spite of the lack of available species for the international biostratigraphic correlation.

The biostratigraphic boundary between the *Fusulinella kamitakarensis* Zone and *Fusulina*? sp. Zone is indeterminable because there are no exposures more than 30 m in thickness toward the limestone bed, from which sample Ic-28 consisting of bioclastic wackestone was collected (Figure 2). Foraminifers are still sporadic or barren in the stratigraphic interval from Ic-28 to the level below Ic-29. This interval is tentatively named the *Fusulina*? sp. Zone. The species *Fusulina*? sp., *Eoschubertella* sp., *Turrispiroides multivolutus* (Reitlinger, 1949), and *Endothyranella protracta* Rauzer-Chernousova, 1938 rarely occur in Ic-28 (Figure 10.15), but no species positively suggesting either the Kashirian or Podolskian are identified in Ic-28.

The *Fusulinella hanzawai*–*Fusulina kamensis* Zone is designated for the stratigraphic interval from units 24 to 28 composed of grey thick-bedded limestone and reddish to dark grey mudstone. This zone might be compared to the upper part of the *Fusulinella kamitakarensis*–*Fusulinella hanzawai* Zone of Igo *et al*. (1984). The abundance and species diversity of fusulines and non-fusulines become rich in the lower part of this zone (Figure 2). Fusulines characteristic in and confined to this zone are *Fusulinella hanzawai* Igo, 1957, *Fusulina kamensis* Safonova in Rauzer-Chernousova *et al*., 1951, *Fusulinella pseudobocki* Lee and Chen in Lee *et al*., 1930, *Fusulinella* sp. A, and *Beedeina* sp. A. Among the species present, *F. hanzawai* is the most prolific. *Fusulina kamensis* was proposed from the upper part of Podolskian of the Kama

River region and Samara Bend of the Russian Platform (Rauzer-Chernousova *et al*., 1951). *Fusulinella asiatica* Igo, 1957 and *F. pseudobocki* were designated as the zonal species of the zone overlying the *F. kamitakarensis–F. hanzawai* Zone by Igo *et al*. (1984) (Figure 3). The former species, however, first appears in this zone and extends to the *Fusulinella rhomboidalis*-*Fusulinella soligalichi* Zone, along with *Pseudojanischewskina titinica* sp. nov., *Bradyinelloides paranautiliformis* sp. nov., *Bradyina nautiliformis* von Möller, 1878, *Ozawainella* cf. *angulata* (Colani, 1924), *Iriclinella mameti* (Igo and Adachi, 1981), *Globivalvulina moderata* Reitlinger, 1949, and others. Their stratigraphic range is shown in Figure 2. Taking the known ranges of *Fusulinella hanzawai* in the Ichinotani Formation (Igo *et al*., 1984) and *Fusulina kamensis* in Russia into account, this zone is correlated to the Podolskian.

The *Fusulinella rhomboidalis–Protriticites ovatus* Zone, designated for the stratigraphic interval from units 29 to 36, mainly consists of grey to light grey bedded limestones dominated by ooid grainstone in the lower part, and dark grey to black bioclastic limestone irregularly containing seams of black mudstone in the upper part. Age-diagnostic species of this zone are represented by the two zonal species. *Fusulinella rhomboidalis* was proposed by Niikawa (1978) both from the Lower Zone of *Fusulinella–Fusulina* correlated to the Vereian? to the Kashirian by Niikawa and the Upper Zone of *Fusulinella–Fusulina* done to the Myachkovian by Niikawa (Figure 3). On the other hand, this species is restricted to the Myachkovian, and not found in the Vereian, Kashirian, and Podolskian of the Akiyoshi and Omi limestones (Kobayashi, 2017). *Protriticites ovatus* was originally described from the Myachkovian of Donbas (Putrya, 1948) and later from the Myachkovian of Moldova (Rauzer-Chernousova *et al*., 1951). It is designated as the zonal species of the uppermost Moscovian (Leven *et al*., 2006; Davydov *et al*., 2012). Accordingly, the *Fusulinella rhomboidalis–Protriticites ovatus* Zone is correlatable to the Myachkovian. *Beedeina* sp. B and *Fusulina* sp. exclusively occur in this zone. Other fusuline and non-fusuline foraminiferal species recognized in this zone are shown in Figure 2.

The *Beedeina lanceolata* Zone, designated for the stratigraphic interval from units 37 to 40, consists of black micritic limestone highly dominant in fusulines in the lower part, and of dark grey limestone poor in fusulines and calcareous sandstone in the upper part. The occurrence of Fusulinidae in the upper part is restricted to *Fusulinella*? sp. On the other hand, *Beedeina lanceolata* (Lee and Chen in Lee *et al*., 1930) and *Neostaffella umbilicata* (Putrya and Leontovich, 1948) are very abundant in many black limestone beds of the lower part. The former species, originally assigned to *Fusulina* (*Girtyina*), is considered to be a senior homonym of *Fusulina ichinotaniensis* Igo, 1957 that was designated as the zonal species of the "*Beedeina ichinotaniensis* Zone" by Igo *et al*. (1984). *Neostaffella umbilicata* ranges from the Kashirian to Podolskian in Russia (Rauzer-Chernousova *et al*., 1951), and is inferred to be as old as the Podolskian taking the one-way trend evolution of *Pseudostaffella–Neostaffella* lineage from the upper Bashkirian to Moscovian (Rauzer-Chernousova, 1963) into consideration. Accordingly, this zone is correlated to the Podolskian, though age-diagnostic species have not been distinguished in the upper part of this zone.

Thus, the faunal composition of characteristic and age-diagnostic species, as mentioned above, is significantly different between the *Fusulinella rhomboidalis–Protriticites ovatus* Zone and the *Beedeina lanceolata* Zone. The biostratigraphic distribution of these species suggests the fault-bounded relation between the seemingly lowerlying former zone (Myachkovian) and seemingly upperlying latter zone (Podolskian). However, any conspicuous disturbance suggesting post-depositional tectonic deformation has not been distinguished between the two zones in the field.

Hidaella kameii Fujimoto and Igo, 1955 and *Ozawainella vozhgalica* Safonova in Rauzer-Chernousova *et al*., 1951 are also characteristic in the *Beedeina lanceolata* Zone and always occur in association with *B. lanceolata* and *Neostaffella umbilicata*. These four species are confined to the lower part of this zone in the Ichinotani section. Those species from the upper part of the Zone of *Beedeina* shown by Niikawa (1980, figs. 2, 3) are not from that of the Ichinotani section, but are from that of the Mizuboradani section. The acme of occurrences of *Fusiella typica* and *Fusiella hayashii* Igo, 1957 agrees with the lower part of this zone. On the other hand, both *Fusulina* and fusulines surely assignable to *Fusulinella* are absent in this part. Likewise, subordinate faunal elements such as *Eoschubertella*, *Semistaffella*, *Schubertella*, and *Eostaffella*, common to rare in the lowerlying and upperlying zones of this zone, are almost absent in the *Beedeina lanceolata* Zone. *Pseudojanischewskina* aff. *akiyoshiensis* Kobayashi and Vachard, 2019 is confined to this zone.

The *Fusulinella rhomboidalis–Fusulinella soligalichi* Zone is designated for the stratigraphic interval from units 41 to 51, and is composed of medium- to thick-bedded, mainly grey partly black to dark grey limestone beds. The unit 51 is conformably overlain by unit 52 containing *Protriticites variabilis* Bensh, 1972 referable to the lower Kasimovian (Kobayashi, 2022).

The generic composition of fusulines is considerably different between this zone and the *Beedeina lanceolata*

Zone. *Fusulinella* and *Eoschubertella* are dominant and characteristic in the former zone are entirely or nearly absent in the latter zone. On the other hand, *Beedeina*, *Neostaffella*, and *Hidaella* are absent in the former zone. *Fusiella typica* and *F. hayashii* are characteristic in both zones. *Fusulinella igoi* sp. nov. is confined to this zone and *Fusulinella asiatica* commonly occurs in this zone. The faunal composition of non-fusuline foraminifers is more or less similar between both zones and more than 20 taxa are recognized in this zone and in the *Beedeina lanceolata* Zone.

The occurrence of two zonal species, *Fusulinella rhomboidalis* and *Fusulinella soligalichi* Dalmatskaya, 1961 is available for the correlation of this zone. The former species is also present in the Myachkovian *F. rhomboidalis–Protriticites ovatus* Zone, as noted above. The latter species, confined to this zone, was originally described from the upper Podolskian and the lower Myachkovian along the Volga of the Russian Platform (Dalmatskaya, 1961). It is closely similar to *Fusulinella soligalichi polasnensis* Rauzer-Chernousova, 1961 and *F. valida* Reitlinger, 1961 proposed from the lower part of the Myachkovian in the Russian Platform. Based on the stratigraphic ranges of the two zonal species, this zone is correlated to the Myachkovian. From the units 46 and 51, Igo *et al*. (1984) showed the occurrence of *F. soligalichi polasnensis*, by which the upper part of the Zone of *Fusulina* by Igo (1957) is presumed to have been replaced to the "*Fusulinella soligalichi*" Zone by Igo *et al*. (1984) (Figure 3), though this interpretation is uncertain in the details due to their insufficient biostratigraphic description.

Description of species

Twenty species of fusulines and five species of non-fusuline foraminifers are described below. Registration numbers and sample localities of the illustrated specimens are shown in the explanation of Figures 4–10. Four species that are abundant, very characteristic in, and restricted to the *Beedeina lanceolata* Zone (*Beedeina lanceolata*, *Neostaffella umbilicata*, *Hidaella kameii*, and *Ozawainella vozhgalica*) are described in another paper. In this paper, only three or five specimens per species are illustrated.

Genus ***Endothyra*** Phillips, 1846

Type species.—*Endothyra bowmani* Phillips, 1846.

Endothyra igoi Kobayashi, 1994

Figure 5.25–5.27, 5.32–5.35

Endothyra igoi Kobayashi, 1994, p. 620, 622, 624, figs. 3.1–3.7.

Remarks.—This large-sized *Endothyra* is abundant to common in the Upper Member of the Ichinotani Formation and is identified with *Endothyra igoi* proposed by Kobayashi (1994) from the upper Serpukhovian limestone blocks of the southern Kanto Mountains. They are closely similar to each other in size and shape, and ontogenetic change of coiling pattern of the test, long septa inclined anteriorly, and distinct septal sutures. *Endothyra* sp. A (Figures 5.18–5.24) is provisionally distinguished from this species by having smaller test.

Genus ***Planoendothyra*** Reitlinger in Voloshinova and Reitlinger, 1959

Type species.—*Endothyra aljutovica* Reitlinger, 1950.

Planoendothyra sp.

Figure 5.30, 5.31

Remarks.—Two specimens illustrated are marked by a narrowly discoidal test with broad umbilical depressions, initial two whorls coiled at a large angle to outer evolute and planispiral whorls, and distinct basal floor deposits. They are assigned to *Planoendothyra* rather than to *Iricrinella* by their perpendicularly coiled inner whorls highly skewed to outer whorls and fewer evolute whorls, and having distinct basal floor deposits. This unnamed species is similar to *Planoendothyra irinae* (Reitlinger, 1950), originally assigned to *Endothyra* and proposed from the Kasimovian of Moldova, in its evolute and rapidly expanding outer whorls, but has a larger test with more deeply umbilical depressions and a more rounded periphery. It is easily distinguished from *Iriclinella mameti* (Igo and Adachi, 1981) from the Middle and Upper members of the Ichinotani Formation (Figure 5.1) by a larger test, thicker wall, and the presence of basal floor deposits.

Genus ***Bradyinelloides*** Mamet and Pinard, 1992

Type species.—*Bradyina pseudonautiliformis* Reitlinger, 1950.

Bradyinelloides paranautiliformis sp. nov.

Figure 6.14, 6.15, 6.18–6.21

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Etymology.—Similar to *Bradyina nautiliformis* von Möller, 1878.

Type specimens.—Holotype MNHAH D2-036020 (axial section, Figure 6.21) from Fj-12. Paratypes: two axial sections (Figures 6.14, 6.15), one tangential section

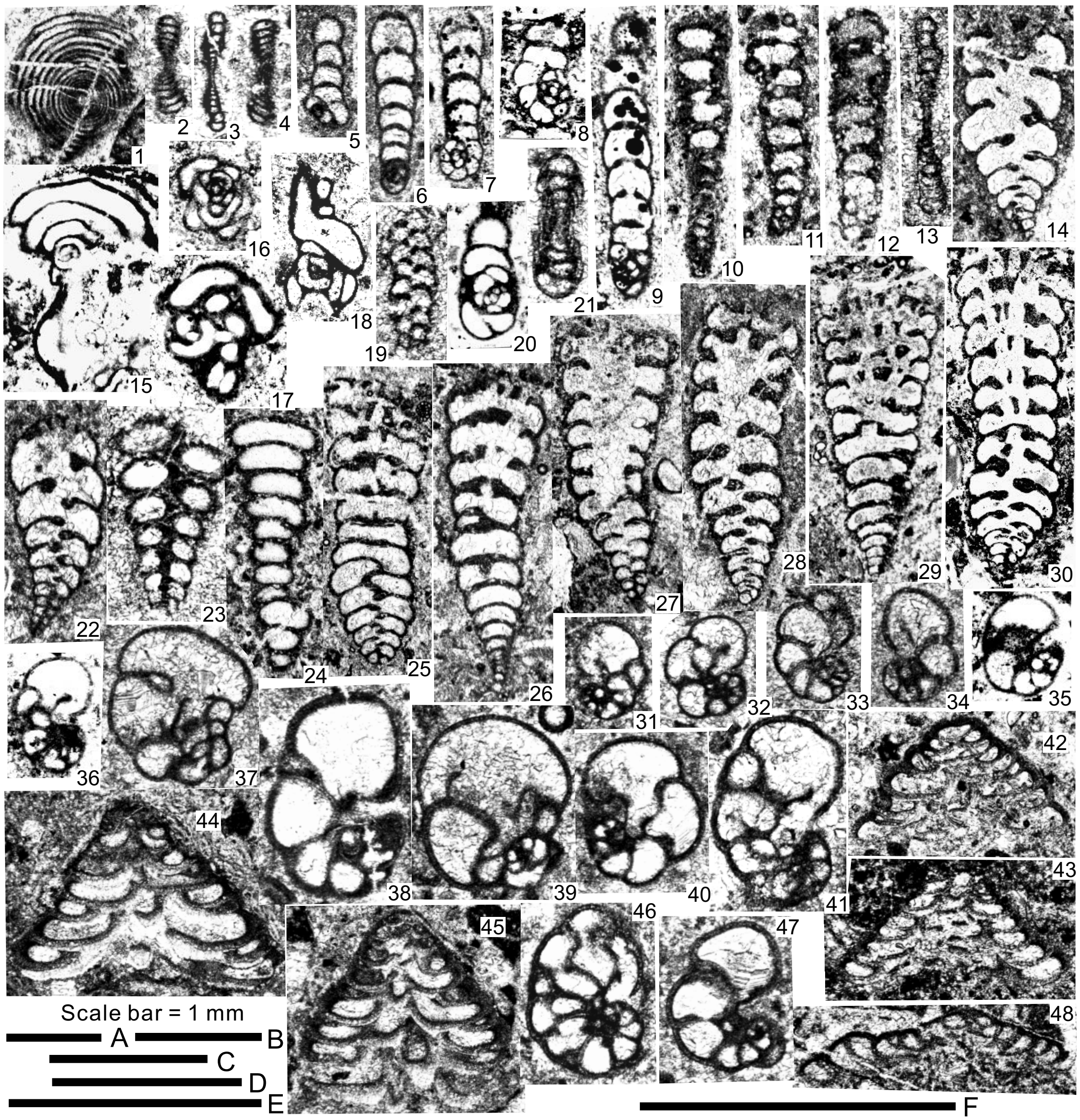

Figure 4. **1–4,** *Turrispiroides multivolutus*; 1, D2-059418, Ic-55; 2, D2-058996, Ic-30; 3, D2-059138, Ic-37; 4, D2-059188, Ic-40; **5–7,** *Endothyranella protracta*; 5, D2-058922, Ic-28; 6, D2-058916, Ic-28; 7, D2-059194, Ic-40; **8,** *Endothyranella gracilis* Rauzer-Chernousova, 1938, D2-036032, Fj-13; **9,** *Endothyranella* sp. A, D2-059205, Ic-40; **10–12,** *Spiroplectammina* sp.; 10, D2-059200, Ic-40; 11, D2-059331, Ic-52; 12, D2-059300, Ic-50; **13,** *Ammodiscus*? sp., D2-059421, Ic-55; **14, 22** *Cribrostomum* sp.; 14, D2-059453, Ic-58; 22, D2-059046, Ic-30; **15,** *Ammovertella*? sp., D2-036017, Fj-13; **16,** *Pseudoglomospira* sp., D2-036017, Fj-13; **17, 18,** *Palaeonubecularia* spp.; 17, D2-035934, Fj-12; 18, D2-059199, Ic-40; **19,** *Spireitlina tokmovensis* (Reitlinger, 1961), D2-059504, Ic-62; **20,** *Endothyranella* sp. B, D2-035956, Fj-12; **21,** *Hemigordius*? sp., D2-059302, Ic-50; **23,** *Palaeotextularia* sp., D2-058949, Ic-29; **24,** *Deckerella*? sp., D2-059398, Ic-54; **25,** *Climacammina tenuis* Lin, 1978, D2-059511, Ic-62; **26,** *Climacammina longissimoides* Lee and Chen in Lee *et al*., 1930, D2-059355, Ic-52; **27, 28,** *Deckerella bashkirica* Morozova, 1949; 27, D2-059401, Ic-54; 28, D-058948, Ic-29; **29,** *Cribrogenerina celebrata* Lin, 1978, D2-059364, Ic-53; **30,** *Climacammina* cf. *aljutovica* Reitlinger 1950, D2-036017, Fj-13; **31–36,** *Globivalvulina moderata*; 31, D2-059355, Ic-52; 32, D2-059521, Ic-62; 33, D2-059366, Ic-53; 34, D2-058947, Ic-29; 35, D2-035992, Fj-13; 36, D2-036013, Fj-13; **37–40,** *Globivalvulina* sp. A, 37, D2-059522, Ic-62; 38, D2-059402, Ic-54; 39, D2-059393, Ic-54; 40, D2-059398, Ic-54; **41, 46, 47,** *Globivalvulina* sp. B, 41, D2-059480, Ic-61; 46, D2-059350, Ic-52; 47, D2-059477, Ic-61; **42, 43,** *Tetrataxis conica* Ehrenberg, 1854; 42, D2-059484, Ic-61; 43, D2-059322, Ic-52; **44, 45,** *Tetrataxis* cf. *paraconica* Reitlinger, 1950; 44, D2-059421, Ic-55; 45, D2-059394, Ic-54; **48,** *Polytaxis* sp., D2-059273, Ic-47. Scale bar is 1 mm; bar A for 24, 25, 27, 29; bar B for 14, 26, 30, 42; bar C for 45, 48; bar D for 22, 28, 43, 44; bar E for 1, 10–12, 15, 18; bar F for 2–9, 13, 16, 17, 19–21, 23, 31–41, 46, 47.

Figure 5. **1,** *Iriclinella mameti*; 1, D2-059465, Ic-60; **2–4,** *Endothyra paraprisca* Schlykova, 1951; 2, D2-059029, Ic-30; 3, D2-059156, Ic-38; 4, D2-059108, Ic-35; **5–11,** *Endothyra* cf. *expressa* Ganelina, 1956; 5, D2-036012; 6, D2-059201; 7, D2-036029; 8, 11, D2-036003; 9, D2-035966; 10, D2-035987; 5, 7, 8, Fj-13; 6, Ic-40; 9–11, Fj-12; **12–14,** *Tetratxis* sp.; 12: D2-035883, Fj-12; 13, D2-035952, Fj-12; 14, D2-036029, Fj-13; **15–17,** *Endothyra* sp. B; 15, D2-059521, Ic-62; 16, D2-059145, Ic-38; 17, D-059146, Ic-38; **18–24,** *Endothyra* sp. A; 18, D2-035953; 19, D2-035994; 20, D2-035909; 21, D2-036039; 22, D2-036063; 23, D2-035948; 24, D2-035921; 18, 20, 23, 24, Fj-12; 19, 21, 22, Fj-13; **25–27, 32–35,** *Endothyra igoi*; 25, D2-035881; 26, D2-035874; 27, D2-035956; 32, D2-059306, Ic-50; 33, D2-035948; 34, D2-036033, Fj-13; 35, D2-035915; 25–27, 33, 35, Fj-12; **28, 29,** *Latiendothyra* sp.; 28, D2-059110, Ic-35; 29, D2-059205, Ic-40; **30, 31,** *Planoendothyra* sp.; 30, D2-059488, Ic-61; 31, D2-059143, Ic-38; **36–38,** *Bradyina compressa* Morozova, 1949; 36, D-059201, Ic-40; 37, D2-036015, Fj-13; 38, D2-059500, Ic-62; **39–44,** *Pseudojanischewskina* aff. *akiyoshiensis*; 39, D2-035975; 40, D2-035902; 41, D2-035961; 42, D-035895; 43, D2-035927; 44, D2-059210, Ic-40; 39–43, Fj-12. Scale bar is 1 mm; bar A for 1–11, 15–35; bar B for 36, 37, 39–44; bar C for 12–14, 38.

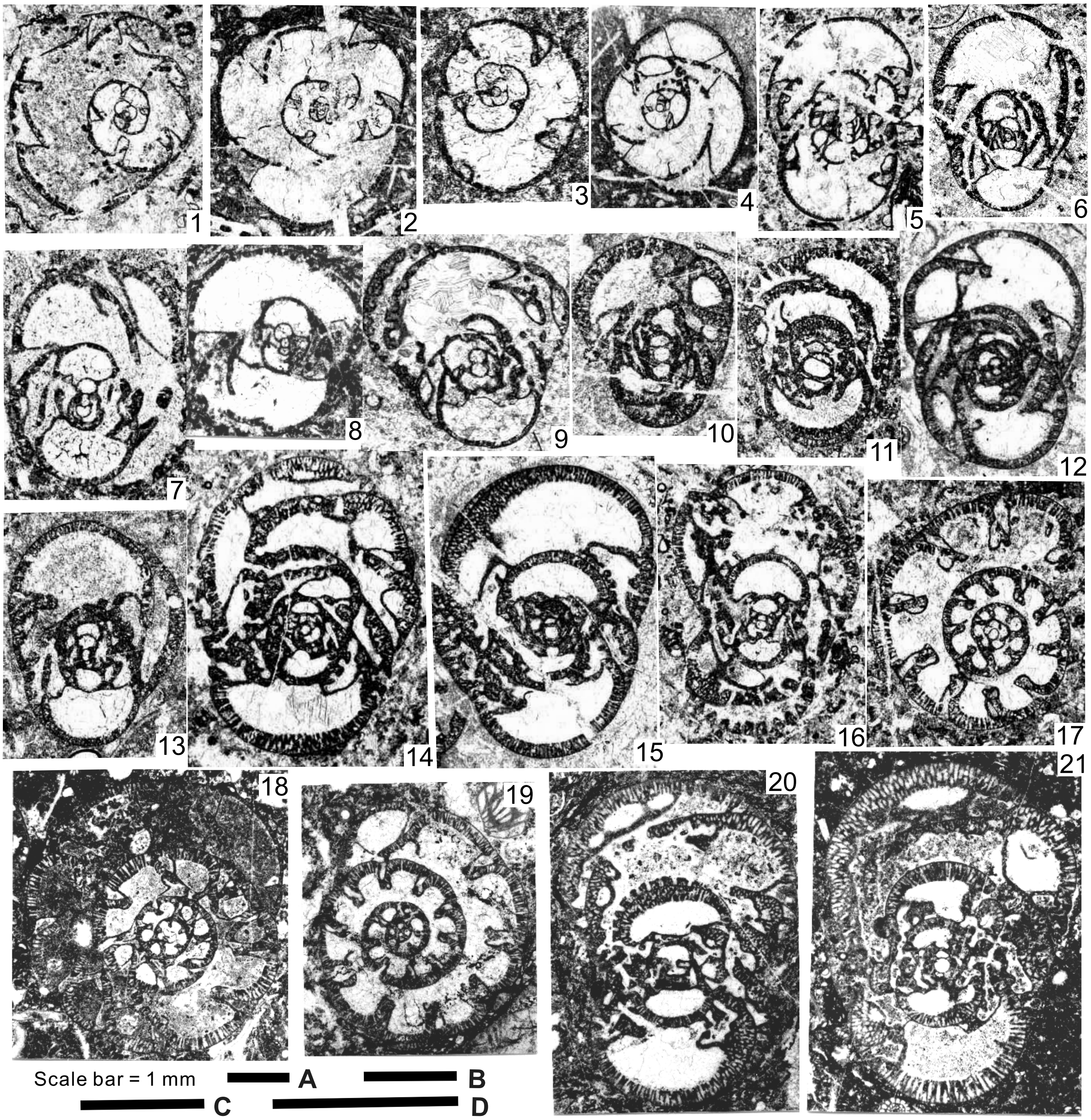

Figure 6. 1–6, *Pseudojanischewskina titanica* sp. nov.; 5, Holotype; 1–4, 6, Paratypes; 1, D2-059382, Ic-54; 2, D2-058940, Ic-29; 3, D2-059004, Ic-30; 4, D2-058934, Ic-29; 5, D2-059492, Ic-61; 6, D2-059502, Ic-62; **7–9,** *Bradyina* aff. *regularis* Lin, 1978; 7, D2-059211, Ic-40; 8, D2-036004, Fj-13; 9, D2-059487, Ic-61; **10,** *Bradyinelloides* sp. A, D2-058933, Ic-29; **11,** *Bradyinelloides* sp. B, D2-059334, Ic-52; **12, 13, 16, 17,** *Bradyina nautiliformis*; 12, D2-058958, Ic-29; 13, D2-058952, Ic-29; 16, D2-059339, Ic-52; 17, D2-059345, Ic-52; **14, 15, 18–21,** *Bradyinelloides paranautiliformis* sp. nov.; 21, Holotype; 14, 15, 18–20, Paratypes; 14, D2-059288, Ic-49; 15, D2-058964, Ic-29; 18, D2-036021, Fj-12; 19, D2-036036, Fj-13; 20, D2-036030, Fj-13; 21, D2-036020, Fj-12. Scale bar is 1 mm; bar A for 2, 4, 5, 18, 19; Bar B for 1, 3, 6, 11, 12, 14–17, 20, 21; bar C for 9, 10, 13; bar D for 7, 8.

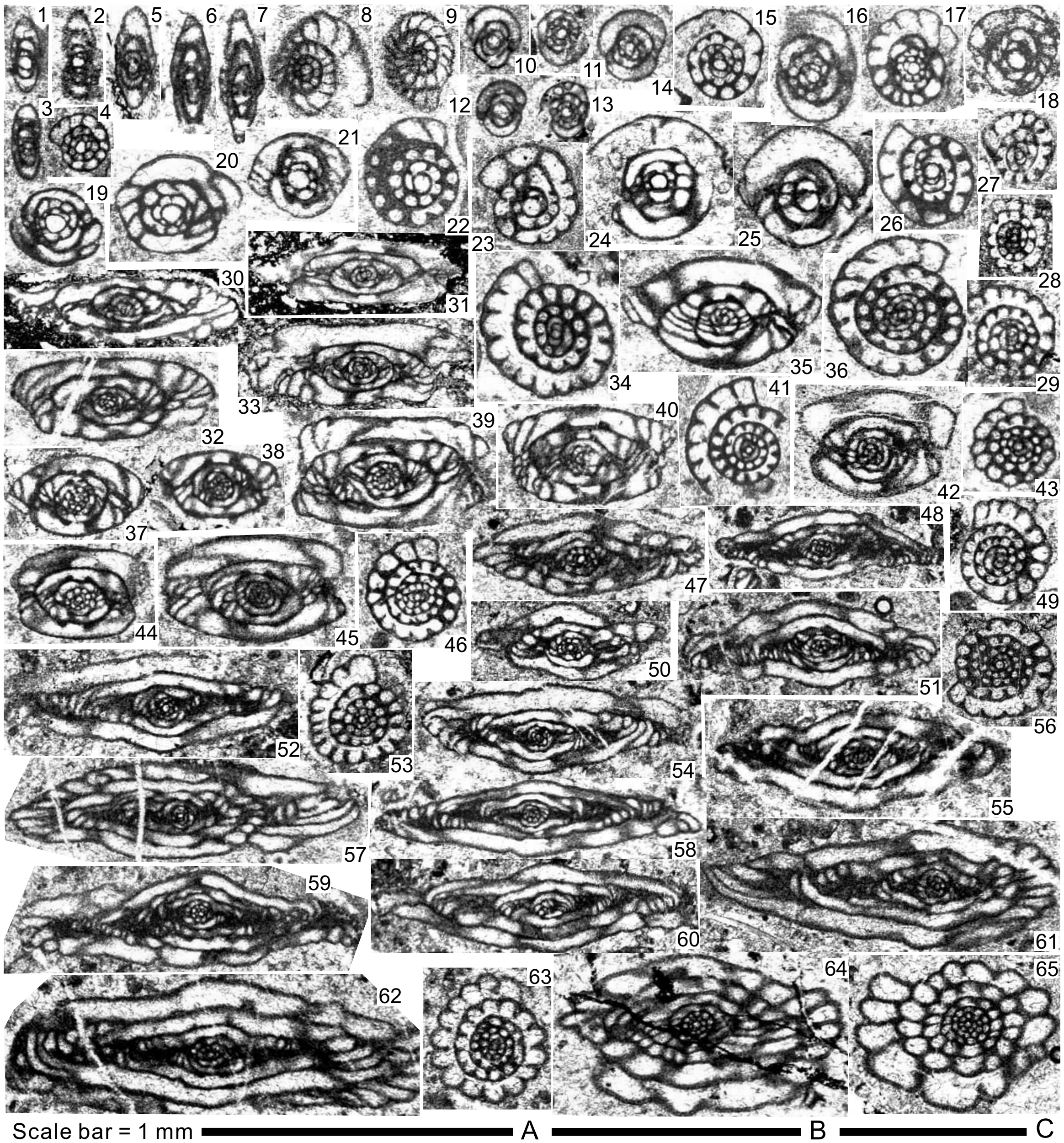

Figure 7. **1–5,** *Eostaffella* spp.; 1, D2-058949, Ic-29; 2, D2-058980, Ic-30; 3, D2-059448, Ic-58; 4, D2-059032, Ic-30; 5, D2-058949, Ic-29; **6–9,** *Ozawainella* cf. *angulata*; 6, D2-059386, Ic-54; 7, D2-059381, Ic-54; 8, D2-058966, Ic-29; 9, D2-059015, Ic-30; **10–13,** *Semistaffella variabilis*; 10, D2-059046, Ic-30; 11, D2-059323, Ic-52; 12, D2-05896, Ic-29; 13, D2-059259, Ic-45; **14–18,** *Semistaffella multiforme*; 14, D2-058956, Ic-29; 15, D2-059519, Ic-62; 16, D2-058951, Ic-29; 17, D2-059402, Ic-54; 18, D2-059267, Ic-46; **19–22,** *Eoschubertella obscura*; 19, D2-059391, Ic-54; 20, D2-059321, Ic-52; 21, D2-058936, Ic-29; 22, D2-058953, Ic-29; **23–26,** *Eoschubertella* sp.; 23, D2-058948, Ic-29; 24, D2-059406, Ic-54; 25, D2-058957, Ic-29; 26, D2-059389, Ic-54; **27, 28, 43, 47, 48, 50–52,** *Fusiella typica*; 27, D2-059066, Ic-33; 28, D-059109, Ic-35; 43, D2-059363, Ic-53; 47, D2-059511, Ic-62; 48, D2-059335, Ic-52; 50, D2-059105, Ic-35; 51, D-059336, Ic-52; 52, D2-059322, Ic-52; **29–33,** *Schubertella kingi*; 29, D2-059355, Ic-52; 30, D-059159, Ic-38; 31, D2-059145, Ic-38; 32, D2-059008, Ic-30; 33, D2-059163, Ic-38; **34–36,** *Eoschubertella magna*; 34, D2-059003, Ic-30; 35, D2-059453, Ic-58; 36, D2-059499, Ic-62; **37, 38, 44,** *Eoschubertella lata*; 37, D2-059369, Ic-53; 38, D2-059337, Ic-52; 44, D2-059348, Ic-52; **39–42, 45, 46,** *Schubertella mjachkovensis*; 39, D2-059349; 40, D2-059324; 41, D2-059337; 42, D2-058983; 45, D2-059031; 46, D2-059341; 42, 45, Ic-30; others, Ic-52; **49, 53–63,** *Fusiella hayashii*; 49, D2-059087, Ic-34; 53, D2-059151, Ic-38; 54, D2-059363; 55, D2-059309, Ic-50; 56, D-059363; 57, D2-059376; 58, D2-059366; 59, D2-059350; 60, D2-059335; 61, D2-059330; 62, D-059354; 63, D2-059328; 54, 56–58, Ic-53; 59–63, Ic-52; **64, 65,** *Fusiella* sp.; 64, D2-059304; 65, D2-059315; both Ic-50. Scale bar is 1 mm; bar A for 1–14, 16, 18, 21–23, 25, 27–29, 34, 36, 43, 49, 53, 56; bar B for 15, 17, 19, 20, 24, 26, 30–33, 35, 37–42, 44–47, 50, 52, 55, 61–65; bar C for 48, 51, 54, 57–60.

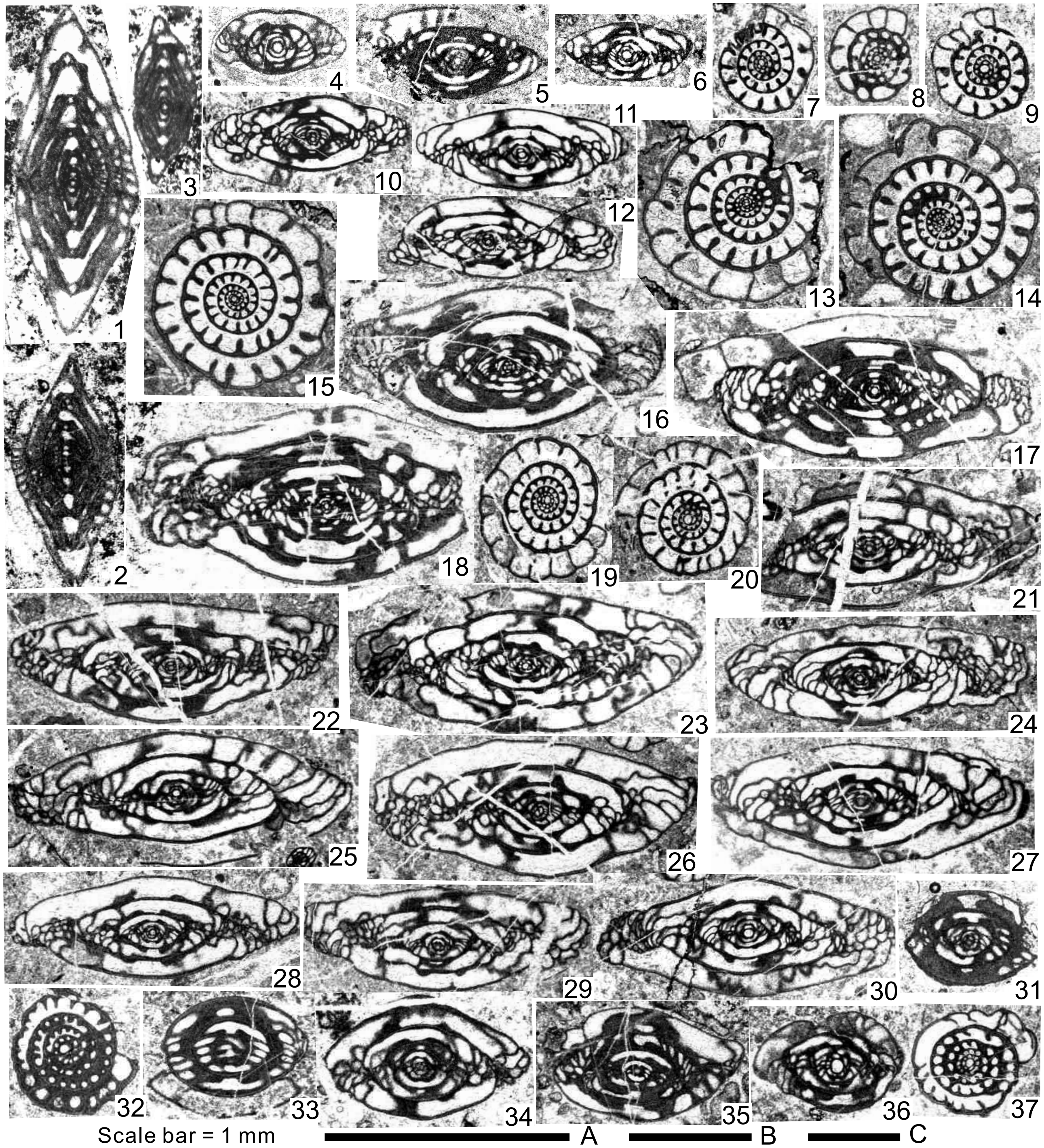

Figure 8. **1–3,** *Ozawainella vozhgalica*; 1, 3, D2-035895, Fj-12; 2, D2-059181, Ic-40; **4, 5,** *Fusulinella kamitakarensis*; 4, D2-058890; 5, D2-058898; both Ic-27; **6–12,** *Fusulinella* sp.; 6, D2-059014; 7, D2-059032; 8, D2-058999; 9, D2-058981; 10, D2-059003; 11, D2-059039; 12, D2-058996; all Ic-30; **13–18,** *Fusulinella pseudobocki*; 13, D2-058945; 14, D2-058931; 15, D2-058935; 16, D2-058937; 17, D2-058948; 18, D2-058953; all Ic-29; **19–30,** *Fusulinella hanzawai*; 19, D2-058975; 20, D2-059006; 21, D2-059004; 22, D2-058982; 23, D2-058993; 24, D2-059036; 25, D2-059044; 26, D2-058998; 27, D2-058987; 28, D2-059028; 29, D2-058966; 30, D2-059042; all Ic-30; **31–37,** *Fusulinella asiatica*; 31, D2-059360, Ic-53; 32, D2-059390, Ic-54; 33, D2-059133, Ic-37; 34, D2-059411, Ic-55; 35, D2-059080, Ic-34; 36, D2-059112, Ic-30; 37, D2-058974, Ic-30. Scale bar is 1 mm; bar A for 1–3; bar B for 4, 5, 31–37; bar C for 6–30.

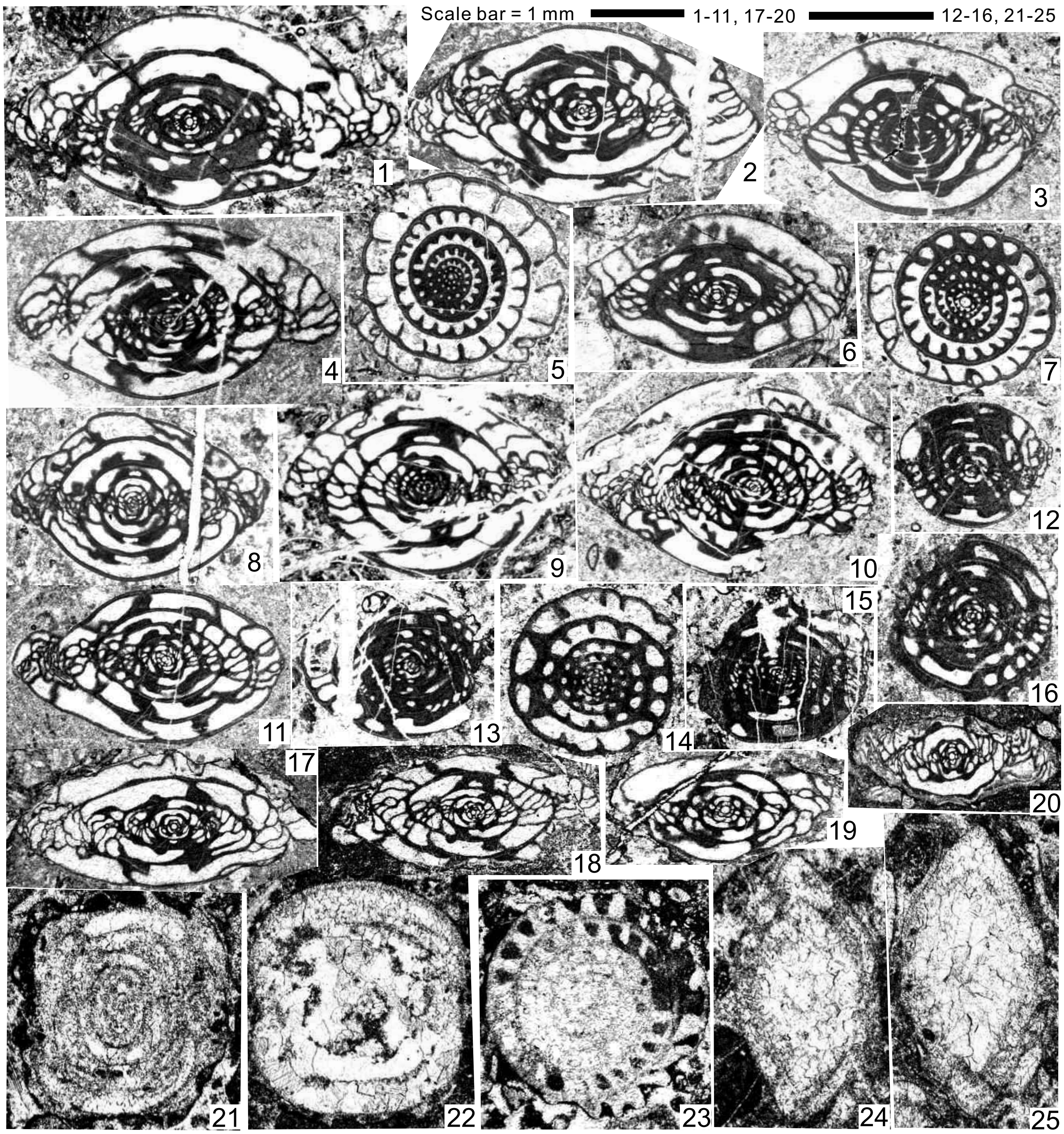

Figure 9. **1–7,** *Fusulinella rhomboidalis*; 1, D2-059090, Ic-34; 2, D2-059440, Ic-58; 3, D2-059361, Ic-53; 4, D2-059446, Ic-58; 5, D2-059343, Ic-52; 6, D2-059088, Ic-34; 7, D2-059476, Ic-61; **8–11,** *Fusulinella soligalichi*; 8, D2-059477, Ic-61; 9, D2-059261, Ic-45; 10, D2-059442, Ic-58; 11, D2-059437, Ic-58; **12–16,** *Fusulinella igoi* sp. nov.; 16, Holotype; 12–15, Paratypes; 12, D2-059335, Ic-52; 13, D2-059373, Ic-53; 14, D2-059415, Ic-55; 15, D2-059323, Ic-52; 16, D2-059341, Ic-52; **17–20,** *Protriticites ovatus*; 17, D2-059108; 18, 20, D2-059100; 19, D2-059103; all Ic-35; **21–23,** *Staffella* sp.; 21, D2-059078; 22, D2-059095; 23, D2-059075; all Ic-34; **24, 25,** *Reitlingerina* sp., both D2-058960, both Ic-29. Scale bar is 1 mm.

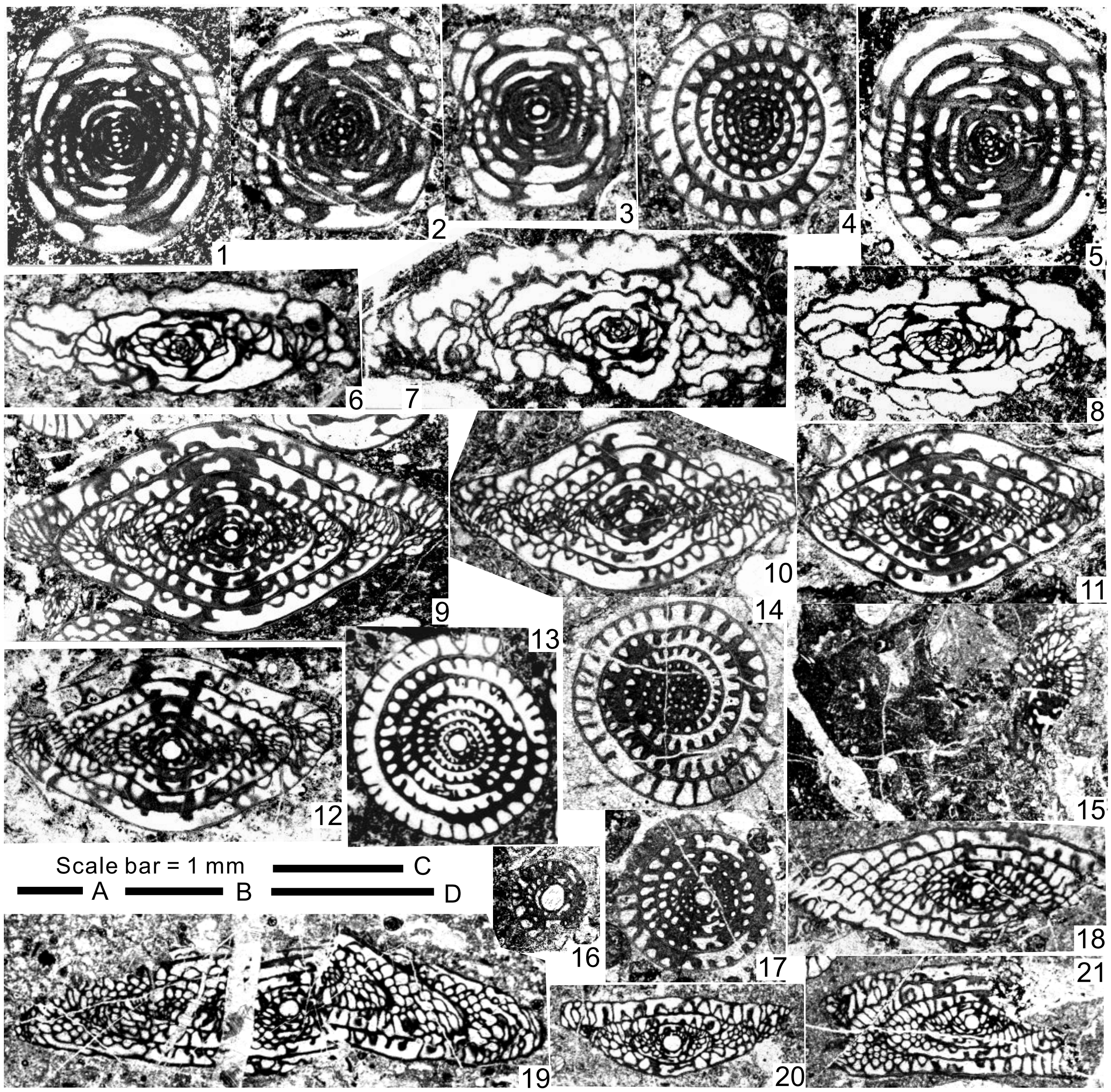

Figure 10. **1–5,** *Neostaffella umbilicata*; 1, D2-036063; 2, D2-059180; 3, D2-59189; 4, D2-059182; 5, D2-036024; 1, 5, Fj-13; 2–4, Ic-40; **6–8,** *Hidaella kamei*; 6, D2-059203, Ic-40; 7, D2-035889, Fj-12; 8, D2-035856, Fj-12; **9–13,** *Beedeina lanceolata*; 9, D2-036044, Fj-13; 10, D2-059198, Ic-40; 11, D2-059205, Ic-40; 12, D2-036033, Fj-13; 13, D2-003984, Ic-1A; **14,** *Beedeina* sp. A, D2-058951, Ic-29; **15,** wackestone with *Fusulina*? sp., D2-058917, Ic-28; **16,** *Fusulina* sp., D2-059093, Ic-34; **17,** *Beedeina* sp. B, D2-059081, Ic-34; **18–21,** *Fusulina kamensis*; 18, D2-059019; 19, D2-058969; 20, D2-058999; 21, D2-058995; all Ic-30. Scale bar is 1 mm; bar A for 15, 16, 18–21; bar B for 9–14, 17; bar C for 6–8; bar D for 1–5.

(Figure 6.20), and two nearly centered transverse sections (Figure 6.18, 6.19). Their registration numbers and sample localities are shown in the explanation of Figure 6.

Type locality.—Ichinotani, Fukuji, Takayama City, Gifu Prefecture.

Diagnosis.—Large nautiloid test involute and almost planispirally coiled. Thick lenticular first whorl is followed by rapidly expanding nautiloid outer whorls planispirally coiled. Wall thick and composed of tectum and coarsely and regularly perforate keriotheca in the middle and outer whorls. Septa accompany the post-septal lamella converging toward the septa.

Measurement.—Diameter = 3.18 to 4.53 mm, width = 2.02 to 2.47 mm, width/diameter = 0.61 to 0.71, number of whorls = 3.5 to 4.5, diameter of proloculus = 0.09 to 0.15 mm, wall thickness in the final whorl = 0.20 to 0.28 mm.

Description.—Test nautiloid, involute and almost planispirally coiled, and consisting of three and a half to four and a half whorls with a broardly rounded periphery and shallow umbilicus. Proloculus spherical and small for the test size. Thick lenticular first whorl is followed by rapidly expanding and planispirally coiled outer whorls without marked oscillation of the axis of coiling. Wall very thick and consists of microgranular tectum, and a coarsely and regularly perforate keriotheca in the middle and outer whorls. Septa inclined anteriorly and thickened from the second whorl. Post-septal lamella converging toward the septa form chamberlets near the septa.

Remarks.—Although the present specimens resemble *Bradyina nautiliformis* or its allies, they are assigned to *Bradyinelloides* by their thicker wall with a more coarsely perforate keriotheca than those of *Bradyina*. They are referable to a new species of the genus, since the size of the test is much larger and the wall is much thicker than those of the known species of bradyinids. Two specimens described by Adachi (1985, p. 117, pl. 19, figs. 8, 9) named as *Bradyina* sp. D from the Upper Member of the Ichinotani Formation are reassigned to *Bradyinelloides*. Although they are poorly oriented far from the center and smaller, they might be allied to this new species.

Occurrence.—Common in the *Beedeina lanceolata* Zone (Fj-12, Fj-13), and rare in *Fusulinella hanzawai*-*Fusulina kamensis* Zone (Ic-29) and rare in the *Fusulinella rhomboidalis*-*Fusulinella sologalichi* Zone (Ic-49).

Genus ***Pseudojanischewskina*** Mamet and Pinard, 1992

Type species.—*Pseudojanischewskina multicribrata* Mamet and Pinard, 1992.

Pseudojanischewskina titanica sp. nov.

Figure 6.1–6.6

ZooBank lsid: urn:lsid:zoobank.org:act:B71CD03E-DA2B-445F-89E2-8796AFF90721

Etymology.—From a large test.

Type specimens.—Holotype MNHAH D2-059492 (axial section, Figure 6.5) from Ic-61. Paratypes: one axial section Figure 6.6), four transverse sections (Figure 6.1–6.4). Their registration numbers and sample localities are shown in the explanation of Figure 6.

Type locality.—Ichinotani, Fukuji, Takayama City, Gifu Prefecture.

Diagnosis.—Large nautiloid test with shallow umbilical depressions. Lenticular inner one to two whorls are somewhat skewed to rapidly expanding nautiloid outer whorls. Wall thin, even in the outer whorls, composed of tectum and finely porous layer. Loosely-spaced few septa curved anteriorly. Septal lamellae converging toward the septa form chamberlets near the septa.

Measurement.—Diameter = 2.14 to 3.41 mm, width = 1.33 to 1.88 mm, width/diameter = 0.58 to 0.63, number of whorls = 3.5 to 3.9, diameter of proloculus = 0.05 to 0.10 mm, wall thickness in the final whorl = 0.04 to 0.08 mm.

Description.—Test nautiloid, nearly planisirally coiled, and with shallow umbilical depressions. Proloculus minute to small. Inner one to two whorls lenticular, thin to very thin, and somewhat skewed to the rapidly expanding outer whorls. Wall very thin and not differentiated in the inner lenticular whorls. Wall still thin in the outer whorls and composed of a very thin microgranular tectum and inner granular, finely porous layer similar to keriotheca. Septa short, few, loosely spaced, and curved anteriorly. Septal lamellae converging toward the septa form chamberlets near the septa.

Remarks.—Detailed comparison to the type species of the genus (*Pseudojanischewskina multicribrata*) is not easy, because no axial sections and no centered transverse sections were illustrated in Mamet and Pinard (1992). Size and shape of the test, and loosely spaced septa in transverse sections of this new species resemble those of the type species, but the former has a thinner wall and thicker septa than the latter. The former might be also distinguished from the latter probably by its minute proloculus and no differentiation of wall in the inner lenticular whorls. *Pseudojanichewskina tiainica* is distinguished from *P. akiyoshiensis* Kobayashi and Vachard, 2019 and *P.* aff. *akiyoshiensis* Kobayashi and Vachard, described below, by its much larger test and more number of septa. *Bradyina* sp. F described by Adachi (1985) from the Upper Member of the Ichinotani Formation, reassigned to *Pseudojanischewskina* by Kobayashi and Vachard (2019), is different from this new species by having a larger proloculus and loosely coilied whorl(s) in juvenile stage.

Occurrence.—Common to rare in the *Fusulinella hanzawai–Fusulina kamensis* Zone (Ic-29, Ic-30) and in the upper part of the *Fusulinella rhomboidalis*-*Fusulinella soligalichi* Zone (Ic-54, Ic-61, Ic-62).

Pseudojanischewskina aff. ***akiyoshiensis*** Kobayashi and Vachard, 2019

Figure 5.39–5.44

Aff. *Pseudojanischewskina akiyoshiensis* Kobayashi and Vachard, 2019, p. 371, pl. 3, figs. 24–29, 32, 33.

Remarks.—Tightly coiled inner lenticular whorls more or less skewed to rapidly expanding outer nautiloid whorls of the present Ichinotani specimens are closely similar to those of *Pseudojanischewskina akiyoshiensis* described by Kobayashi and Vachard (2019). They are also similar in their small proloculus, very thin microgranular wall in inner whorls, and short septa with preseptal and postseptal lamellae. On the other hand, the present specimens have a smaller test, lower chamber height in the outer whorls, and thicker wall with a more distinct porous layer referable to keriotheca in the outermost whorl of most specimens.

Genus ***Semistaffella*** Reitlinger, 1971

Type species.—*Pseudostaffella variabilis* Reitlinger, 1971.

Semistaffella variabilis (Reitlinger, 1961)

Figures 7.10–7.13

Pseudostaffella variabilis Reitlinger, 1961, p. 240, pl. 3, fig. 8; Brazhnikova *et al*., 1967, pl. 21, fig. 22.
Pseudostaffella primitiva Reitlinger, 1961, p. 241, pl. 3, fig. 9.
Semistaffella variabilis (Reitlinger, 1961). Reitlinger, 1971, pl. 1, figs. 11, 12; Brenckle, 2005, p. 86, pl. 15, figs. 5, 6; Kobayashi, 2019, p. 12, figs. 4.15–4.17.
Semistaffella primitiva (Reitlinger, 1961). Reitlinger, 1971, pl. 1, fig. 13.
Pseudostaffella (*Semistaffella*) *variabilis* (Reitlinger, 1961). Groves, 1988, p. 391, figs. 17.22–17.29.

Remarks.—The illustrated four specimens are closely similar to *Semistaffella variabilis* first described by Reitlinger (1961) from the core samples of the lower Akavasky Horizon (lower Bashkirian) of the Russian Platform and later reassigned to *Semistaffella* by Reitlinger (1971) in their size and shape of the test with irregularly coiled whorls throughout growth. In Japan, this species was described from the Bashkirian limestone block at Tatego, Yura area, Wakayama Prefecture (Kobayashi, 2019). Although the illustrated specimens herein are younger than the Yura specimens, they are closely related morphologically and not easily distinguished from each other.

Semistaffella multiforme (Villa in Villa and Merino-Tomé, 2016)

Figure 7.14–7.18

Schubertella multiforme Villa in Villa and Merino-Tomé, 2016, p. 249, figs. 8.1–8.11.

Remarks.—The illustrated five specimens are different from *Semistaffella variabilis*, described above, by having a larger test, more rapidly and regularly expanding outer whorls planispirally coiled at a large angle to the inner whorls. They are closely similar to and identified with *Semistaffella multiforme* originally assigned to *Schubertella* by Villa. This species, described from the Bashkirian/Moscovian of the Cantabrian Mountains (NW Spain), exhibits broad intraspecific variations in size and shape of the test, development of chomata, and other features. Villa assumed that this species belongs to the "*Schubertella*" *obscura* species group from the similarities of size and shape of the test.

Genus ***Eoschubertella*** Thompson, 1937

Type species.—*Schubertella obscura* Lee and Chen in Lee *et al*., 1930.

Eoschubertella obscura (Lee and Chen in Lee *et al*., 1930)

Figure 7.19–7.22

Schubertella obscura Lee and Chen in Lee *et al*., 1930, p. 112, 113, pl. 6, figs. 12–22; Sheng, 1958, p. 20, pl. 2, figs. 21–26.
Eoschubertella obscura (Lee and Chen, 1930). Igo, 1957, p. 187, 188, pl. 3, figs. 9–11; Toriyama, 1958, p. 25–27, pl. 1, figs. 10–14; Niikawa, 1978, pl. 5, fig. 8; Kobayashi, 2017, p. 37, pl. 1, figs. 6–10.
Eoschubertella sp. A Toriyama, 1958, p. 27, 28, pl. 1, figs. 15, 19.
Eoschubertella toriyamai Ishii, 1962, p. 5, 6, pl. 6, figs. 23–37.
Eoschubertella cf. *obscura* (Lee and Chen, 1930). Ishii, 1962, p. 8, 9, pl. 6, figs. 41–44.
Schubertella sp. 2 ex gr. *obscura* Lee and Chen. Villa and Ginkel, 2000, p. 230, 231, pl. 2, figs. 13–16.
Schubertella cf. *toriyamai* (Ishii, 1962). Villa and Ginkel, 2000, p. 231, pl. 2, fig. 17.

Remarks.—This species, first described from the Moscovian Huanglung Limestone of southeast China, was designated as the type species of *Eoschubertella* by Thompson (1937). Eleven type specimens illustrated are considerably variable in shape and size, the number of whorls, and coiling pattern of the test. Though uncertain, some specimens (pl. 6, figs. 16, 17 in Lee *et al*., 1930) seem better separated from others by their tightly coiled inner whorls, smaller proloculus, and more number of whorls. Four specimens illustrated herein, and identified with this species, are different from *Semistaffella multiforme*, described above, in having a larger proloculus, thicker wall, and less rapidly expanding whorls. Despite the similarities of a large proloculus and few whorls, *Eoschubertella* sp. (Figure 7.23–7.26) is distinguished from this species by its more rounded test with greater length and width of corresponding whorls. *Eoschubertella toriyamai* proposed by Ishii (1962) from the Moscovian limestone of western Shikoku was distinguished from *E. obscura* by its almost absent or rudimentary chomata, whereas specimens with more distinct chomata were compared to this species by Ishii (1962). Variable test characters of these two species described by Ishii (1962) are presumed to represent the broad intraspecific variations of *E. obscura*.

Eoschubertella lata (Lee and Chen in Lee *et al*., 1930)

Figure 7.37, 7.38, 7.44

Schubertella lata Lee and Chen in Lee *et al*., 1930, p. 111, pl. 6, figs. 9–11; Niikawa, 1978, pl. 5, figs. 6, 7.
Eoschubertella lata (Lee and Chen, 1930). Igo, 1957, p. 186, 187, pl. 3, figs. 6–8; Leven and Davydov, 2001, p. 15, pl. 1, figs. 10, 11.
Eoschubertella cf. *lata* (Lee and Chen, 1930). Ishii, 1962, p. 6–8, pl. 6, figs. 38–40.

Remarks.—Morphologic variations of schubertellids identified with this species by Igo (1957) and Niikawa (1978) are not obvious because of few well-oriented specimens. The illustrated three and other specimens herein have a small test with shallowly depressed poles, minute proloculus, and tightly coiled initial few whorls followed by planispirally coiled later whorls at large angles. They are identified with *Eoschubertella lata* by these test characters common to those of the types.

Eoschubertella magna (Lee and Chen in Lee *et al*., 1930)

Figure 7.34–7.36

Schubertella magna Lee and Chen in Lee *et al*., 1930, p. 113, pl. 6, figs. 24, 25; Rauzer-Chernousova *et al*., 1951, p. 82, pl. 3, fig. 17; Sheng, 1958, p. 22, pl. 2, fig. 36; Kobayashi, 2017, p. 37, 38, pl. 1, figs. 13–15, 19–21.

Remarks.—In spite of no axial sections, the present specimens are distinguished from other species of *Eoschubertella* from the Ichinotani Formation by their larger fusiform test with bluntly pointed poles. They are closely similar to and identified with *Schubertella magna* first described from the Huanglung Limestone by Lee and Chen, and later by Rauzer-Chernousova *et al*. (1951) from the Moscovian, mainly from the Kashirian and Podolskian of Russia, and by Sheng (1958) from the Penchi Series of Taitzeho, Liaoning in their size, shape, and coiling pattern of the test, and small proloculus. This species is assigned to *Eoschubertella* and not to *Schubertella* herein, based on plane septa throughout their growth.

Genus ***Schubertella*** Staff and Wedekind, 1910

Type species.—*Schubertella transitoria* Staff and Wedekind, 1910.

Schubertella kingi Dunbar and Skinner, 1937

Figure 7.29–7.33

Schubertella kingi Dunbar and Skinner, 1937, p. 610, 611, pl. 45, figs. 10–8.15; Toriyama, 1958, p. 73–75, pl. 7, figs. 1–8; par Igo, 1957, p. 192, 193, pl. 4, figs. 9–11, 13–15, non pl. 4, figs. 12; non Niikawa, 1978, pl. 5, figs. 9, 10; Kobayashi, 2017, p. 37, pl. 1, figs. 22, 23, 26–30.

Remarks.—Elongate fusiform to subcylindrical forms of *Schubertella* illustrated herein resemble *S. kingi* proposed from the Wolfcampian of Texas (Dunbar and Skinner, 1937) in many respects. They are also similar to *Schubertella donetzica* Putrya, 1940 from the upper part of the Moscovian of the Donetz Basin (Putrya, 1940), but have a more elongate test with fewer inner endothyroid whorls. Some specimens listed above from Ichinotani, identified with *S. kingi* by Igo (1957) and Niikawa (1978), are separated from this species by their not so elongate test.

Schubertella mjachkovensis Rauzer-Chernousova in Rauzer-Chernousova *et al*., 1951

Figure 7.39–7.42, 7.45, 7.46

Schubertella mjachkovensis Rauzer-Chernousova in Rauzer-Chernousova *et al*., 1951, p. 84, 85, pl. 3, fig. 21, pl. 4, fig. 1; Leven and Davydov, 2001, p. 15, pl. 1, fig. 9.

Remarks.—The present specimens are characteristic in their short subcylindrical to oval test with broadly arched to almost straight periphery and distinct umbilical cavities, and minute proloculus. Discoidal to lenticular inner few whorls are skewed to fusiform, three to three and a half outer whorls planispirally coiled. Septa are plane to weakly folded in the polar regions. From these morphologic features, they are identified with *Schubertella mjachkovensis* known from the early Moscovian (Kashirian) to Kasimovian of eastern European Platform (Rauzer-Chernousova *et al*., 1951) and southwestern Darvas (Leven and Davydov, 2001). They are distinguished from *Schubertella donezica* by their shorter subcylindrical test with more distinct umbilical cavities, from *Eoschubertella magna* by their test with distinct umbilical cavities and weakly folded septa, and from *Eoschubertella lata* by their larger test and thicker wall.

Genus ***Fusiella*** Lee and Chen in Lee *et al*., 1930

Type species.—*Fusiella typica* Lee and Chen in Lee *et al*., 1930.

Fusiella typica Lee and Chen in Lee *et al*., 1930

Figure 7.27, 7.28, 7.43, 7.47, 7.48, 7.50–7.52

Fusiella typica Lee and Chen in Lee *et al*., 1930, p. 107, 108, pl. 6, figs. 1–6; Rauzer-Chernousova *et al*., 1951, p. 87, 88, pl. 4, figs. 7, 8; Igo, 1957, p. 188, pl. 3, figs. 12–15, 18; Niikawa, 1978, p. 571, pl. 12, figs. 6–8.
Fusiella paradoxa Lee and Chen in Lee *et al*., 1930, p. 108, 109, pl. 6, figs. 7, 8.
Fusiella praecusor Rauzer-Chernousova in Rauzer-Chernousova *et al*., 1951, p. 90, 91, pl. 4, figs. 15–17; par Niikawa, 1978, p. 569, 570, pl. 5, figs. 13, 14, non pl. 5, figs. 15, 16 (*Fusiella hayashii*).
Fusiella praelancetiformis Safonova in Rauzer-Chernousova *et al*., 1951, p. 91, 92, pl. 5, fig. 1.
Fusiella praetypica Safonova in Rauzer-Chernousova *et al*., 1951, p. 89, 90, pl. 4, figs. 13, 14.
Fusiella inouei Igo, 1957, p. 190, par pl. 3, figs. 16, 19, non pl. 3, fig. 17 (*Schubertella* indet.); Niikawa, 1978, p. 570, 571 pl. 5, figs. 17, 18.
Fusiella typica var. *sparsa* Sheng, 1958, p. 81, 82, pl. 3, figs. 3–8.
Fusiella typica sparsa Sheng, 1958. Ishii, 1962, p. 9, 10, pl. 6, figs. 45, 46, pl. 7, figs. 1–15, 17, 18.
Fusiella cf. *mui* Sheng, 1958. Niikawa, 1978, p. 570, pl. 5, fig. 12.

Remarks.—This species was proposed by Lee and Chen from the base of the Huanglung Limestone in southeast China. Other species and subspecies listed above are more or less similar to the original specimens of *Fusiella typica* and not easily distinguished from the original ones. They are supposed to be junior synonyms of *typica*, including *F*. *typica* var. *sparsa* by Sheng from the Penchi Series of of the Taitzeho Valley and *F*. *typica sparsa* by Ishii from western Shikoku, which were separated from *F*. *typica* by their fewer whorls, and less prominent chomata and axial fillings. Three specimens identified with *F*. *typica* by Leven and Davydov (2001) from the middle Kasimovian of southwestern Darvas are different from the types by having more whorls and more pointed poles of the middle and outer whorls.

Among the illustrated specimens assigned to *Fusiella* from the Ichinotani Formation, one specimen of *Fusiella inouei* by Igo (1957) might be reassigned to *Schubertella* on account of its weakly folded septa in axial regions and massive chomata. Two specimens named as *Fusiella praecusor* by Niikawa (1978) are transferred to *F*. *hayashii*, described below, by their larger test with not broadly arched periphery and concave lateral sides, and more whorls.

Fusiella hayashii Igo, 1957

Figure 7.49, 7.53–7.63

Fusiella hayashii Igo, 1957, p. 191, pl. 4, figs. 1–8.
Fusiella spatiosa Sheng, 1958, p. 24, 82, pl. 3, fig. 14.
Fusiella praecusor Rauzer-Chernousova. par Niikawa, 1978, p. 569, 570, pl. 5, figs. 15, 16, non pl. 5, figs. 13, 14 (*Fusiella typica*).

Remarks.—Igo (1957) proposed *Fusiella hayashii* for the form having larger test with more whorls than *Fusiella typica*. In the illustrated eight types, broad variations are recognized in the mode of shift of the axis of coiling ontogenetically, periphery and lateral sides of the test, and chamber height of corresponding whorls. These variabilities might lead to variable appearances of size and shape of the test in thin sections as well as in the orientation of axial sections of mature stage. More or less different appearances of the twelve specimens illustrated herein are inferred to be connected with the broad intraspecific variations of this species, with an orientation of an axial section, and with either mature or immature stage of a specimen. These morphologic variabilities in this species are more clearly discernible in many axial sections of this species from the *Beedeina lanceolata* Zone of the Ichinotani Formation not illustrated in this paper, because they will be described and illustrated elsewhere. *Fusiella* sp. (Figure 7.64, 7.65) is distinguished from this species by its larger test, more whorls, and larger height of chambers.

Elongate forms of this species are similar to *Fusiella elongatissima* Putrya, 1940 and *F. lancetiformis* Putrya, 1940 originally described from the Kasimovian of the Donetz Basin (Putrya, 1940). However, these two Russian species have a much more elongate test with broadly flattened periphery, more whorls, and lesser-developed chomata than *F. hayashii*. *F. lancetiformis* was also reported by Sheng (1958), though not illustrated, from possibly the Myachkovian of the Penchi Series of the Taitzeho Valley. Although a detailed comparison of *F. hayashii* to *F. spatiosa* is not easy because of only one specimen illustrated by Sheng, both species are presumably conspecific from their common test characters such as an elongate fusiform test with not broadly arched periphery and concave lateral sides, and poorly developed axial fillings and chomata. *Fusiella segyrdashtiensis* proposed from the middle Kasimovian of southwestern Darvas by Davydov in Leven and Davydov (2001) is distinguished from *F. hayashii* by its more whorls attaining to eight, and more massive axial fillings.

Genus ***Fusulinella*** von Möller, 1877

Type species.—*Fusulinella bocki* von Möller, 1878.

Fusulinella asiatica Igo, 1957

Figure 8.31–8.37

Fusulinella (*Neofusulinella*) *bocki* von Möller, 1878. Lee and Chen in Lee *et al*., 1930, p. 121, 122, pl. 8, figs. 8–15, pl. 9, figs. 1–9.

Fusulinella asiatica Igo, 1957, p. 202–204, pl. 6, figs. 4–22.

Remarks.—Herein the illustrated seven and many other specimens are identified with Igo's (1957) type material showing broad intraspecific variations. They are common in many test characters such as shape and size of the test and of corresponding whorls, size of the proloculus, the degree of askew coiling between inner and outer whorls, and development of chomata. As pointed out by Igo (1957), specimens identified with *Fusulinella bocki* by Lee and Chen, listed above, are transferred to this species.

Fusulinella hanzawai Igo, 1957

Figure 8.19–8.30

Fusulinella hanzawai Igo, 1957, p. 209–211, pl. 7, figs. 10–21.
Fusulinella schubertellinoides elshanica Rauzer-Chernousova in Rauzer-Chernousova *et al*., 1951. Niikawa, 1978, p. 550, pl. 6, figs. 8, 9.
Fusulinella colaniae (Lee and Chen in Lee *et al*., 1930). par Niikawa, 1978, p. 547, 548, pl. 6, figs. 10, 12, non pl. 6, figs. 11, 13 (possibly *Fusulinella pseudobocki*).

Description.—Test fusiform to elongate fusiform with a broadly arched periphery, straight to slightly convex lateral sides, and narrowly rounded to bluntly pointed poles, and composed of five to six whorls. Length 3.06 to 3.80 mm and width 1.06 to 1.60 mm, giving a form ratio of about 2.43 to 2.77.

Proloculus almost spherical, 0.053 to 0.081 mm in diameter. Inner one to one and a half whorls thick lenticular to oval and askew to subsequent whorls gradually increasing their length and width, and form ratio. Wall thin throughout the test, and 0.022 to 0.042 mm in the thicker part of outer whorls. It is undifferentiated in inner one to two whorls. Wall gradually thickened outwards in the succeeding whorls, and consists of an obscure upper tectorium, thin tectum, thin diaphanotheca, and discontinuous lower tectorium in the outer whorls. Diaphanotheca is discernible in all specimens, but it is poorly continuous laterally.

Septa thin and weakly folded in the polar regions of outer whorls. Septal counts 8, 10, 14, 14, 15, and 10> from the first to sixth whorl (Figure 8.19), and 8, 11, 13, 15, and 14< from the first to fifth whorl (Figure 8.20). Tunnel low and its path almost straight, and bordered by low chomata. Axial fillings not present.

Remarks.—Though the test is somewhat larger, the present specimens are identified with *Fusulinella hanzawai* by their fusiform to elongate fusiform test with a broadly arched periphery, relatively thin wall, weakly folded septa, absence of axial fillings, and other features. Two specimens named *Fusulinella schubertellinoides elshanica* by Niikawa (1978) cannot be identified with the original Russian ones by their larger test, larger length and width in corresponding whorls, and weaker chomata. They might be reassigned to this species, as well as two specimens having a relatively thinner wall and weaker chomata among four specimens named *Fusulinella colaniae* by Niikawa (1978). *Fusulinella hanzawai* is distinguished from *Fusulinella itadorigawensis* Ishii, 1962 by its wall structure of a less conspicuous and less continuous diaphanotheca.

Fusulinella igoi sp. nov.

Figure 9.12–9.16

ZooBank lsid: urn:lsid:zoobank.org:act:429FB41B-ADD9-4E3B-AE60-9F80CC7ECD23

Etymology.—In honor of the late Hisayoshi Igo for his contribution to Late Paleozoic paleontologic works.

Type specimens.—Holotype MNHAH D2-059341 (axial section, Figure 9.16) from Ic-52. Paratypes: one tangential section (Figure 9.12), two oblique axial sections (Figures 9.13, 9.15), and one sagittal section (Figure 9.14). Registration numbers and sample localities of four paratypes are shown in the explanation of Figure 9.

Type locality.—Ichinotani, Fukuji, Takayama City, Gifu Prefecture.

Diagnosis.—Subspherical to nearly spherical *Fusulinella* characterized by a relatively small test with broadly rounded poles, minute proloculus, tightly coiled inner few whorls askew to outer subspherical whorls, thick wall with distinct diaphanotheca, and well-developed chomata extending poleward.

Measurement.—Length = 1.25 to 1.87 mm, width = 1.02 to 1.54? mm, length/width = about 0.8 to 1.1, number of whorls = 6.5 to 7, diameter of proloculus = 0.03 to 0.05 mm, wall thickness in the final whorl = 0.05 to 0.07 mm.

Description.—Test subspherical to nearly spherical with broadly rounded poles. Mature test with six and a half to seven whorls. Proloculus minute. Lenticular to oval, tightly coiled inner few whorls are askew to outer subspherical to nearly spherical whorls.

Wall thick for the size of the test, and consists of a discontinuous outer tectorium, tectum, diaphanotheca, and rather thick lower tectorium in outer whorls. Wall differentiation is obscure in inner tightly coiled whorls. Septa also thick, partly covered by secondary deposits, and weakly folded only in the polar regions. They are closely spaced in the inner whorls and become loosely spaced outerward. Septal counts from the second to seventh whorl 11, 12, 13, 15, 14, and 14 in the paratype.

Tunnel low in the inner whorls and gradually higher outward. Its path narrow and almost straight, but irregularly zigzag in some specimens. Chomata well developed, mostly more than a half as high as the chambers and extend toward the poles. They appear asymmetrical partly and more developed than the actual state due to calcareous coated material.

Remarks.—This new species is clearly different from the known species of the genus by its subspherical to nearly spherical test. It is distinguished from *F. asiatica* by its shape of the test, smaller proloculus, more number of and more tightly coiled inner whorls that are more remarkably askew to outer whorls, and taller chomata mostly extending to poles. The shape and size of *Fusulinella igoi* might appear more similar to those of *Staffellaeformes* than of *Fusulinella*. However, this new species cannot be assigned to *Staffellaeformes* because of its thicker wall with a distinct diaphanotheca and more massive chomata.

Occurrence.—Common to rare in five samples (Ic-51–Ic-55) of the middle part of the *Fusulinella rhomboidalis*-*Fusulina soligalichii* Zone.

Fusulinella kamitakarensis Igo, 1957

Figure 8.4, 8.5

Fusulinella kamitakarensis Igo, 1957, p. 201, 202, pl. 6, figs. 1–3; non Niikawa, 1978, p. 548, pl. 6, figs. 4, 6, 7 (incomplete specimens of *Fusulinella*).

Remarks.—This species was thought to be a primitive form of *Fusulinella* by Igo (1957) because of its thin wall with a poorly developed diahanotheca. Three specimens identified with this species by Niikawa (1978) from the uppermost part of the Lower Zone of *Fusulinella*–*Fusulina* are not identified with this species in their thick wall with distinct diaphanotheca. They are assumed to be incomplete specimens of a different species of *Fusulinella* lacking outer whorl(s).

Fusulinella pseudobocki (Lee and Chen in Lee *et al*., 1930)

Figure 8.13–8.18

Neofusulinella pseudobocki Lee and Chen in Lee *et al*., 1930, p. 122, 123, pl. 9, figs. 10–14, pl. 10, figs. 1–7.
Fusulinella pseudobocki (Lee and Chen, 1930). Igo, 1957, p. 207–209, pl. 8, figs. 1–12; par Niikawa, 1978, p. 551, 552, pl. 7, figs. 2–4, non pl. 7, fig. 1 (*Fusulinella*? sp.).

Remarks.—The illustrated six specimens are identified with this species originally described from the middle part of the Moscovian Huanglung Limestone in southeast China in association with *Fusulina quasicylindrica* (Lee, 1927). Among the four specimens illustrated by Niikawa (1978), three correspond to an elongate form of this species. The remaining one is assumed to be separated from this species by its thinner wall and weaker chomata.

Fusulinella rhomboidalis Niikawa, 1978

Figure 9.1–9.7

Fusulinella rhomboidalis Niikawa, 1978, p. 549, 550, pl. 8, figs. 1–9; Kobayashi, 2017, p. 39, 40, pl. 5, figs. 17–23 (from Akiyoshi), p. 23, figs. 8.1–8.6 (8.1 = Niikawa, 1978, pl. 8, fig. 9; figs. 8.2–8.6 = from Omi).

Remarks.—This species proposed from the Lower and Upper zones of *Fusuinella–Fusulina* of the Ichinotani Formation by Niikawa (1978) is also known from the Myachkovian (*Fusulinella bocki–Kanmeraia pulchra* Zone) of the Akiyoshi and Omi limestones (Kobayashi, 2017). It is distinguishable from *Fusulinella bocki* and its allies such as *F. bocki timanica* Rauzer-Chernousova in Rauzer-Chernousova *et al*., 1951 by its tightly coiled inner whorls, more whorls, more strongly folded septa in the polar regions, and weaker development of the chomata. Kobayashi (2017) thought that this species might be a junior synonym of *Fusulinella soligalichi* and its allies, but postponed its taxonomic conclusion on account of little information on the morphologic variations of these Russian species. *Fusulinella rhomboidalis* is distinguished from *Fusulinella biconica* (Hayasaka, 1924) by its thinner wall and chomata not sloping down toward poles, and from *Fusulinella biconiformis* Ishii, 1962 by its larger test with higher chamber heights in the outer whorls.

Fusulinella soligalichi Dalmatskaya, 1961

Figure 9.8–9.11

Fusulinella soligalichi Dalmatskaya, 1961, p. 27, pl. 1, figs. 6, 7.
Fusulinella soligalichi subsp. *polasnensis* Rauzer-Chernousova, 1961, p. 214, pl. 1, figs. 3, 4.
Fusulinella valida Reitlinger, 1961, p. 243, 244, pl. 4, fig. 3.

Remarks.—The illustrated four and other specimens are distinguished from *Fusulinella rhomboidalis* described above in their more number of and more tightly coiled inner whorls. In this paper, they are identified with *Fusulinella soligalichi* originally described by Dalmatskaya (1961) from the Podolskian and Myachkovian of the Gorky and Ul'yanovsk regions along the Volga. *F. soligalichi polasnensis* and *F. valida* proposed from the lower part of Myachkovian around the localities of *F. soligalichi* are closely similar to *F. soligalichi*. Although morphologic variations of these three taxa are uncertain, they might be conspecific. *F. soligalichi firma* Reitlinger, 1961 might be distinguished from these three taxa and *F. rhomboidalis* by its more elongate fusiform test and somewhat thicker wall.

Fusulinella sp.

Figure 8.6–8.12

Fusulinella cf. *hanzawai* Igo. Villa and Ginkel, 2000, p. 235, pl. 5, figs. 1–4.

Remarks.—Seven specimens illustrated herein are associated with *Fusulinella hanzawai*. The former is separated from the latter by their smaller test with smaller length and width in corresponding whorls. *Fusulinella* sp. is distinguished from *Fusulinella kamitakarensis* by its more tightly coiled inner whorls, though this conclusion is uncertain due to incompleteness of the type specimens of *F*. *kamitakarensis*. Four specimens compared to *F*. *hanzawai* by Villa and Ginkel (2000) from the upper Myachkovian of the Cantabrian Mountains are more similar to this unnamed species than *F*. *hanzawai* in their smaller test, and smaller length and width of corresponding whorls. Other test characters more or less resemble among *Fusulinella* sp., *F*. cf. *hanzawai* of Villa and Ginkel, and *F*. *hanzawai*.

This unnamed species appears to be related to nine specimens (Igo, 1957, p. 206, 207, pl. 7, figs. 1–9) that were identified with *Fusulinella jamesensis* Thompson *et al*., 1953 from central British Columbia. However, the chomata of the former are not so distinct as of the latter.

Genus *Protriticites* Putrya, 1948

Type species.—*Protriticites globulus* Putrya, 1948.

Protriticites ovatus Putrya, 1948

Figure 9.17–9.20

Protriticites ovatus Putrya, 1948, p. 93, 94, pl. 1, fig. 9; Rauzer-Chernousova *et al*., 1951, p. 318, 319, pl. 57, fig. 3.

Remarks.—The present specimens are characterized by an inflated fusiform test composed of six whorls, tightly coiled inner two and gradually to rather rapidly expanding outer four whorls, asymmetrical massive chomata, and thin wall composed of a tectum and finely perforate translucent layer gradually thickening and clearer in outer whorls. Based on close similarities of these features, they are identified with *Protriticites ovatus* decribed from the Myachkovian of Donvas (Putrya, 1948) and Moldova (Rauzer-Chernousova *et al*., 1951).

Genus *Beedeina* Galloway, 1933

Type species.—*Fusulinella girtyi* Dunbar and Condra, 1928.

Beedeina sp. A

Figure 10.14

Remarks.—Fusulines assignable to *Beedeina* that occur seemingly below the *Beedeina lanceolata* Zone are sporadically contained in samples Ic-29 and Ic-34 (Figure 2). Those in Ic-29 are tentatively named as *Beedeina* sp. A, and in Ic-34 and as *Beedeina* sp. B (Figure 10.17). They are separated simply by the appearance of the size of the test. Their distinction from *Beedeina lanceolata* from the *B*. *lanceolata* Zone (Figures 10.9–10.13) and other species assignable to the genus described and/or illustrated by Igo (1957) and Niikawa (1978) is impossible because of no axial sections of *B*. sp. A and *B*. sp. B.

Genus *Fusulina* Fischer de Waldheim, 1829

Type species.—*Fusulina cylindrica* Fischer de Waldheim, 1830.

Fusulina kamensis Safonova in Rauzer-Chernousova *et al*., 1951

Figure 10.18–10.21

Fusulina kamensis Safonova in Rauzer-Chernousova *et al*., 1951, p. 306, 307, pl. 52, figs. 5, 6, pl. 53, fig. 1.

Remarks.—Fusulines certainly assignable to *Fusulina* were recognized in sample Ic-30 in association with *Fusulinellla hanzawai*. They are similar to *Fusulina kamensis* first described by Safonova from the upper part of Podolskian of the Kama River region and Samara Bend in their large, elongate subcylindrical test with bluntly pointed poles, large proloculus, and intensely folded septa. *Fusulina kamensis* is distinguished from *F*. *quasicylindrica* (Lee, 1927) by its much larger test. More well-oriented axial sections of mature specimens are necessary for further morphologic comparison of the Ichinotani specimens.

Fusulina kamensis is easily distinguished from *Fusulina consobrina* Safonova in Rauzer-Chernousova, 1951 described by Niikawa (1978) from the Upper Zone of *Fusulinella–Fusulina* at west of Ohzako just north of the Ichinotani valley in its much larger test and proloculus, and more intensely folded septa. All species assigned to *Fusulina* by Igo (1957) are reassigned to *Beedeina*. *Fusulina* sp. A in association with *Fusulinella kamitakarensis* and *Fusulina* sp. B in association with *Fusulinella hanzawai* are shown in Igo *et al*. (1984, fig. 4). However, details on their morphologies are uncertain because of only one hand-drawn specimen of *Fusulina* sp. A and *Fusulina* sp. B with no magnification in Igo *et al*. (1984).

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