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Late Carboniferous and Early Permian non-fusuline foraminifers of the Akiyoshi Limestone Group in the Wakatakeyama area, Akiyoshi (Japan)

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Abstract
Carboniferous and Permian marine faunas in Japan are principally derived from the Akiyoshi Limestone in the Akiyoshi Terrane (Permian accretionary complex), southwest Japan. The lower Moscovian (Kashirian) to the lowest Cisuralian (Asselian) and middle Cisuralian (Yakhtashian) of the Akiyoshi Limestone Group are subdivided into 12 fusuline zones from the *Fusulinella biconica* Zone to *Paraleeina magna* Zone. Stratigraphic distribution of 42 species assignable to 21 genera of non-fusuline foraminifers, besides two indeterminate taxa, is given in these 12 fusuline zones established in the Wakataketaya area. The Wakatakeyama non-fusuline foraminiferal fauna is characterized by predominant bradyinids and palaeotextulariids, and subordinate tetrataxids. Seven species of *Bradyina* and two species of *Pseudojanischewskina* are described. Among them, newly proposed herein is *Pseudojanischewskina akiyoshiensis* n. sp. ranging from the Podolskian to the early Asselian.

Keywords
Non-fusuline foraminifers, *Bradyina*, Moscovian to Asselian, Yakhtashian, Akiyoshi, Japan.

1. INTRODUCTION

The Akiyoshi Limestone is a huge Panthalassan-originated block allochthonous in the Akiyoshi Terrane (Permian accretionary complex), southwest Japan. The Akiyoshi Limestone Group, composed of basaltic rocks at the basal part and overlying massive limestone, is in thrust contact with the surrounding non-calcareous rock units (Fig. 1). These calcareous and non-calcareous formations (groups) are unconformably overlain by the post-accretional Mine Group (Upper Triassic) with conspicuous lithological changes (Kanmera *et al*., 1990; Kobayashi, 2012). The Mine Group consists of several thousand meters thick terrigenous rocks showing molasse facies with shallow marine bivalves, terrestrial plant fossils, and coal seams.

The Carboniferous and Permian marine faunas in Japan are principally derived from the Akiyoshi Limestone Group. Biostratigraphic zonation and correlation based on fusuline foraminifers have been extensively studied by many researchers (e.g., Y. Ozawa, 1923, 1925; Toriyama, 1958; Ota, 1977; Ueno, 1989, 1995; T. Ozawa & Kobayashi, 1990). However, taxonomy of fusulines and biostratigraphic subdivision scheme of the group are considerably different among authors, especially in the Late Pennsylvanian and Cisuralian. Moreover, paleontologic studies of non-fusuline foraminifers remain relatively poorly studied in comparison with fusulines in the Akiyoshi Limestone Group. They are mostly confined to those of the pre-Moscovian (Okimura, 1963; Matsusue, 1986; Ueno, 1989), Roadian and Wordian (Kobayashi, 2019), and Capitanian (Kobayashi, 2012). Ueno (1989) showed the stratigraphic ranges of upper Visean to Asselian non-fusuline foraminifers based on his biostratigraphic subdivision scheme. However, taxonomic studies of Carboniferous and Lower Permian non-fusulines are very few in the Group, as well as in most of other areas of Japan, in marked contrast to extensive fusuline works.

Kobayashi (2017) reported the results of fusuline taxonomic and biostratigraphic reexamination from the Kashirian to Asselian and Yakhtashian in the Wakatakeyama area of the Akiyoshi Limestone. The Sakmarian is not exposed in the mapped area. In addition to fusulines, many non-fusuline foraminifers consisting of 42 species assignable to 21 genera, besides two indeterminate taxa, are distinguished in these biostratigraphic intervals. Most of them are illustrated and some are described in this paper. The purpose of this paper is to describe six species of *Bradyina* and two species of

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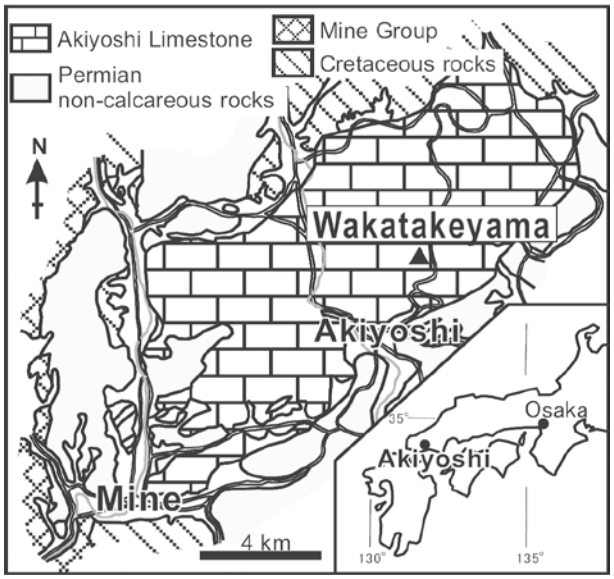

Fig. 1: Distribution of the Akiyoshi Limestone Group and surrounding rocks and the studied Wakatakeyama area (after Kobayashi, 2017).

Pseudojanischewskina, one of which is *P. akiyoshiensis* n. sp., and further to show faunal composition and stratigraphic distribution of 44 taxa in the Wakatakeyama area so as to progress paleontologic researches of non-fusuline foraminifers in Japan. Limestone samples and thin sections in the Wakatakeyama area are stored in the Museum of Nature and Human Activities, Hyogo, Japan (Fumio Kobayashi Collection, MNHAH).

2. STRATIGRAPHY AND FUSULINE BIOSTRATIGRAPHY

The limestone in the Wakatakeyama area is massive without showing any distinct stratification along with other areas of the Akiyoshi Limestone. It is structurally more complicated than supposed by previous workers, since the same fusuline zone cut by faults is tectonically repeated many times (Kobayashi, 2017; Figs 2, 3). There are many thin sections and samples very poor or barren of foraminifers among 4446 thin sections prepared from 312 limestone samples from the area. Four stratigraphic columns were prepared in the Wakatakeyama area (Fig. 3).

Biostratigraphically, the Akiyoshi Limestone Group in the area is subdivided into 12 fusuline zones, based on the stratigraphic distribution of age-diagnostic species and their associated species (Kobayashi, 2017). These zones (with letter codes) are arranged comformably from lower to upper: (1) *Fusulinella biconica* (Fb, Kashirian), (2) *Kanmeraia itoi* (Ki, Podolskian), (3) *Fusulinella bocki* – *Kanmeraia pulchra* (FK, Myachkovian), (4) *Protriticites subschwagerinoides* (Ps, lower Kasimovian), (5) *Montiparus matsumotoi* – *Quasifusulinoides ohtanii* (MQ, middle Kasimovian), (6) *Rauserites arcticus* – *Carbonoschwagerina nipponica* (RC, upper Kasimovian), (7) *Rauserites stuckenbergi* – *Triticites simplex* (RT, lower Gzhelian), (8) *Carbonoschwagerina morikawai* – *Jigulites horridus* (CJ, middle Gzhelian), (9) *Jigulites titanicus* – *Carbonoschwagerina minatoi* (JC, upper Gzhelian), (10) *Sphaeroschwagerina fusiformis* – *Pseudoschwagerina muongthensis* (SP, lower Asselian), (11) *Pseudoschwagerina miharanoensis* – *Paraschwagerina akiyoshiensis* (PP, upper Assselian), and (12) *Paraleeina magna* (Pm, Yakhtashian). Fusuline foraminifers distinguished in the area are classified into 119 species assignable to 39 genera. Fusuline diversity is relatively low in the pre-late Kasimovian (below the RC Zone), gradually increasing from late Kasimovian (RC Zone), reaching its maximum in early Asselian (SP Zone), and decreasing after a peak in the Asselian (Kobayashi, 2017).

3. STRATIGRAPHIC DISTRIBUTION AND FAUNAL COMPOSITION OF NON-FUSULINE FORAMINIFERS

Ueno (1989) distinguished more than 100 species of non-fusuline foraminifers from the upper Visean to Asselian of the Akiyoshi Limestone Group in the Sayama area about 7 km NE of the Wakatakeyama area. Among them, Moscovian to Asselian non-fusuline foraminifers were subdivided into 74 species to have been assigned to 28 genera. Stratigraphic distributions of these taxa were given in nine fusuline zones from the *Akiyoshiella ozawai* Zone to the *Pseudofusulina* ex gr. *vulgaris* Zone, according to his fusuline taxonomic and fusuline biostratigraphic subdivision schemes. The general trend of biostratigraphic distribution and dominance of them, such as those of bradyinins from the Moscovian to Asselian, is similar between the work of Ueno and the present work. However, detailed faunal comparison and correlation done by Ueno with other works in and outside Akiyoshi are not easy, on account of the lack of taxonomic description and few restricted taxa illustrated in Ueno (1989). Furthermore, zonal subdivision and age assignment by fusulines in Ueno (1989) are significantly different from those of Kobayashi (2017).

We classified non-fusuline foraminifers in the Wakatakeyama area into 42 species assignable to 21 genera and two indeterminate taxa (Table 1). Meaningful zonation based on the stratigraphic ranges of these non-fusuline foraminifers is difficult. Because datum planes of the first and/or the last occurrence of taxa are not precisely established in the successive stratigraphic intervals bounded by many faults in the studied area, and there are many samples poor or lacking foraminifers. Stratigraphic ranges of most taxa are assumed to be longer than those of the coeval Fusulinidae and Schwagerinidae.

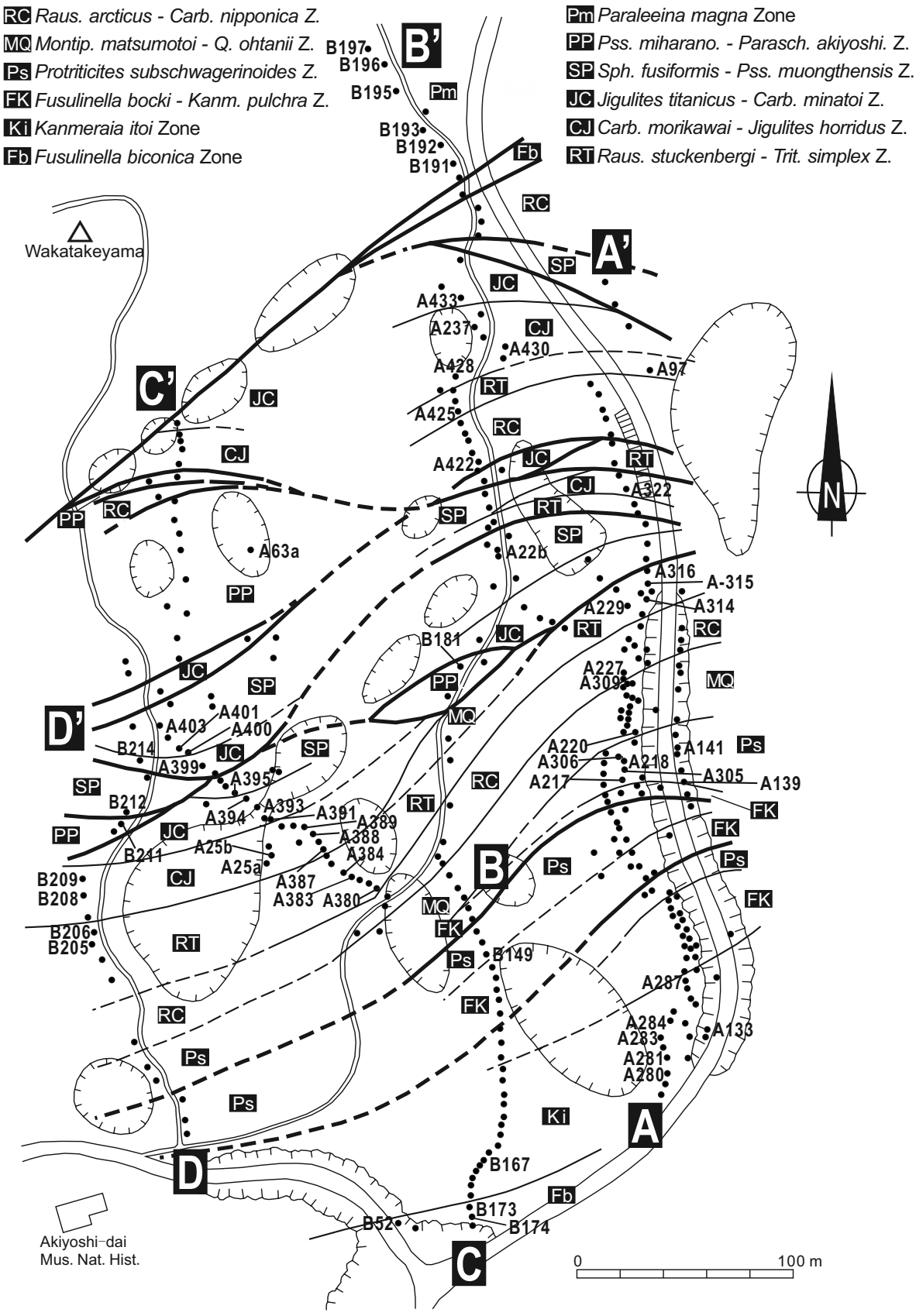

Fig. 2: Geologic map in the Wakatakeyama area showing the biostratigraphic subdivision from the *Fusulinella biconica* Zone (Kashirian) to the *Paraleeina magna* Zone (Yakhtashian), sample localities, and the location of four stratigraphic columns (A-A', B-B', C-C', and D-D').

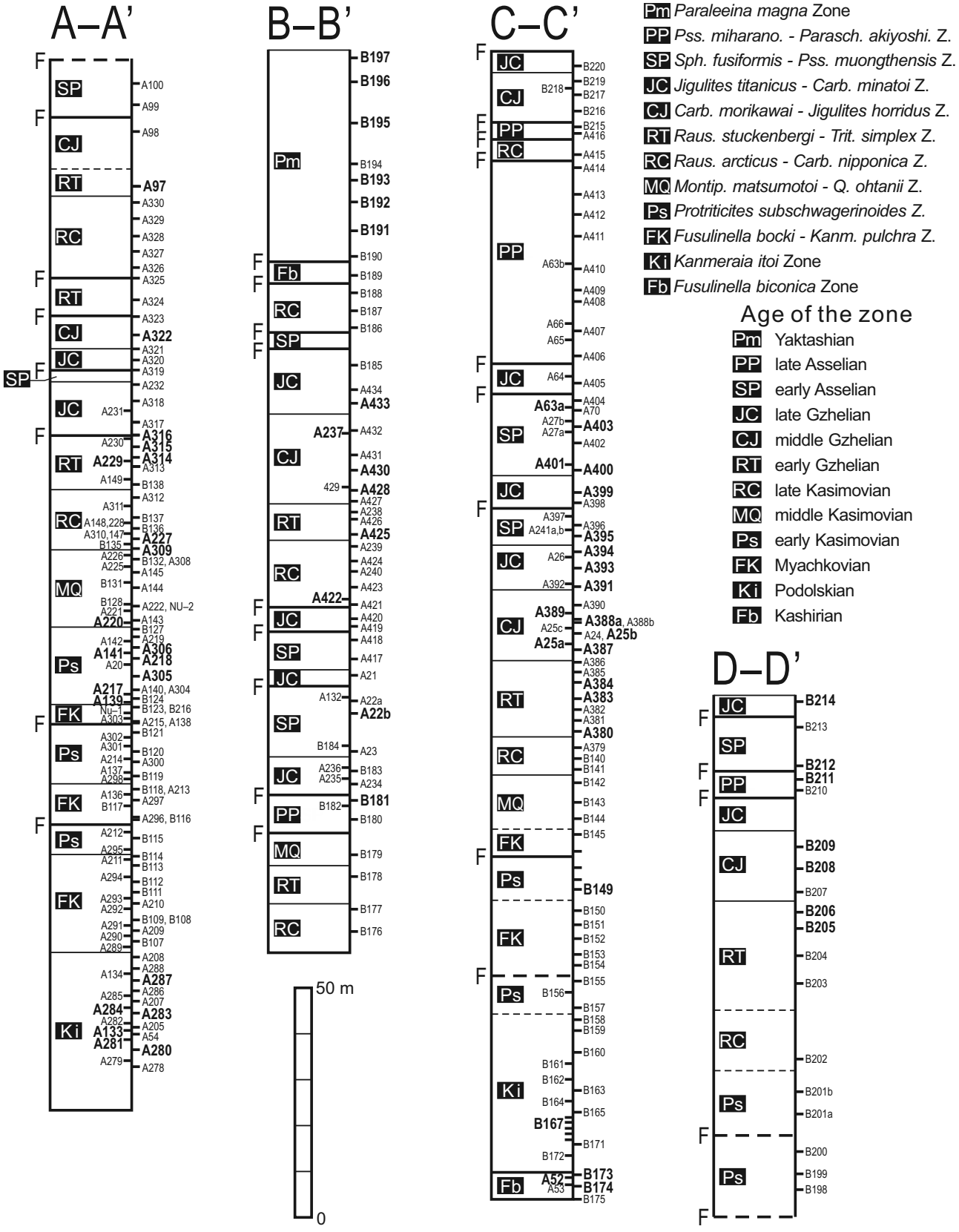

Fig. 3: Four stratigraphic columns in the Wakatakeyama area showing the stratigraphic levels of samples, and the biostratigraphic and chronostratigraphic assignment of a stratigraphic interval. Sample numbers with bold and larger font show the level of the sample from which specimens illustrated were collected. The abbreviation F, immediately on the left side of four columns, means a fault.

Accordingly, they are presented in the twelve fusuline zones (Table 1). Localities and stratigraphic levels of 63 limestone samples having non-fusuline foraminifers illustrated in this paper, selected from more than 270 fossiliferous samples, are shown by bold letters in Fig. 2 and Fig. 3, respectively.

The Wakatakeyama non-fusuline fauna is characterized by diversified *Bradyina*, and predominant bradyinids and palaeotextulariids, and subordinate tetrataxids. Other taxa are accessory, even if, as *Eotuberitina*, they are contained in many samples throughout the 12 zones. *Hemigordius* is found in many samples exclusively within the uppermost Pm Zone (Yakhtashian). More than seven species of *Bradyina* were identified, including *B. cribrostomata* first described from the Serpukhovian of the Samara Bend (Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova & Fursenko, 1937) and ranging up to the Upper Carboniferous, and *B. compressa* from the *Schwagerina* Horizon (Asselian) in the Pre-Urals of Bashkiria (Morozova, 1949) and ranging up to the Sakmarian or Yakhtashian. The latter species ranges down to the Kasimovian (MQ Zone) in the studied area. *Bradyina* is commonly found in many samples of the Fi, Ps, and RC to JC zones, but absent or scarce in the Fb, FK, PP, and Pm. *Pseudojanischewskina*, supposed to be restricted to the Asselian and Sakmarian (Mamet & Pinard, 1990), ranges down into the Podolskian (Ki Zone) in the Wakatakeyama area. Palaeotextulariids and tetrataxids are not limited in their precise stratigraphic distribution. Three unnamed species of *Endothyra*, *E*. sp. A, *E*. sp. B and *E*. sp. C illustrated from the Ki Zone (Kashirian) to the SP Zone (Asselian) are similar to and might be identified as *Endothyra prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova *et al*., 1936, *Endothyra similis* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova *et al*., 1936, and *Endothyra bowmani* Phillips, 1846, emend. Brady, 1876, respectively. However, we hesitate to identify them with the types proposed from the Visean of Russia, as it is uncertain that the species identified with the original Russian ones surely range up to the Asselian or not.

Relatively large-sized *Bradyina*, common until the JC Zone, disappear from the SP Zone, and the genus *Endothyra* becomes a more vestigial element as a whole from the PP Zone. *Hemigordius* and *Hemigordiellina* first occur in the Pm Zone.

Thus, some changes of faunal composition are recognized in the Wakatakeyama material. However, a zonation based on the stratigraphic range of non-fusuline foraminifers is difficult in the studied area. Rapid increase of the number of genera and species of non-fusuline foraminifers beginning from the Yakhtashian is shared with many stratigraphic sections of the Permian of the Akiyoshi Limestone Group (Kobayashi, 2019 and unpublished data). However, it is not remarkable in the Wakatakeyama area, probably due to both the small number and similar limestone lithology (fusuline bioclastic grainstone) of samples in the Yakhtashian (Pm Zone). Noticeable historical changes of taxonomic diversities recognized in fusuline faunas (Kobayashi, 2017) are obscure in the stratigraphic distribution of non-fusuline foraminifers in the Wakatakeyama area (Table 1). They are highly contrasting between fusuline and non-fusuline foraminifers. Moreover, internationally remarkable provincial faunal elements, represented by the late Kasimovian to late Gzhelian fusulines *Carbonochwagerina* and Vereyan/Kashirian *Akiyoshiella* (Kobayashi, 2017), are inconspicuous in the present non-fusuline foraminiferal faunas.

4. DESCRIPTION OF SPECIES

Genus *Bradyina* von Möller, 1878

Type species: *Bradyina nautiliformis* von Möller, 1878

Bradyina nautiliformis von Möller, 1878

Pl. I, figs 62, 63; Pl. III, figs 1-6, 30

1878. *Bradyina nautiliformis* von Möller, pp. 83-86, pl. 3, figs 4a-4d; pl. 10, figs 3a, 3b.
1930. *Bradyina nautiliformis* von Möller.– Lee & Chen in Lee *et al*., pp. 104, 105, pl. 5, figs 5-9.
1940. *Bradyina nautiliformis* von Möller.– Rauzer-Chernousova, Belyaev & Reitlinger, pp. 47-49, pl. 8, figs 1-3; pl. 9, figs 1-3.
1956. *Bradyina nautiliformis* von Möller.– Putrya, p. 371, pl. 1, figs 9-11.
1963. *Bradyina nautiliformis* von Möller.– Bogush, p. 55, pl. 1, fig. 7, pl. 2, fig. 2.
1978. *Bradyina nautiliformis* von Möller.– Lin, p. 36, pl. 7, fig. 16.
1984. *Bradyina nautiliformis* von Möller.– Xia & Zhang, pp. 44, 45, pl. 9, figs 21-27.
1984. *Bradyina nautiliformis* von Möller.– Igo *et al*., text-fig. 3B (p. 457).
non 1984. *Bradyina nautiliformis* von Möller.– Zhao *et al*., p. 108, pl. 19, figs 1, 2 [=*Bradyinelloides pseudonautiliformis* (Reitlinger, 1950)].
1985. *Bradyina nautiliformis* von Möller.– Adachi, pp. 115, 116, pl. 18, fig. 1.
1985. *Bradyina* sp. A Adachi, pp. 117, 118, pl. 18, figs 2, 3.
1985. *Bradyina* sp. E Adachi, pp. 117, 118, pl. 19, fig. 10, pl. 19, fig. 1.
1989. *Bradyina* cf. *nautiliformis* von Möller.– Ueno, pl. 8, fig. 16.
1990. *Bradyina nautiliformis* von Möller.– Lin *et al*., p. 197, pl. 20, fig. 16.
1991. *Bradyina nautiliformis* von Möller.– Vachard & Beckary, p. 327, pl. 3, figs 7, 9.
1991. *Bradyina nautiliformis* von Möller.– Vachard, pl. 2, fig. 11.
1992. *Bradyina nautiliformis* von Möller.– Kulagina *et al*., pl. 1, fig. 10, pl. 9, fig. 27.
2001a. *Bradyina nautiliformis* von Möller.– Vachard & Krainer, pl. 1, figs 20, 21.

Age	Moscovian			Kasimovian			Gzhelian			Asselian		Yaktashian
	Kashirian	Podolskian	Myachkovian	early	middle	late	early	middle	late	early	late	
Fusuline zone	Fb	Ki	FK	Ps	MQ	RC	RT	CJ	JC	SP	PP	Pm
Tuberitina sp.								X			X	
Eotuberitina spp.	X	X	X	X	X	X	X	X	X	X	X	X
Calcivertella sp.							X					
Globivalvulina bulloides		X								X	X	
Globivalvulina ex gr. *bulloides*										X	X	X
Globivalvullina mosquensis				X						X	?	
Iriclinella cf. *evoluta*		X										
Endothyra sp. A		X								X		
Endothyra sp. B						X	X			X		
Endothyra sp. C	X	X				X	X			X		
Endothyra sp. D		X								X		
Endothyra sp. E		X				X		X				
Planoendothyra cf. *aljutovica*	X			X		X		X		X		
Endothyridae indet.	X		X		X	X			X		X	X
Endothyranella ? sp.			X									X
Spireitlina conspecta				X			X			X		X
Spiroplectammina ? sp.												X
Tetrataxis paraconica	X			X			X	X	X		X	
Tetrataxis sp. A												X
Tetrataxis sp. B								X				
Tetrataxis spp.		X	X		X				X	X		
Polytaxis spp.									X		X	X
Haplophragmina ? sp.												X
Palaeotextularia ? sp.	X		X									
Deckerella baschkirica	X	X		X	X			X		X		
Deckerella spp.	X	X	X	X		X	X			X		
Climacammina spp.							X	X	X	X	X	X
Cribrogenerina ? sp.		X					X			X	X	
Palaeotextulariidae indet.	X	X	X		X	X		X	X		X	
Bradyina compressa					X	X		X	X			
Bradyina cribrostomata		X	?	X	X	X		X	X			
Bradyina nautiliformis		X		X		X		X	X			
Bradyina regularis		X					X	X				
Bradyina subsphaerica				X	X		X	X	X	X		X
Bradyina aff. *compressa*							X	X	X		X	
Bradyina sp. A						X	X					
Bradyina spp.							X	X			X	X
Pseudojanischewskina akiyoshiensis n. sp.		X		X			X		X	X		
Pseudojanischewskina sp.								X				X
Pseudojanischewskina ? sp.						X		X				
Hemigordiellina sp.												X
Hemigordius rotundatus												X
Hemigordius sp. A												X
Hemigordius sp. B												X
Number of taxa	9	16	8	11	8	13	15	18	13	17	13	17
Number of samples	6	34	39	39	23	34	30	25	28	27	19	8
Number of thin sections	137	383	280	339	230	522	436	493	430	762	335	99

Table I: Occurrence of non-fusuline foraminifers from the Fb (*Fusulinella biconica*) Zone to the Pm (*Paraleeina magna*) Zone, and number of taxa, samples, and thin sections in each zone. Number of taxa shown in this table is restricted to the total number of taxa that is distinguished in samples from which specimens are illustrated in this paper. Number of samples and thin sections shown in this table corresponds to that prepared in the mapped area.

Description: Test nautiloid, broadly rounded, and with shallow umbilical depressions. Mature test consists of three to four whorls, 1.58 to 1.88 mm in diameter, 0.92 to 1.50 mm in width, and 0.56 to 0.81 width/diameter ratio. Proloculus 0.08 to 0.21 mm in its longer diameter. The lenticular first whorl is followed by rapidly expanding two to three outer whorls. Inflated, hemispherical, five to seven chambers in the final whorl. Septa thickened from the second whorl, inclined vertically, and with preseptal and postseptal lamellae. Wall of final whorl 0.07 to 0.11 mm in its thickest part. It consists of thin microgranular tectum and regularly perforate keriotheca in outer whorls.

Remarks: Size and shape of the test and proloculus, degree of depth of umbilicus, and thickness of wall of many specimens identified with this species are considerably variable among authors. Two specimens assigned to this species by Zhao *et al*. (1984) from the Upper Carboniferous of southwestern margin of the Tarim Basin (China) are excluded from this species and reassigned herein to *Bradyinelloides pseudonautiliformis* based on their larger test having a thicker wall with porous keriotheca branching off multiply. *Bradyina* sp. E, described by Adachi (1985) from the upper Member of the Ichinotani Formation, assumed to be somewhat similar to *B. pseudonautiliformis*, is better to be reassigned to this species. Among many forms assigned to *Bradyina* by Adachi (1985), *Bradyina* sp. D can surely be transferred to *Bradyinelloides*.

Bradyina cribrostomata Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova & Fursenko, 1937

Pl. II, figs 21-25, 27-30, 34-36

1937. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova & Fursenko, pp. 295, 296, figs 231a-231c, 234a, 234b.
1940. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Rauzer-Chernousova, Belyaev & Reitlinger, pp. 51, 77, text-fig. 16a, 16b, pl. 8, figs 4, 5; pl. 9, figs 4-6.
1950. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Reitlinger, pp. 48, 49 (no illustration).
1960. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Grozdilova & Lebedeva, pp. 76, 77, pl. 3, fig. 3.
1964. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Potievskaya, pp. 38, 39, pl. 1, figs 8-11.
1967. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Brazhnikova *et al*., pl. 23, fig. 1.
1969. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Manukalova *et al*., p. 22, pl. 4, figs 12-14, pl. 5, fig. 1, pl. 4 (p. 179), fig. 20, pl. 5 (p. 229), fig. 29.
1970. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Rumyantseva, pl. 3, fig. 9.
1978. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Lin, p. 35, pl. 7, figs 7, 8.
1979. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Bensaïd *et al*., pl. 15, fig. 14.
1980. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Malakhova, pl. 6, fig. 2, pl. 7, fig. 1.
1982. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Wang, p. 11, pl. 2, figs 12, 13.
1983. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Aizenverg *et al*., pl. 9, fig. 11.
1984. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Zhao *et al*., p. 107, pl. 18, figs 1-5.
1984. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Xia & Zhang, pp. 43, 44, pl. 9, figs 9, 10.
1984. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Igo *et al*., text-fig. 3B (p. 457).
1985. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Adachi, pp. 43, 44, pl. 17, figs 9, 10.
1987. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Sinitsyna & Sinitsyn, pl. 3, fig. 14, pl. 6, fig. 5, pl. 9, fig. 4.
1988. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Groves, p. 384, figs 14.23-14.28.
1988. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Kulagina, pl. 3, fig. 26.
1989. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Ueno, pl. 8, fig. 13.
1989. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Vachard *et al*., pl. 1, fig. 1.
1990. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Lin *et al*., p. 195, pl. 19, figs 32, 33.
1991. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Vachard, pl. 2, fig. 12.
1991. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Vachard *et al*., pl. 1, fig. 3.
1992. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Kulagina *et al*., pl. 1, fig. 10, pl. 9, fig. 27.
1993. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Perret, pl. F1, figs 2, 3, pl. F2, fig. 17, pl. F12, fig. 12.
2003. *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger.– Brenckle & Milkina, pl. 6, fig. 41.

Description: Relatively large *Bradyina* with 1.32 to 2.20 mm in diameter, 0.86 to 1.33 mm in width, and width/diameter ratio 0.57 to 0.72. Proloculus 0.03 to 0.14 mm in diameter. Three to four whorls coiled almost planispirally and rapidly expanding in later stage. Four to five inflated, hemispherical chambers in the final whorl. Septa short to medium, curved anteriorly, and flanked by thin preseptal and/or postseptal lamellae. Septal sutures slightly depresssed. Wall of outer whorls consists of outer thin tectum and underlying much thicker, coarsely porous, alveolar layer, and its thickness 0.04 to 0.08 mm in the final whorl.

Remarks: Although test size and width/diameter ratio are considerably variable, the present specimens are identical with *Bradyina cribrostomata* originally described by Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova & Fursenko (1937) from the Serpukhovian core samples of Samara Bend region, Volga River basin (Russia). This species differs from *Bradyina nautiliformis* by its smaller test, wall with more distinct alveolar pores, and shorter septa more

gently inclined anteriorly. In addition to the examples listed above, bradyinins identified with this species were described and/or illustrated by many Russian workers (e.g., Grozdilova & Lebedeva, 1960; Brazhnikova *et al*., 1967; Fomina, 1977).

Bradyina subsphaerica Morozova, 1949

Pl. II, figs 26, 31-33, 37-41

1949. *Bradyina subsphaerica* Morozova, pp. 252, 253, pl. 1, figs 20, 25.
1977. *Bradyina subsphaerica* Morozova.– Korolyuk & Rauzer-Chernousova, pl. 3, figs 9-11.
1984. *Bradyina samarica* Reitlinger, 1950.– Zhao *et al*., p. 107, pl. 18, figs 6-12.
1990. *Bradyina samarica* Reitlinger.– Lin *et al*., p. 198, pl. 20, figs 20, 21, 24.
1990. *Bradyina saucra* Lin *et al*., pp. 198, 199, pl. 20, figs 22, 23, 25-27.
1990. *Bradyina saucraeforma* Lin *et al*., p. 199, pl. 21, figs 1-4.

Description: See Morozova (1949) and Korolyuk & Rauzer-Chernousova (1977).
Remarks: Many specimens of small subspherical *Bradyina* of the present material are characterized by three to four whorls tightly coiled in early stage and wall consisting of microgranular in early stage and thin tectum underlain by finely perforate alveolar layer in later stage. They are closely similar to three specimens illustrated by Korolyuk & Rauzer-Chernousova (1977) from the Sakmarian of Bashkiria, which were identified with the original two excentered specimens by Morozova (1949) from the same stratigraphic levels. By these common test characters, two examples, listed above, identified with *Bradyina samarica* from the Upper Carboniferous of China and newly proposed two species from the Upper Carboniferous (Huanlung and Maping limestones) of South China by Lin *et al*. (1990) are reassigned to this species.

Bradyina regularis Lin, 1978

Pl. III, figs 17-23

1978. *Bradyina regularis* Lin, p. 36, pl. 7, fig. 18; pl. 8, fig. 1.
1984. *Bradyina regularis*.– Xia & Zhang, p. 45, pl. 10, fig. 8. 1.
1984. *Bradyina regularis*.– Zhao *et al*., p. 108, pl. 19, fig. 3.

Description: Subspherical test with shallowly depressed umbilici and planispirally coiled 3½ to 4½ whorls. Diameter 1.55 to 1.82 mm, width 1.11 to 1.80 mm, and width/diameter ratio about 0.71 to 1.05. Proloculus 0.04 to 0.09 mm. Inner 1½ to 2½ whorls lenticular with distinct umbilici are followed by rapidly expanding outer whorls with a slight change of axis of coiling. Septa half to two-thirds as high as chambers and inclined anteriorly at high angle to wall. The number of septa from the first to third whorl is 5, 7, and possibly 8 in the specimen illustrated in Pl. III, fig. 18. Thin preseptal and postseptal lamellae are present around septa. Remnants of septa and lamellae are present in axial regions of outer whorls. Wall very thin and of unilayered in lenticular, initial whorls then gradually thickened, and of thin tectum and underlying alveolar layer finely and regularly perforated. Wall 0.05 to 0.10 mm in the thickest part of the final whorl.
Remarks: Among the described species, the present specimens are identical with *Bradyina regularis* proposed by Lin (1978) from the Mapingian (Upper Carboniferous) of Guangxi and later described from other regions of China by Xia & Zhang (1984) and Zhao *et al*. (1984). Among the three, they closely resemble one specimen illustrated by Zhao *et al*. (1984) in tiny lenticular inner whorls succeeded by rapidly expanding subspherical outer whorls with shallowly depressed umbilicus and distributional pattern of remnant septa and septal lamellae in axial regions. Characteristic features of initial whorls in the Wakatakeyama specimens are not clear in the Lin's original specimens.
This species is somewhat similar to *Bradyina lucida* Morozova, 1949, as redescribed by Korolyuk & Rauzer-Chernousova (1977) from the Asselian and Sakmarian of Bashkorstostan. However, inner whorls of the former attain to two and are more tightly coiled than those of the latter. Wall of this species is thinner than the types of *B. lucida* by Morozova (1949). Moreover, this species is distinguished from these Russian specimens by its thinner wall throughout the test and more finely perforated wall in outer whorls.

Bradyina compressa Morozova, 1949

Pl. III, figs 7-10

1949. *Bradyina compressa* Morozova, p. 252, pl. 1, figs 21, 28.
1990. *Bradyina compressa* Morozova.– Lin *et al*., p. 195, pl. 19, figs 27, 28.
1998. *Bradyina*? *arctica* Pinard & Mamet, p. 125, pl. 38, figs 6, 7?, pl. 40 figs 5-7.
2001a. *Bradyina compressa* Morozova.– Vachard & Krainer, pl. 1, fig. 26.
2001a. *Bradyina arctica* Pinard & Mamet.– Vachard & Krainer, pl. 2, fig. 4.
2001b. *Bradyina arctica* Pinard & Mamet.– Vachard & Krainer, pl. 12, fig. 7.
2001b. *Bradyina compressa* Morozova.– Vachard & Krainer, pl. 12, figs 6, 8, 11, 17.
2003. *Bradyina compressa* Morozova.– Krainer *et al*., pl. 5, fig. 32.

Description: See Morozova (1949).
Remarks: Four illustrated and other diagonal sections with smaller width/diameter ratio are identified with *Bradyina compressa* first described from the Asselian and Sakmarian in the Pre-Urals of Bashkiria. They are common in their tightly coiled lenticular inner whorls and

rapidly expanding outer whorls increasing the thickness of wall. On the other hand, umbilical depressions of the final whorl conspicuous in smaller individuals are more reduced in larger ones of the present material and the types. Although these characters were not described in two specimens identified with this species from the Upper Carboniferous Maping and Huanlung limestones of Kwangsi (Lin *et al*., 1990), the present, Bashkiria and Kwangsi specimens, closely resemble each other.
The species *B. compressa* and *B.*? *arctica* are considered here as synonyms due to their morphological characters and sizes.

***Bradyina* aff. *compressa* Morozova, 1949**
Pl. III, figs 11-14

Related to:
1949. *Bradyina compressa* Morozova, p. 252, pl. 1, figs 21, 28.

Remarks: Four large specimens illustrated having small width/diameter are similar to *Bradyina compressa* described above. However, they are separated from the species by their larger diameter and width in the corresponding whorls. *Bradyina hubeiensis* proposed by Xia & Zhang (1984) from the Penchian (Moscovian) of Hubei (China) was distinguished from *B. nautiliformis* by having distinct umbilical depressions and more numerous preseptal lamellae. Two specimens illustrated in Pl. III, figs 13-14 appear to be more alike to the Hubei species than other two in Pl. III, figs 11-12. Although differences of the degree of umbilical depression and coiling pattern of inner whorls are found in them, the present four specimens are treated as an alliance with *Bradyina compressa* without subdivision.

***Bradyina* sp. A**
Pl. III, figs 15, 16

Remarks: Illustrated two specimens have more rounded test with tapering longer septa than other species of *Bradyina* in the Wakatakeyama area. They are distinguished from both *Bradyina nautiliformis* and *Bradyina magna* Roth & Skinner, 1930 by their thinner wall, and also from *B. magna* by more septa throughout the test.

Genus *Pseudojanischewskina* Mamet & Pinard, 1990
Type species: *Pseudojanischewskina multicribrata* Mamet & Pinard, 1990.

***Pseudojanischewskina akiyoshiensis* n. sp.**
Pl. III, figs 24-29, 32, 33

Etymology: From the Akiyoshi Limestone.
Type specimens: Holotype D2-056043 (axial section, Pl. III, fig. 26). Paratypes: one axial section (Pl. III, fig. 25), one tangential section (Pl. III, fig. 24), one diagonal section (Pl. III, fig. 27), and four transverse sections (Pl. III, figs 28, 29, 32, 33). Register numbers of paratypes are shown in the explanation of Pl. III.
Type locality: E and S of Wakatakeyama, Shuho-cho, Mine City, Yamaguchi Prefecture, Japan.
Diagnosis: Lenticular inner whorls without distinct wall differentiation are somewhat skewed to rapidly expanding nautiloid outer whorls. Wall composed of thin tectum and finely porous layer comparable to a fusulinid keriotheca in outer whorls. Septa become shorter and gently curved outwards. Remnants of septa and lamellae present in axial regions.
Description: Test nautiloid with planispirally coiled 2 ½ to 3 ½ whorls, faint umbilical depressions and rounded periphery. Diameter 1.50 to 1.98 mm, width 1.03 to 1.46, and width/diameter ratio 0.60 to 0.75. Proloculus 0.065 (?) to 0.145 mm in diameter. Inner one to two whorls lenticular, thin to very thin, and somewhat skewed to rapidly expanding, more rounded outer whorls. Septa become shorter and gently curved anteriorly during growth, as well as preseptal and postseptal lamellae. Remnants of septa and lamellae present in axial regions. Wall composed of very thin microgranular tectum and inner granular, finely porous layer similar to a keriotheca exclusively in outer whorls. Wall differentiation is obscure in inner whorls.
Material examined: Six types and other oblique sections.
Remarks: Although detailed comparison with the type species of the genus is not easy on account of no axial sections illustrated in Mamet & Pinard (1990), this new species may be distinguished from the type species in having a smaller test with thinner wall and longer septa. Wall with finely alveolar structure in middle and outer whorls is common between the two. However, finely porous layer of proloculus and the initial whorl shown in the hand-drawn transverse section of Mamet & Pinard's is not found in the new species. The latter is distinguished from *Bradyina regularis*, described above, by its nautiloid test with more rapidly enlarging final whorl, thinner and more finely porous wall, and less developed septa.
Among the illustrated species included within *Bradyina*, one excentered specimen named *Bradyina* sp. F by Adachi (1985) from the Upper Member of the Ichinotani Formation, is tentatively reassigned to *Pseudojanischewskina* by its mode of arrangement of septa and septal lamellae, and relatively thin and finely porous wall. However, it is largely different from this new species by its larger test, more whorls and distinct septal sutures.
Occurrence and stratigraphic distribution: Rare to common in A-281 (Ki Zone), A-305 (Ps Zone), A-229 (RT Zone), A-384 (RT Zone), A-393 (JC Zone), A-433 (JC Zone), and A-63a (SP Zone).

***Pseudojanischewskina* sp.**
Pl. III, figs 34, 35

Remarks: This unnamed species is different from *Pseudojanischewskina akiyoshiensis* by its somewhat thicker wall and larger proloculus succeeded by rounded outer whorls without lenticular initial whorls. Though not illustrated due to weak recrystallization and outer whorls mostly broken off, few forms from the Ps, RC, and CJ zones are questionably referable to *Pseudojanischewskina* from their thin wall without distinct alveolar structure.

ACKNOWLEDGMENTS

We are much indebted to two reviewers, Dr Ian Somerville and Dr Pedro Cózar for their constructive comments and helpful suggestions, by which this paper was greatly improved. Financial support from Grant-in Aid for Scientific Research (C) of Japan Society for promotion of Science in 2004-2005 (Project No. 16540428), 2007-2009 (Project No. 19540497), and 2013-2015 (Project No. 25400501) is thankfully acknowledged for the field and laboratory works.

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Plate I

Fig. 1: *Tuberitina* sp. D2-057141, B-209 (CJ Zone).
Fig. 2: *Eotuberitina* sp. D2-05707, B-206 (RT Zone).
Fig. 3: *Calcivertella* sp. D2-057069, B-205b (RT Zone)
Fig. 4: *Iriclinella* cf. *evoluta* (Reitlinger, 1950). D2-051014, A-133 (Ki Zone).
Figs 5, 6: *Endothyra* sp. A. 5: D2-051011, A-133 (Ki Zone); 6: D2-056602, B-167 (Ki Zone).
Figs 7-10: *Endothyra* sp. B. 7: D2-051854, A-314 (RT Zone); 8: D2-051871, A-316 (RT Zone); 9: D2-041477, A-63a (SP Zone): 10: D2-050053, A-227 (RC Zone).
Figs 11-16: *Endothra* sp. C. 11: D2-052473, A-380 (RT); 12: D2-056654, B-173 (Fb Zone); 13: D2-051529, A-284b (Ki Zone); 14: D2-056684, B-174 (Fb Zone); 15: D2-055780, A-422 (RC Zone); 16: D2-052764, A-395a (SP Zone).
Figs 17-21: *Planoendothyra* cf. *aljutovica* (Reitlinger, 1950). 17: D2-049891, A-217 (Ps Zone); 18: D2-056664, B-173 (Fb Zone); 19: D2-041448, A-63a (SP Zone); 20: D2-050056, A-227 (RC Zone); 21: D2-056012, A-430 (CJ Zone).
Figs 22, 23: *Endothyra* sp. D. 22; D2-052990, A-403 (SP Zone); 23: D2-051441, A-280 (Ki Zone).
Figs 24, 25: *Endothyra* sp. E. 24: D2-051463, A-281 (Ki Zone); 25: D2-055780, A-422 (RC Zone).
Figs 26-28: *Globivalvulina bulloides* (Brady, 1876). 26: D2-052905, A-401 (SP Zone); 27: D2-052890, A-400 (SP Zone); 28: D2-051439, A-280 (Ki Zone).
Fig. 29: *Hemigordius* sp. B. D2-056915, B-192 (Pm Zone).
Fig. 30: *Hemigordiellina* sp. D2-056926, B-192 (Pm Zone).
Fig. 31: *Globivalvulina mosquensis* Reitlinger, 1950. D2-047755, A-139 (Ps Zone).
Figs 32, 33: *Globivalvulina* ex gr. *bulloides* (Brady, 1876). 32: D2-056905, B-192 (Pm Zone); 33: D2-040795, A-22b (SP Zone).
Figs 34-37: *Tetrataxis paraconica* Reitlinger, 1950. 34: D2-052486, A-380 (RT Zone); 35: D2-051928, A-322 (CJ Zone); 36: D2-052715, A-393 (JC Zone); 37: D2-055996, A-430 (CJ Zone).
Figs 38-41: *Polytaxis* spp. 38: D2-057244, B-214 (JC Zone); 39: D2-056985, B-197 (Pm Zone); 40: D2-057162, B-211 (PP Zone); 41: D2-057168, B-211 (PP Zone).
Fig. 42: *Tetrataxis* sp. A. D2-056975, B-196 (Pm Zone).
Fig. 43: *Tetrataxis* sp. B. D2-056008, A-430 (CJ Zone).
Figs 44-47, 50: *Spireitlina conspecta* (Reitlinger, 1950). 44: D2-057053, B-205a (RT Zone); 45: D2-047766, A-141 (Ps Zone); 46: D2-057061, B-205a (RT Zone); 47: D2-056942, B-193 (Pm Zone); 50: D2-056923, B-192 (Pm Zone).
Fig. 48: *Endothyranella*? sp. D2-056908, B-191 (Pm Zone).
Fig. 49: *Haplophragmina*? sp. D2-056915, B-192 (Pm Zone).
Figs 51, 52: *Hemigordius rotundatus* Wang, 1982. 51: D2-056974, B-196 (Pm Zone); 52: D2-056991, B-197 (Pm Zone).
Fig. 53: *Hemigordius* sp. A. D2-056924, B-192 (Pm Zone).
Figs 54-56, 58: *Deckerella baschkirica* Morozova, 1949. 54: D2-047721, A-133 (Ki Zone); 55: D2-040890, A-25a (CJ Zone); 56: D2-051718, A-306 (Ps Zone); 58: D2-041442, A-63a (SP Zone).
Figs 57, 59-61: *Deckerella* spp. 57: D2-057242, B-214 (JC Zone); 59: D2-055854, A-425 (RT Zone); 60: D2-040791, A-22b (SP Zone); 61: D2-030193, A-141 (Ps Zone).
Figs 62, 63: *Bradyina nautiliformis* von Möller, 1878. 62: D2-051449, A-280 (Ki Zone); 63: D2-055392, B-149 (Ps Zone).

Plate I

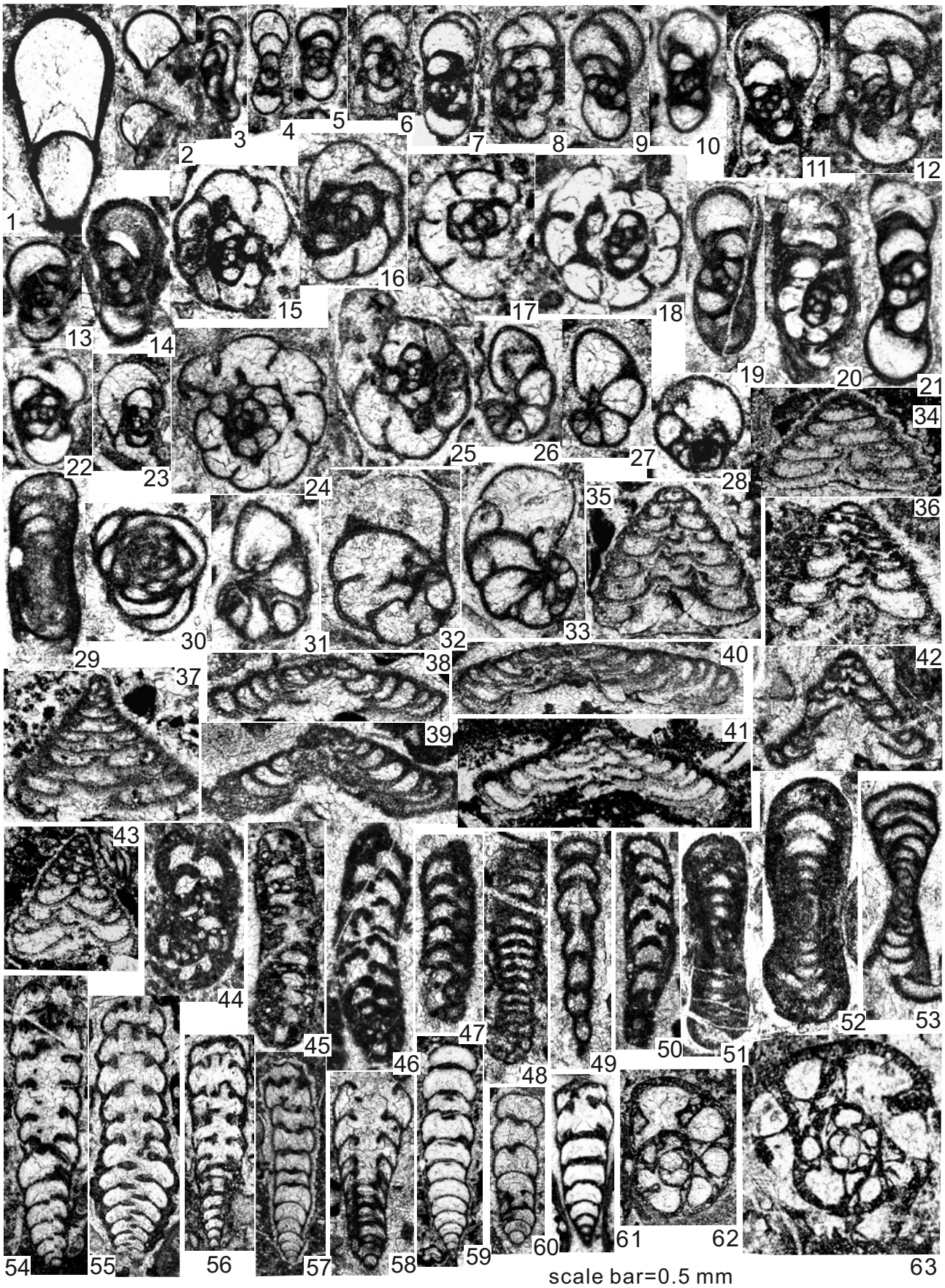
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Plate II

Figs 1-6, 8-14, 17, 18: *Climacammina* spp. 1: D2-056935, B-193 (Pm Zone); 2: D2-040894, A-25a (CJ Zone); 3: D2-057180, B-212 (SP Zone); 4: D2-057119, B-208 (CJ Zone); 5: D2-057173, B-212 (SP Zone); 6: D2-056937, B-193 (Pm Zone); 8: D2-056931, B-193 (Pm Zone); 9: D2-056907, B-191 (Pm Zone); 10: D2-056939, B-193 (Pm Zone); 11: D2-0528223, A-399 (JC Zone); 12: D2-052848, A-399 (JC Zone); 13: D2-052930, A-403 (SP Zone); 14: D2-040915, A-25b (CJ Zone); 17: D2-041459, A-63a (SP Zone); 18: D2-041477, A-63a (SP Zone).

Figs 7, 19, 20: *Cribrogenerina*? sp. 7: D2-041475, A-63a (SP Zone); 19: D2-041462, A-63a (SP Zone); 20: D2-047271, A-97 (RT Zone).

Figs 15, 16: *Climacammina*? sp. 15: D2-051556, A-287a (Ki Zone); 16: D2-041277, A-52 (Fb Zone).

Figs 21-25, 27-30, 34-36: *Bradyina cribrostomata* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova & Fursenko, 1937. 21: D2-055778, A-422 (RC Zone); 22: D2-047699, A-133 (Ki Zone); 23: D2-051022, A-133 (Ki Zone); 24: D2-049907, A-218 (Ps Zone); 25: D2-055775, A-422 (RC Zone); 27: D2-047687, A-133 (Ki Zone); 28: D2-052676, A-393 (JC Zone); 29: D2-049905, A-218 (Ps Zone); 30: D2-051771, A-309 (RC Zone); 34: D2-051442, A-280 (Ki Zone); 35: D2-049982, A-220 (MQ Zone); 36: D2-049976, A-220 (MQ Zone).

Figs 26, 31-33, 37-41: *Bradyina subsphaerica* Morozova, 1949. 26: D2-052583, A-387 (CJ Zone); 31: D2-052697, A-393 (JC Zone); 32: D2-052674, A-393 (JC Zone); 33: D2-041480, A-63a (SP Zone); 37: D2-056969, B-195 (Pm Zone); 38: D2-052645, A-391 (JC Zone); 39: D2-057139, B-209 (CJ Zone); 40: D2-052718, A-393 (JC Zone); 41: D2-052471, A-380 (RT Zone).

Plate II

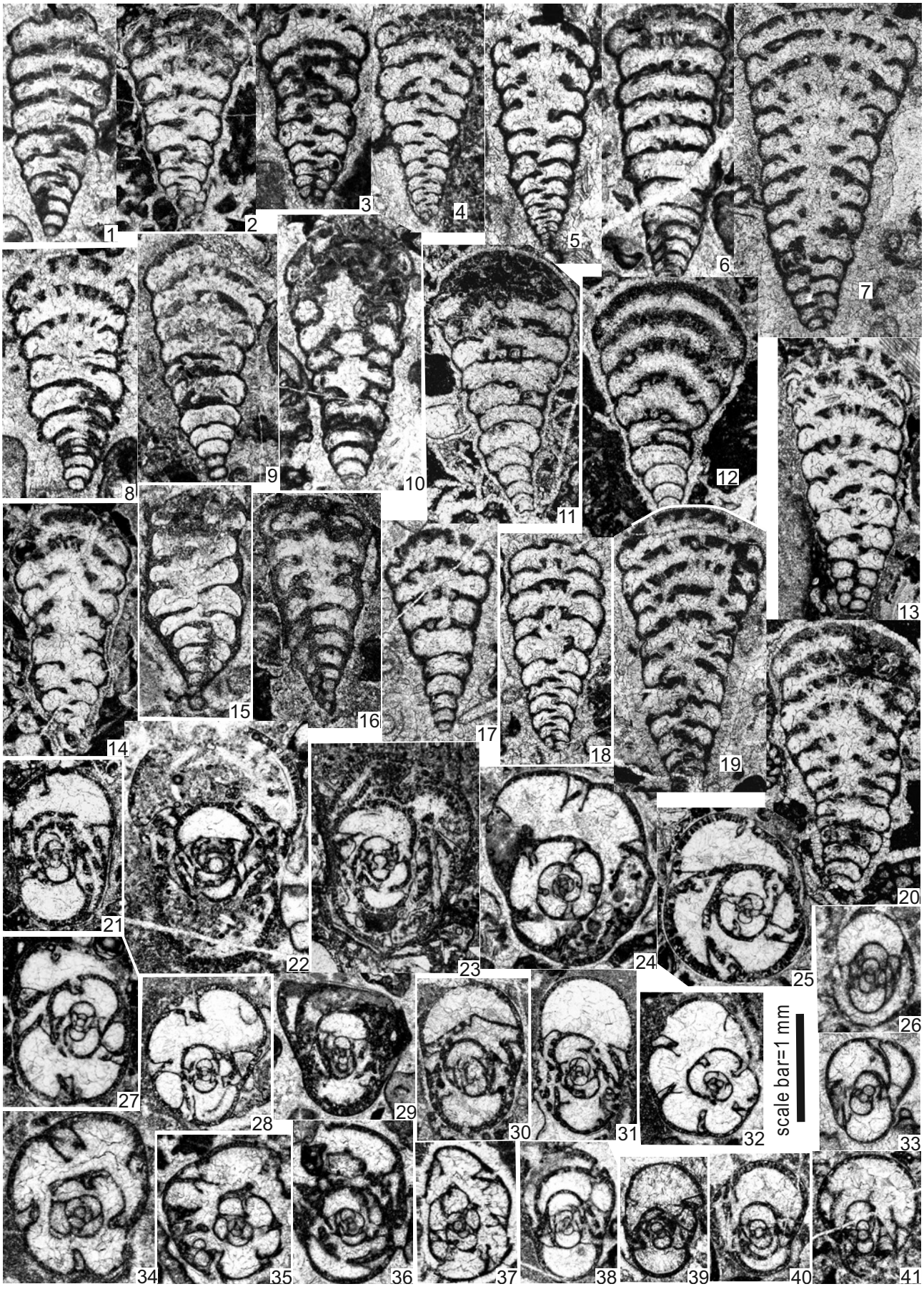
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Plate III

Figs 1-6, 30: *Bradyina nautiliformis* von Möller, 1878. 1: D2-055953, A-428 (CJ Zone); 2: D2-052647, A-391 (JC Zone); 3: D2-040919, A-25b (CJ Zone); 4: D2-047698, A-133 (Ki Zone); 5: D2-055783, A-422 (RC Zone); 6: D2-040878, A-25a (CJ Zone); 30: D2-055954, A-428 (CJ Zone).

Figs 7-10: *Bradyina compressa* Morozova, 1949. 7: D2-052581, A-387 (CJ Zone); 8: D2-052591, A-387 (CJ Zone); 9: D2-052722, A-394 (JC Zone); 10: D2-052713, A-393 (JC Zone).

Figs 11-14: *Bradyina* aff. *compressa* Morozova, 1949. 11: D2-0525334, A-384 (RT Zone); 12: D2-050132, A-229 (RT Zone); 13: D2-052604, A-388 (CJ Zone); 14: D2-052693, A-393 (JC Zone).

Figs 15, 16: *Bradyina* sp. A. 15: D-052509, A-383 (RT Zone); 16: D2-051769, A-309 (RC Zone).

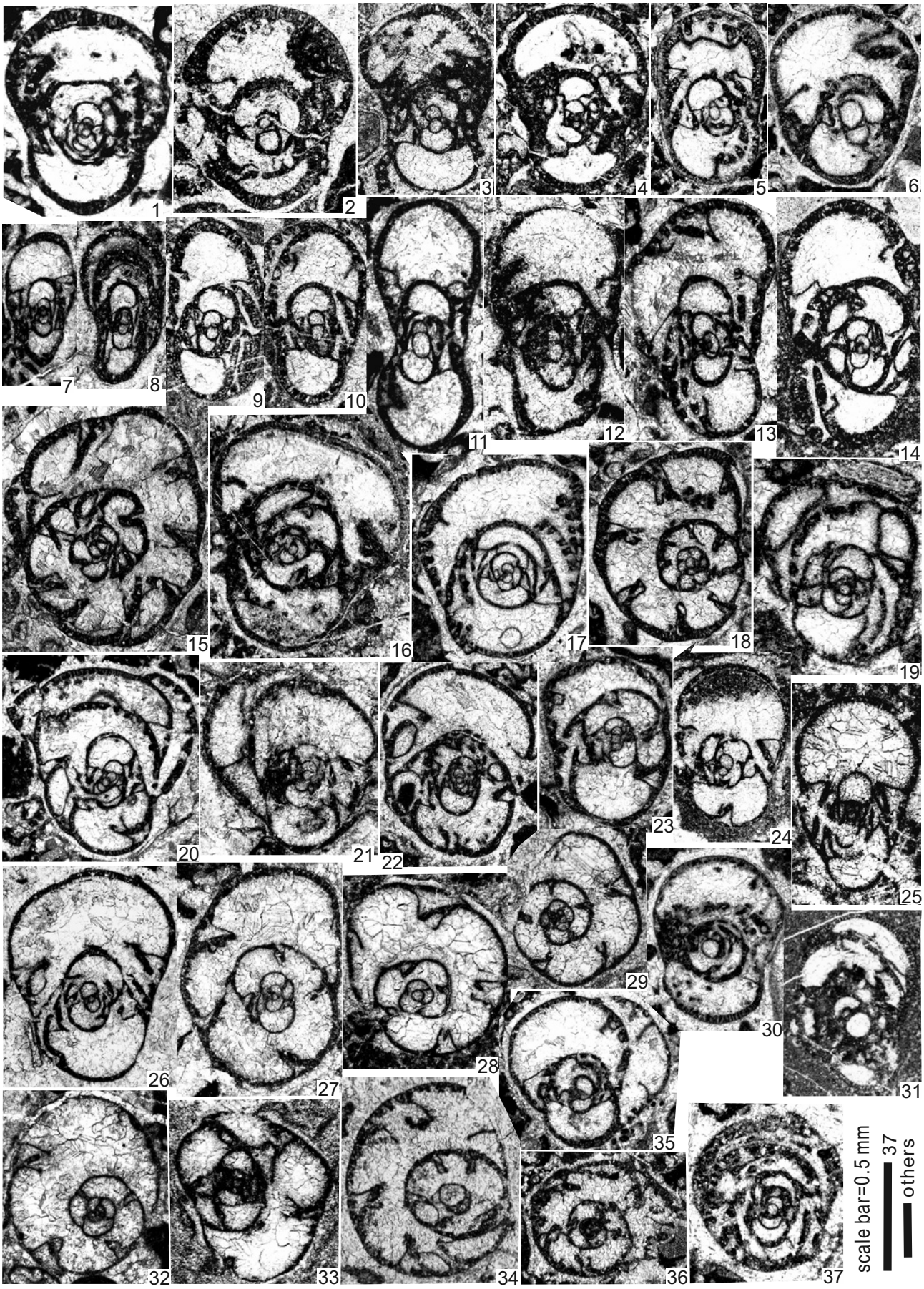
Figs 17-23: *Bradyina regularis* Lin, 1978. 17: D2-055963, A-428 (CJ Zone); 18: D2-051505, A-283 (Ki Zone); 19: D2-051446, A-280 (Ki Zone); 20: D2-050208, A-237 (CJ Zone); 21: D2-051859, A-315 (RT Zone); 22: D2-040919, A-25b (CJ Zone); 23: D2-051861, A-315 (RT Zone).

Figs 24-29, 32, 33: *Pseudojanischewskina akiyoshiensis* n. sp. 24: D2-052689, A-393 (JC Zone); 25: D2-051711, A-305 (Ps Zone); 26: D2-056043, A-433 (JC Zone); 27: D2-052512, A-384 (RT Zone); 28: D2-051713, A-305 (Ps Zone); 29: D2-041470, A-63a (SP Zone); 32: D2-050127, A-229 (RT Zone); 33: D2-051474, A-281 (Ki Zone).

Figs 31, 36, 37: *Bradyina* spp. 31: D2-052622, A-389 (CJ Zone); 36: D2-056816, B-181 (PP Zone); 37: D2-055978, A-428 (CJ Zone).

Figs 34, 35: *Pseudojanischewskina* sp. A. 34: D2-056956, B-193 (Pm Zone); 35: D2-056023, A-430 (CJ Zone).

Plate III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