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Middle Permian foraminifers of Kaize, southern part of the Saku Basin, Nagano prefecture, central Japan

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Abstract. 52 species assignable to 39 genera of Middle Permian (Midian in the Tethyan standard scale) foraminifers are distinguished in the limestone blocks exposed in Kaize, southern part of the Saku Basin, Nagano prefecture, central Japan. Faunal composition and biostratigraphic distribution of these taxa are described and discussed, in addition to systematic description of eleven species including *Yabeina kaizensis* based on the topotype materials. The ozawainellid genus, *Primoriina* is concluded to be probably a junior synonym of *Sichotenella*. The Kaize fauna is represented by (1) abundant occurrence of *Yabeina kaizensis* and *Yabeina higoensis*, (2) complete absence of genera assignable to Verbeekinidae and Staffellidae, (3) variable non-fusulinacean foraminifers consisting of 39 species assignable to 31 genera, and (4) occurrence of *Robuloides*, *Dagmarita*, and *Postendothyra*, characteristic of the Tethyan Upper Permian. These foraminifers are important paleogeographically in relation to the faunal composition and taxonomic diversity of the Tethyan and Circum-Pacific regions in the late Middle Permian time.

Key words: foraminifers, Middle Permian, limestone block, Kaize, faunal composition, taxonomic diversity

Introduction

Pre-Cretaceous rocks are narrowly distributed in Kaize, southern part of the Saku Basin, Nagano Prefecture, central Japan. They are isolated from the Jurassic accretionary complexes that are widely distributed in the Kanto Mountains by a Quaternary sedimentary cover of volcanic, lacustrine, and fluvial origin. Although details of the pre-Cretaceous geology near Kaize remain as uncertain as ever, the fossiliferous limestone in Kaize is well known on account of an occurrence of the Middle Permian fusulinacean, *Yabeina kaizensis* Huzimoto, 1936. Huzimoto (1936) also described *Yabeina globosa* (Yabe, 1906) and *Neoschwagerina craticulifera* (Schwager, 1883) from this limestone.

Recently, many fossiliferous limestone samples from Kaize, collected by S. Yui, were sent to me. Field occurrence and lithology of these limestones suggest their exotic origin along with most Upper Paleozoic limestones of Japan. In addition to two species of *Yabeina*, *Y. kaizensis* and *Y. higoensis* Kobayashi, 2001, many non-fusulinacean genera characteristic of Middle and Upper Permian limestones, such as *Dagmarita* Reytlinger, 1965, *Sichotenella* Tumanskaya, 1953, and *Robuloides* Reichel, 1946 are contained in these samples. Some of these foraminifers are very rare or have not been reported from Japan. On the other hand, fusulinaceans assignable to Verbeekinidae which are common in Middle Permian limestones are completely absent in them. The Kaize fauna distinguished herein is important not only taxonomically and biostratigraphically but also paleogeographically in relation to the faunal composition of the Middle Permian foraminifers in the Tethyan realm and Circum-Pacific (Kobayashi, 1997a; 1997b; 2005).

The main purpose of this paper is to describe and discuss the Kaize foraminiferal fauna. *Yabeina kaizensis* is redescribed based on topotype materials, and the taxonomic validity of *Primoriina* Sosnina, 1981 is discussed. All limestone thin sections used in this study are registered and stored in the collection of the Museum of Nature and Human Activities, Hyogo (Fumio Kobayashi Collection).

Material

Five limestone samples used in this paper were collected from a cliff, composed of siliciclastic rocks containing limestone blocks, that secured a place for building materials at the foot of the slope north of Ichinofuchi, Kaize, Sakuho-machi, Minamisaku-gun,

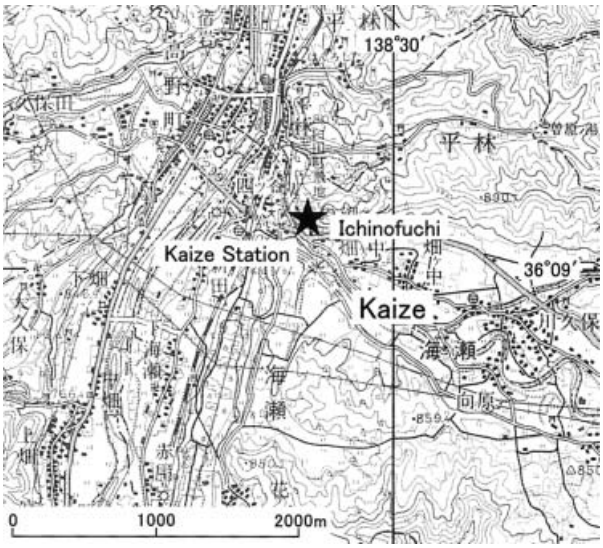

Figure 1. Index map showing the fossil locality in Kaize. Topographic map from 1:50,000 map "Tateshinayama and Jyukkokutoge" of Geographical Survey Institute of Japan.

Nagano Prefecture (Figure 1). The limestone is gray, massive, and less than 10 m in length, and the surrounding muddy sandstone and mudstone are sheared and foliated (Figure 2). Although the age of the siliciclastic rocks is unknown, from the geologic structure of the Kanto Mountains, pre-Cretaceous rocks isolated in Kaize are thought to correspond to the western extension of the Otchizawa Formation (Metallic Mining Industry Agency of Japan, 1975; Hisada and Kishida, 1986) or a part of the Hamadaira Group (Hisada and Kishida, 1986) distributed in the boundary area between Nagano and Gumma prefectures.

Petrographically, five limestone samples are largely divided into two types. One is fusulinacean bioclastic packstone in which many bioclasts are packed within fine-grained lime-mud (Kaize-1 and Kaize-2). The other is fusulinacean packstone/grainstone showing partly conglomeratic appearance (Kaize-3, -4, and -5). All of these limestone are fossiliferous, and contain marine algae, crinoids, brachiopods, porifers, bryozoans, gastropods, and ostracodes in addition to many foraminifers.

Fauna and biostratigraphy

After the microscopic observation of 143 limestone thin sections, 52 species assignable to 39 genera of foraminifers are discriminated in five limestone samples (Table 1). Among the five, taxonomic diversity is the highest in the sample Kaize-1, but *Yabeina kaizensis*, abundantly contained in other four samples, is not found in Kaize-1. *Chusenella* is also absent in Kaize-1. Faunal composition is different between Kaize-2 and Kaize-3 to -5 with respect to the absence of *Ya-*

Figure 2. The occurrence of fossiliferous limestone blocks surrounded by sheared siliciclastic rocks in Kaize. Photographed by S. Yui.

Table 1. Occurrences of foraminifers in five limestone samples of Kaize.

	Kaize-1	Kaize-2	Kaize-3	Kaize-4	Kaize-5
Spireitlina sp.	X				
Brunsiella sp.	X				
Pseudoglomospira sp.	X		X	X	X
Lunucammina? sp.	X				
Pachyphloia ovata Lange	X	X	X	X	X
Pachyphloia schwageria Sell. de Civ. and Dess.	X				
Pachyphloia sp.	X				
Climacammina sp.	X				
Palaeotextulariidae gen. and sp. indet.		X			
Globivalvulina cyprica Reichel	X				
Dagmarita chanakchiensis Reytlinger	X				
Neoendothyra sp.	X				
Postendothyra guangxiensis (Lin)	X	X	X	X	X
Postendothyra tenuis Lin, Li and Sun	X				
Abadehella sp.	X				
Kahlerina cf. *nautiloidea* Sosnina	X	X			
Rauserella ellipsoidalis Sosnina	X				
Rauserella sp.	X				
Reichelina sp. A	X				
Reichelina sp. B	X				
Sichotenella ovoidea (Sosnina)	X				
Codonofusiella sp.	X	X			
Dunbarula cascadensis (Thomp., Wh. and Da.)	X	X	X	X	X
Dunbarula sp.	X				
Chusenella atlinensis (Ross)		X	X	X	X
Chusenella? sp.				X	X
Yabeina higoensis Kobayashi	X	X			
Yabeina kaizensis Huzimoto		X	X	X	X
Pseudovidalina sp.	X				
Raphconila sp.	X				
Cornuspira sp.		X			
Calcitornella sp.	X				
Calcivertella sp.	X				
Agathammina sp. A	X				X
Agathammina sp. B	X				
Agathammina? sp.	X				
Hemigordius irregulariformis Zan., Alt. and Catal	X	X			
Hemigordius sp.	X				
Hemigordiopsis? sp.	X	X		X	
Neodiscus sp. A	X				X
Neodiscus sp. B	X	X			
Baisalina sp.	X				
Geinitzina postcarbonica Spandel	X	X			
Nodosinelloides? spp.	X	X			
Vervillerina sp.	X				
Cryptoseptida sp.	X				
Frondina palmata (Wang)	X	X			
Gerkeina? sp.	X				
Langella fragilis (Sell. de Civ. and Dess.)	X	X			
Langella sp.	X				
Robuloides acutus Reichel	X	X			
Partisania sp.	X				

beina higoensis and any forms of Lagenina in the latter. These five samples are certainly Midian in age in the Tethyan standard based on the common occurrence of *Yabeina* (Leven, 1996; Kobayashi, 1997a, 1999).

Yabeina higoensis was originally described by Kobayashi (2001) from a limestone block of the Kuma Formation in the Kurosegawa Terrane of west Kyushu. Faunal composition of fusulinaceans is different between Kaize and Kuma, and *Lepidolina multi-*

septata (Deprat, 1912), *L. kumaensis* Kanmera, 1954, *Metadoliolina gravitesta* (Kanmera, 1954), *Chusenella pseudocrassa* (Kanmera, 1954), and others characteristic in Kuma materials are not recognized in Kaize. Two specimens of *Neoschwagerina craticulifera* and four specimens of *Yabeina globosa* from Kaize were illustrated by Huzimoto (1936). They are not identical with the original materials by Schwager (1883) and Yabe (1906) and subsequent ones by many authors. From morphologic characters they are referable to *Yabeina higoensis*, as mentioned below.

Although no well-oriented specimens of *Yabeina kaizensis* were illustrated by Huzimoto (1936), the present materials are in size and shape of the test, proloculus size, and development of secondary transverse septula similar to the original specimens of Huzimoto (1936). *Yabeina kaizensis* is morphologically more similar to *Yabeina columbiana* (Dawson, 1879), a well known species from the western North American Cordillera, than to other species of *Yabeina* (Kobayashi *et al.*, 2006).

Chusenella atlinensis (Ross, 1971) is associated with *Yabeina cordillerensis* Ross, 1971 in northwest British Columbia. It is thought to be Wordian in age by associated ammonoids (Ross, 1971). Specimens belonging to or comparable to this species are known from the Midian limestones of the Circum-Pacific including southern British Columbia, New Zealand, and Japan (Kobayashi *et al.*, 2006).

Other fusulinaceans such as *Kahlerina*, *Rauserella*, *Reichelina*, *Sichotenella*, *Codonofusiella*, and *Dunbarula* assignable to Ozawainellidae and Schubertellidae are common to the Kaize fauna and other contemporaneous faunas of Japan, especially from the Chichibu and Kurosegawa terranes (Kobayashi, 1986; 2001). Among these smaller-sized fusulinaceans, *Sichotenella ovoidea* (Sosnina, 1981) and *Dunbarula cascadensis* (Thompson *et al.*, 1950) are characteristic in the Kaize fauna. On the other hand, fusulinaceans assignable to Verbeekinidae and Staffellidae are completely absent in the Kaize fauna.

Among the five Kaize samples, non-fusulinacean foraminifers are especially dominant in Kaize-1, as well as smaller-sized fusulinaceans (Table 1). They are highly variable in comparison with the faunas of almost the same age reported from the Gozenyama Formation (Kobayashi, 1986) and Omi Limestone (Kobayashi, 1988) in spite of the smaller sample size of the present materials. *Postendothyra*, *Robuloides* and some other genera assignable to Lagenina are dominant among non-fusulinacean foraminifers of Kaize. On the contrary, tetrataxids and palaeotextulariids commonly and almost always found in the Japanese Middle Permian are completely absent or very few in the examined Kaize materials.

Most of the non-fusulinacean foraminifers are common in and closely related to those of the Middle Permian of the Tethyan regions. On the other hand, the Kaize fauna contains *Robuloides acutus* Reichel, 1946, *Dagmarita chanakchiensis* Reytlinger, 1965, *Postendothya guangxiensis* (Lin, 1978), and *Postendothyra tenuis* Lin, Li, and Sun, 1990, which were originally described from the Upper Permian of Greece (Reichel, 1946), Transcaucasus (Reytlinger, 1965), and Guangxi (Lin, 1978; Lin *et al.*, 1990). In Japan, these genera and species are reported from Upper Permian limestones of the Kanto Mountains (Kobayashi, 1997c), South Kitakami (Kobayashi, 2002), and western Shikoku (Kobayashi, 2004). Their occurrence in Kaize shows that they are not restricted to the Upper Permian and stratigraphically range downward to the upper part of the Middle Permian.

Loeblich and Tappan (1988) advocated that *Neoendothyra reicheli* Reytlinger, 1965 from the Lower Triassic (Induan) of the Transcaucasus (Reytlinger, 1965) and from Anisian limestone of Slovakia (Salaj *et al.*, 1983) should be transferred to *Robuloides*. The microgranular wall of *Neoendothyra* as originally described by Reytlinger (1965), however, is strongly in conflict with its reassignment to *Robuloides*, which has a hyaline wall. *Robuloides* is, therefore, considered to be a characteristic genus for the Upper Permian along with *Dagmarita*, and not to range upward into the Triassic.

In conclusion, the Midian Kaize fauna is represented by (1) abundant occurrence of *Yabeina kaizensis* and *Yabeina higoensis*, (2) complete absence of genera assignable to Verbeekinidae and Staffellidae, (3) variable non-fusulinacean foraminifers consisting of 39 species assignable to 31 genera, and (4) occurrences of *Robuloides*, *Dagmarita*, and *Postendothyra* dominated in the Upper Permian. These are important not only taxonomically and biostratigraphically, but also paleogeographically in relation to the faunal composition of the Middle Permian foraminifers in the Tethyan and Circum-Pacific regions.

Systematic paleontology

Order Foraminiferida
Suborder Fusulinina
Superfamily Palaeotextulariacea
Family Biseriamminidae
Genus ***Globivalvulina*** Schubert, 1921
Globivalvulina cyprica Reichel, 1946

Figures 3.7(?), 3.11–3.14, 3.15(?)

Globivalvulina cyprica Reichel, 1946, p. 553, 554, fig. 39, a–f.

Discussion.—Reichel (1946) recognized four new species of Middle and Late Permian *Globivalvulina* from Greece and Cyprus, *gracea*, *cyprica*, *vonderschmitti*, and *kantharensis*, based on differences of test size, chamber arrangement, and wall structure. These species, especially the former three, are widely distributed in the Middle and Upper Permian throughout the Tethyan region, and their wall structure and chamber arrangement are very important phylogenetically and taxonomically among the Permian biseriamminids (Zaninetti and Altiner, 1981; Altiner, 1997; Altiner and Özkan-Altiner, 2001).

A distinct translucent layer, though indistinct in some specimens, is very characteristic in the present materials. Two-layered wall structure of outer diaphanotheca-like and inner microgranular are thought to be the most important character in recognition of *Globivalvulina cyprica* (Altiner and Özkan-Altiner, 2001). Based on the wall structure and more slowly enlarging chambers than in *G. vonderschmitti* and *G. gracea*, the present materials are identified with *G. cyprica*, originally described from the Middle Permian of Cyprus (Reichel, 1946).

Genus ***Dagmarita*** Reytlinger, 1965
Dagmarita chanakchiensis Reytlinger, 1965

Figures 3.38, 3.39

Dagmarita chanakchiensis Reytlinger, 1965, p. 63, pl. 1, figs. 10–12.

Discussion.—Although the morphology of the early stage is unknown, the present materials are very characteristic in biserially arranged chambers and distinct spinelike projections in outer margins of chambers. From these characters, they are undoubtedly assignable to *Dagmarita* and probably identical with the type species of the genus, *D. chanakchiensis*, described from the Dzhulfian Gnisiksk and Khachisk formations of Transcaucasus (Reytlinger, 1965). The Kaize materials from the Middle Permian (Midian) limestone are also closely similar morphologically to those identified with this species from the Upper Permian (Changxingian) limestone in the Iwai Kanyo area, west Tokyo (Kobayashi, 1997c).

Superfamily Endothracea
Family Endothyridae?
Genus ***Spireitlina*** Vachard and Beckary, 1991
Spireitlina sp.

Figures 3.44–3.46

Granuliferelloides? sp. Kobayashi, 2001, pl. 1, figs. 43, 44. (not described)

Gen. and sp. indet A, Kobayashi, 2001, pl. 2, figs. 10, 11. (not described)

Description.—Test small, elongate, about 0.3 mm in diameter and more than 0.6 mm in length. Initial chamber distinct and about 0.06 mm in diameter. Succeeding one or two endothyroid whorls followed by later biserially arranged rectilinear chambers. Septa radially and rather closely spaced in the coiled stage, and anteriorly convex and regularly spaced in the uncoiled stage. Wall about 0.02 mm, calcareous, and coarsely granular with many adventitious materials.

Material examined.—Illustrated three specimens

Discussion.—Test size, structure and thickness of wall, and chamber arrangement of the present materials are nearly the same as in certain upper Middle Permian (Midian) specimens from the Kuma Formation, west Kyushu (Kobayashi, 2001). Kobayashi questionably referred the Kuma specimens to *Granuliferelloides* and an unknown affinity mainly based on their coarsely granular calcareous wall rather than agglutinated nature and biserially arranged rectilinear chambers in the later stage.

Based on the wall structure and chamber arrangement, the Kaize and Kuma materials are more reasonably assigned to *Spireitlina* proposed by Vachard and Beckary (1991) to accommodate specimens formerly belonging to *Ammobaculites* Cushman, 1910, *Endothyranella* Galloway and Harlton, *in* Galloway and Ryniker, 1930, and others.

Occurrence.—Very rare in the Kaize-1 in association with *Yabeina higoensis* and many others (Table 1).

Family Bradyinidae
Genus ***Postendothya*** Lin, 1984
Postendothyra guangxiensis (Lin, 1978)

Figures 4.21–4.24, 4.30–4.34

Endothyranopsis guangxiensis Lin, 1978, p. 34, pl. 7, figs. 1–3.
Postendothyra guangxiensis (Lin, 1978). Lin, Li, and Sun, 1990, p. 191, pl. 18, figs. 21–26.

Discussion.—The present materials agree with the type specimens of *Endothyranopsis guangxiensis* Lin, 1978, from the Upper Permian of Guangxi and with the further material of Lin *et al.* (1990), in which publication the species was transferred to *Postendothyra*, in having a relatively small test, small number of whorls, microgranular to finely granular thin wall partly showing indistinct alveolar structure in the last whorl, and anteriorly inclined septa. By these test characters, this species is distinguished from other species of *Postendothyra*.

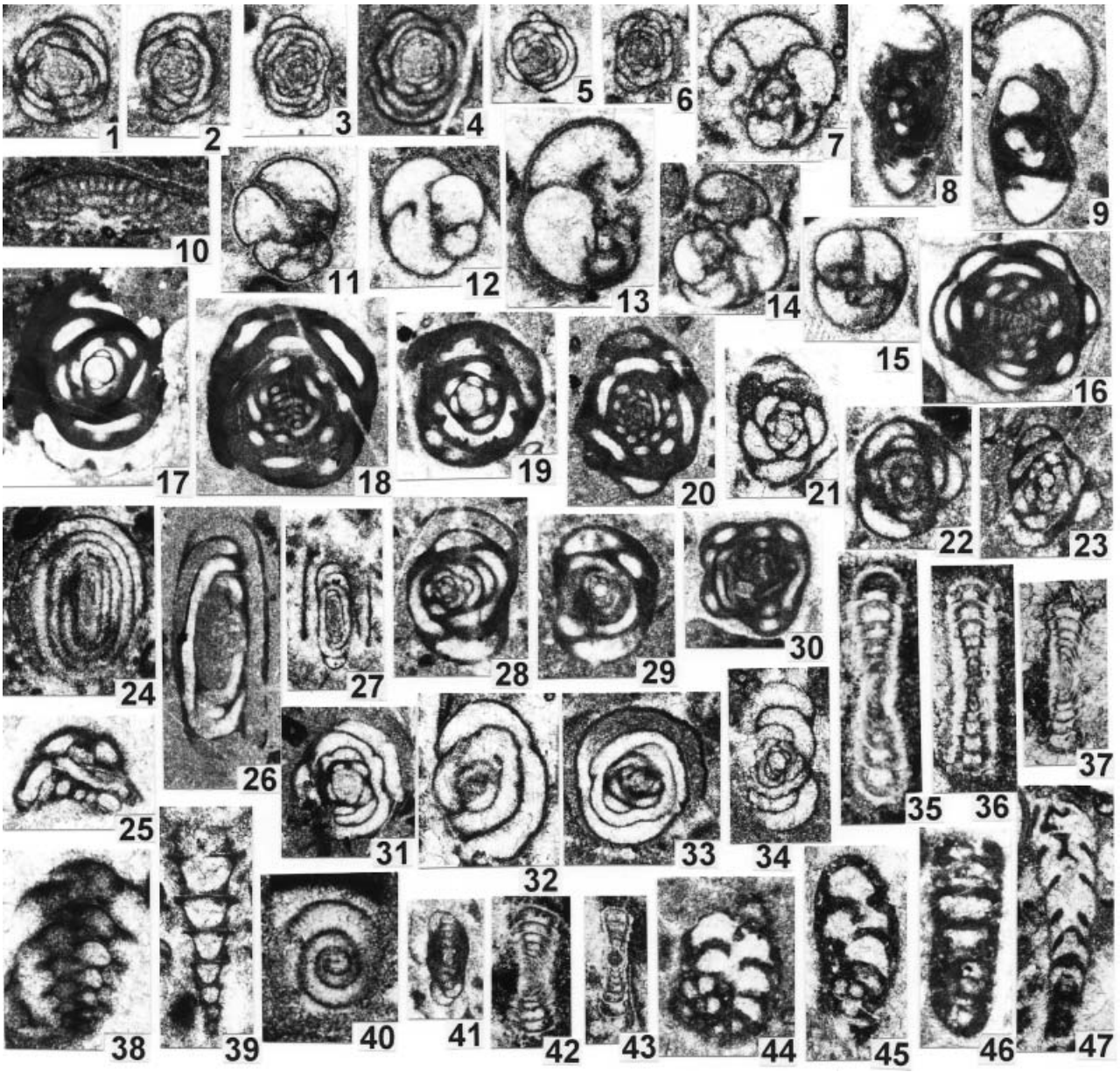

Figure 3. **1–6.** *Pseudoglomospira* sp.: 1, D2-023835; 2, D2-023828c; 3, D2-025763d; 4, D2-023819b; 5, D2-025772c; 6, D2-023828d, all Kaize-1, X50. **7(?), 11–14, 15(?).** *Globivalvulina cyprica* Reichel: 7, D2-025778b; 11, D2-023836d; 12, D2-023825c; 13, D2-025951b; 14, D2-023825d; 15, D2-025769c, all Kaize-1, X50. **8, 9.** *Neoendothyra* sp.: 8, D2-023816b; 9, D2-023836c; both Kaize-1, X50. **10.** *Abadehella* sp., D2-025771a, Kaize-1, X40. **16, 20.** *Neodiscus* sp. A: 16, D2-030117b; 20, D2-025777c; both Kaize-1, X40. **17–19.** *Baisalina* sp.: 17, D2-030091b; 18, D2-030117c; 19, D2-030116a, all Kaize-1, X30. **21.** *Agathammina* sp. B, D2-025779a, Kaize-1, X40. **22, 23, 28–30.** *Neodiscus* sp. B: 22, D2-025944b; 23, D2-025771b; 28, D2-025949; 29, D2-023843; 30, Da-023830, all Kaize-1 except for 29; Kaize-2, 28, X40; others, X50. **24.** *Agathammina*? sp., D2-023826c, Kaize-1, X50. **25.** *Calcitornella* sp., D2-030109b, Kaize-1, X50. **26, 27.** *Agathammina* sp. A: 26, D2-030105d, X30; 27, D2-023828e, X40, both Kaize-1. **31–33.** *Hemigordiopsis*? sp.: 31, D2-023828f; 32, D2-025779b; 33, D2-030104c, all Kaize-1, X40. **34.** *Hemigordius* sp., D2-025777d, Kaize-1, X40. **35.** *Raphconila* sp., D2-025939b, Kaize-1, X40. **36, 37, 42, 43.** *Pseudovidalina* sp.: 36, D2-030101b; 37, D2-025764d; 42, D2-030115b; 43, D2-023830b, all Kaize-1, 36, 37; X40; 42, 43, X50. **38, 39.** *Dagmarita chanakchiensis* Reytlinger: 38, D2-030093e; 39, D2-025768, both Kaize-1, X50. **40.** *Cornuspira* sp., D2-023841, Kaize-2, X125. **41.** *Hemigordius irregulariformis* Zaninetti, Altiner and Catal, 1981, D2-025775d, Kaize-1, X50. **44–46.** *Spireitlina* sp.: 44, D2-025771c; 45, D2-030111b; 46, D2-030095b, all Kaize-1, X50. **47.** *Gerkeina*? sp., D2-030107, Kaize-1, X30.

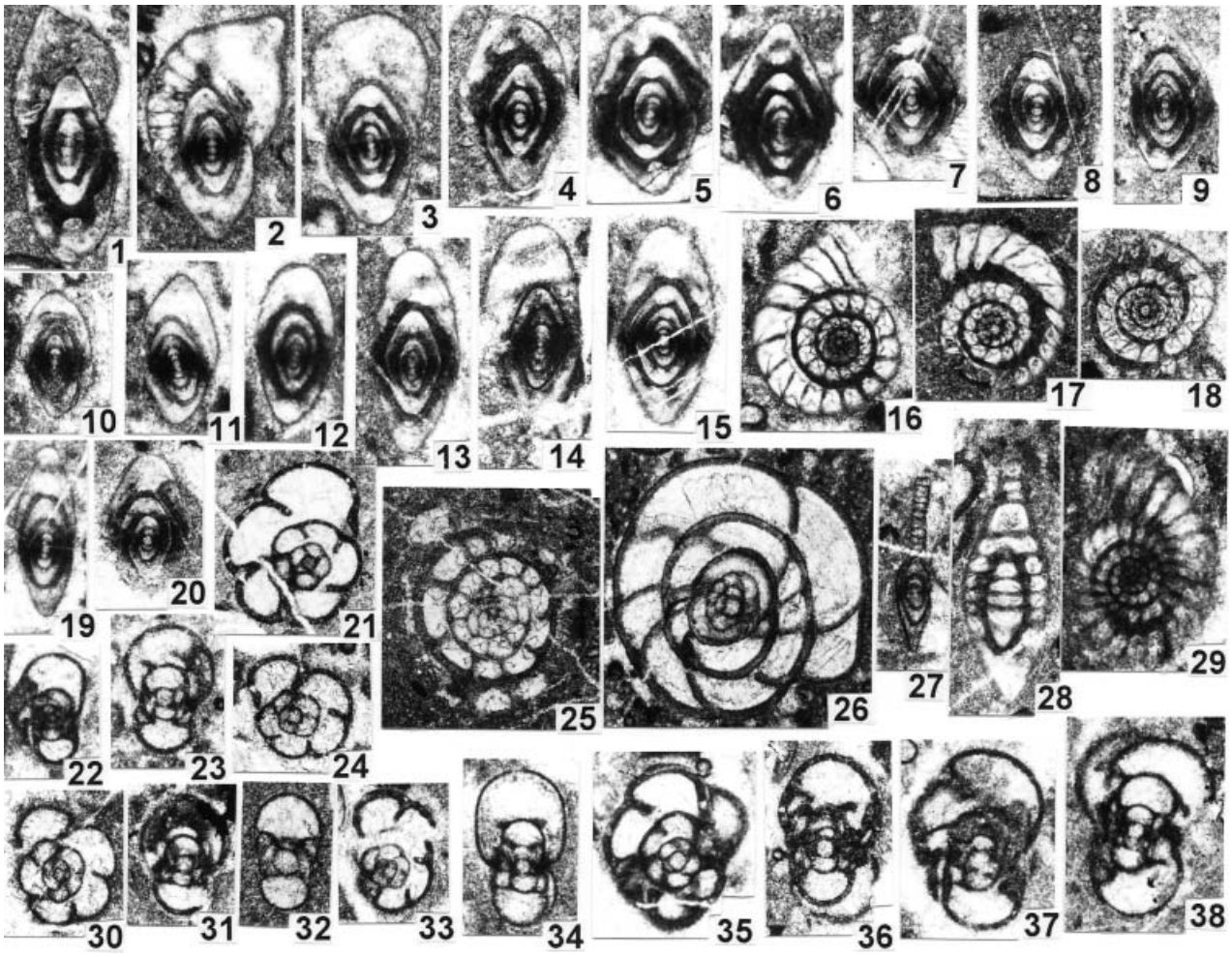

Figure 4. 1–20. *Sichotenella ovoidea* (Sosnina): 1, D2-030113a; 2, D2-025947a; 3, D2-030104a; 4, D2-025780a; 5, D2-025943a; 6, D2-025941b; 7, D2-023815; 8, D2-030093a; 9, D2-025764b; 10, D2-025763a; 11, D2-030113b; 12, D2-023817b; 13, D2-025762a; 14, D2-025772a; 15, D2-023831a; 16, D2-030117a; 17, D2-030093b; 18, D2-030105a; 19, D2-023833a; 20, D2-030098a; all Kaize-1, X50. **21–24, 30–34.** *Postendothya guangxiensis* (Lin): 21, D2-025775b; 22, D2-023824b; 23, D2-025776b; 24, D2-025777b; 30, D2-023819a; 31, D2-023828a; 32, D2-025937; 33, D2-030108b; 34, D2-030105b, all Kaize-1, X50. **25, 26.** *Kahlerina* cf. *nautiloidea* Sosnina, 1968: 25, D2-023839, Kaize-2, X30; 26, D2-025776a, Kaize-1, X30. **27.** *Reichelina* sp. A, D2-023833b, Kaize-1, X50. **28, 29.** *Reichelina* sp. B: 28, D2-030108a; 29, D2-023814, both Kaize-1, X50. **35–38.** *Postendothya tenuis* Lin, Li, and Sun: 35, D2-030097b; 36, D2-025763b; 37, D2-025769b; 38, D2-025938b; all Kaize-1, X50.

Postendothyra tenuis Lin, Li, and Sun, 1990

Figures 4.35–4.38

Postendothyra tenuis, Lin, Li, and Sun, 1990, p. 192, pl. 19, figs. 4–8.

Discussion.—This species somewhat resembles *Postendothyra guangxiensis* in its simple test construction of a relatively large proloculus followed by two to three nearly planispirally coiled whorls with shallow umbilical depressions and five or six chambers in the outer whorl. However, they seem to be separated by larger test, thicker wall, and small chamberlets along the sutures in the former.

Two species of *Postendothyra*, *P. tenuis* and *P.* sp., were distinguished by Kobayashi (1997c) from the Changxingian limestone in the Iwai Kanyo area. *Postendothyra* sp. in the Iwai Kanyo is different from this species in having more rapidly enlarging chambers and larger proloculus.

Superfamily Fusulinacea
Family Ozawainellidae
Genus ***Sichotenella*** Tumanskaya, 1953

Sichotenella Tumanskaya, 1953, p. 22. (original designation)
Primoriina Sosnina 1981, p. 19, 20. (original designation)

Discussion.—*Sichotenella*, proposed by Tumanskaya (1953) from the Midian of Primorye, is not easy to distinguish from some other genera of Ozawainellidae due to its unclear generic diagnosis and not well-oriented illustrations (one tangential and three oblique sections) in the original publication. Lenticular test and rapidly increasing final whorl or uncoiled chambers in later stage are thought to be diagnostic in this genus. *Sichotenella* is morphologically similar to *Chenella* established by A.D. Miklukho-Maklay (1959). However, they are distinguishable from one another by the difference of test size and stratigraphic distribution. It is different from *Reichelina* Erk, 1941, in the more closely spaced and greater number of septa of *Reichelina*.

Sosnina (1981) proposed *Primoriina* and showed well-oriented specimens of *Primoriina* and *Sichotenella* from the Midian of Primorye. Among the 17 specimens illustrated, forms with gradually expanding whorls were referred to *Primoriina* and those with rapidly increasing final whorl to *Sichotenella*, although she did not mention the morphologic variation of the test. The generic validity of *Primoriina* is not easily understood on the basis of a presence of regularly arranged minute openings within massive chomata in the outer whorl as indicated by Sosnina (1981). These openings are clear in the retouched photographs of some specimens, but are obscure in others. Moreover, some specimens referred to *Primoriina* (Sosnina, 1981; pl. 1, figs. 2; pl. 2, fig. 7) have almost the same morphology as some *Sichotenella* (Sosnina, 1981; pl. 1, figs. 6, 19; pl. 2, fig. 8).

Considering the wide variation of many characters in specimens identified as *Sichotenella ovoidea* (Sosnina, 1981) from the sample Kaize-1, it is difficult to maintain the generic independence of *Primoriina* from *Sichotenella* based on slight differences in expansion of outer test, development of chomata, and minute openings within chomata in specimens. These minute openings are also found in the Kaize specimens having massive and well-developed chomata in the last whorl. Accordingly, *Primoriina* is probably best thought to be a junior synomym of *Sichotenella*. Further discussion of this requires a detailed generic diagnosis of *Sichotenella* based on well-oriented specimens of the type species.

Sichotenella ovoidea (Sosnina, 1981)

Figures 4.1–4.20

Primoriina ovoidea Sosnina, 1981, p. 20, 21, pl. 1, figs. 1–5.
Primoriina rotunda Sosnina, 1981, p. 21, pl. 2, figs. 6, 7.
Sichotenella ventricosa Sosnina, 1981, p. 18, 19, pl. 2, figs. 8, 9.

Discussion.—More than forty well-oriented specimens, all of which are from the sample Kaize-1, were examined. Sixteen axial, one tangential, and three sagittal sections illustrated in Figure 4 show wide morphologic variation in proloculus size, length and width of corresponding whorls, shape of the periphery, lateral slope, and polar region, and development of chomata and secondary deposits. Differences of external shape and chamber height of the last whorl, and of the development of chomata are especially conspicuous among specimens. These differences, however, are gradual and change from specimen to specimen. Therefore, they are considered to be intraspecific variation or due to the orientation of thin sections.

The Kaize specimens are closely similar in many respects to *Primoriina ovoidea*, *P. rotunda*, and *Sichotenella ventricosa*, all of which were described from the Midian *Metadoliolina lepida* Zone of Primorye by Sosnina (1981). These three forms are hardly distinguishable from each other by slight differences of test morphology, and are considered to be conspecific. Therefore, the present specimens are named *Sichotenella ovoidea* (Sosnina). *Reichelina* sp. A and *R*. sp. B in this paper are easily distinguished from this species by evident uncoiled final stage and more closely spaced septa.

Family Schubertellidae
Subfamily Boultoniidae
Genus ***Dunbarula*** Ciry, 1948

Dunbarula cascadensis (Thompson, Wheeler, and Danner, 1950)

Figures 5.4–5.19

Boultonia cascadensis Thompson, Wheeler, and Dannner, 1950, p. 53, 54, pl. 3, figs. 1–5.
Dunbarula laudoni Skinner and Wilde, 1966, p. 24, pl. 18, figs. 1–8.
Dunbarula kitakamiensis Choi, 1970, p. 314, 316, pl. 8, figs. 1–6.

Discussion.—*Dunbarula laudoni* is not easily distinguishable from *Boultonia cascadensis* and they are conspecific, as suggested by Kobayashi (1986). Both forms were described from northwestern Washington (Thompson *et al.*, 1950; Skinner and Wilde, 1966). *Dunbarula kitakamiensis* Choi (1970) from the Midian limestone of Iwaizaki, South Kitakami closely resembles these two west North American forms in many respects, and is thought to be a junior synonym of *Dunbarula cascadensis*. It is not possible to distinguish *kitakamiensis* from *cascadensis* and *laudoni* by the difference of wall structure as indicated by Choi (1970), because a distinct diaphanotheca with variable thickness is always present in the outer whorls of these three forms.

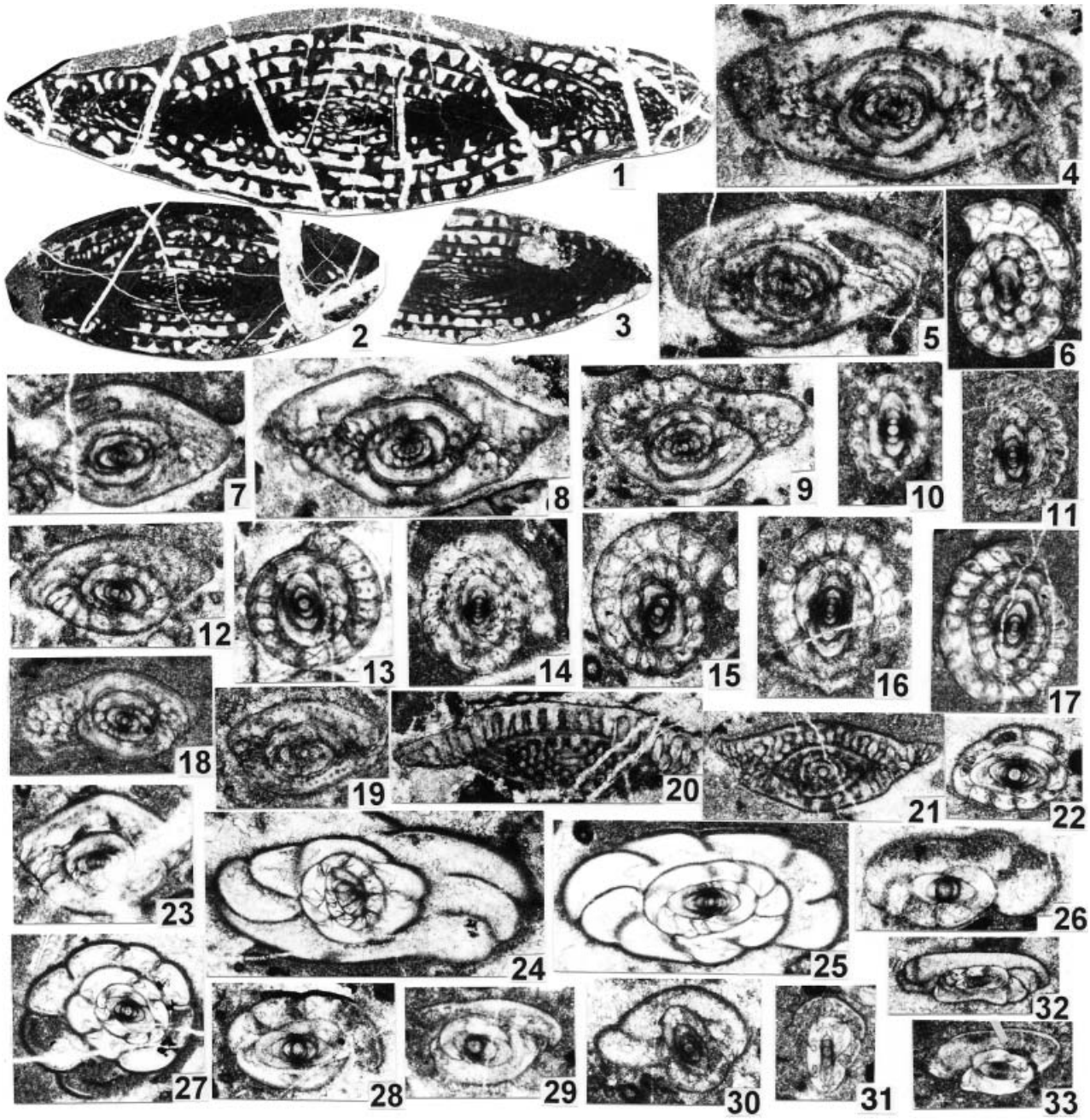

Figure 5. **1.** *Chusenella*? sp., D2-023884, Kaize-5, X10. **2, 3.** *Chusenella atlinensis* (Ross): 2, D2-023840a; 3, D2-023842, both Kaize-2, X10. **4–19.** *Dunbarula cascadensis* (Thompson, Wheeler, and Danner): 4, D2-025781a; 5, D2-025764c; 6, D2-025938c; 7, D2-025941c; 8, D2-025947b; 9, D2-025778c; 10, D2-025939a; 11, D2-023837b; 12, D2-025763c; 13, D2-030109a; 14, D2-030091a; 15, D2-025946a; 16, D2-025943b; 17, D2-030095a; 18, D2-030093c; 19, D2-025778d, all Kaize-1, X40. **20, 21.** *Codonofusiella* sp.: 20, D2-023840b; Kaize-2; X30; 21, D2-025781c; Kaize-1; X40. **22, 24–30.** *Rauserella ellipsoidalis* Sosnina, 1968: 22, D2-030105c; 24, D2-023826b; 25, D2-030104b; 26, D2-025762c; 27, D2-030093d; 28, D2-025946b; 29, D2-025780c; 30, D2-023818a, all Kaize-1, all X40. **23.** *Dunbarula* sp., D2-023816c, Kaize-1, X40. **31–33.** *Rauserella* sp.: 31, D2-025775c; 32, D2-025781d; 33, D2-023828b; all Kaize-1, X40.

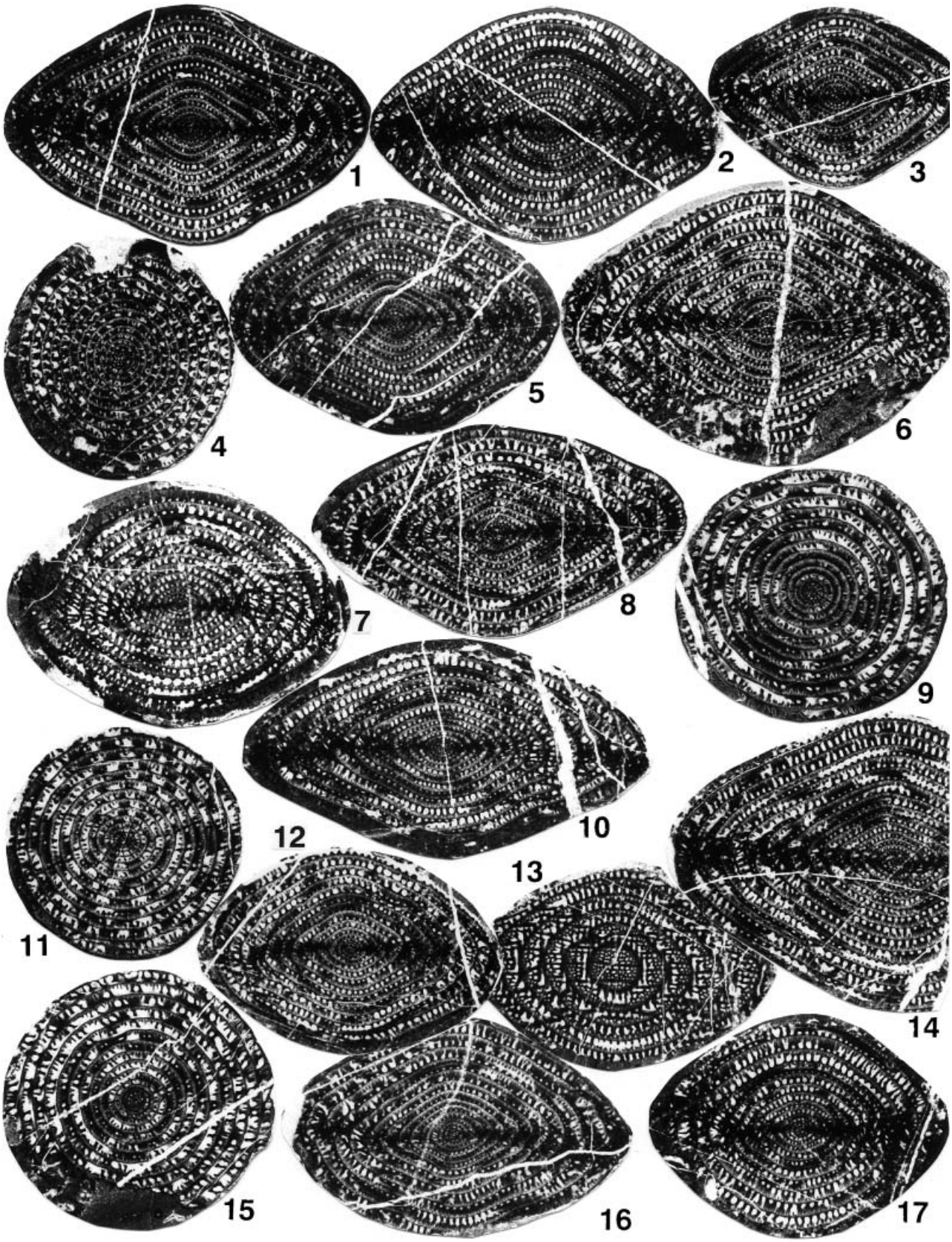

Figure 6.

In addition, mainly based on the lack of septal pores Choi (1970) insisted on the taxonomic independence of *Dunbarula kitakamiensis* from *D. mathieui* Ciry, 1948, type species of *Dunbarula* from Tunisia. However, undoubted septal pores are present in the specimen designated as the holotype of *D. kitakamiensis* (Choi, 1970; pl. 8, fig. 4). *D. mathieui* differs largely from these Circum-Pacific forms of *Dunbarula*, *D. cascadensis* and its synonyms *D. laudoni* and *D. kitakamiensis*, by its larger test and strongly fluted septa throughout the test in the outer whorls.

Family Schwagerinidae
Genus ***Chusenella*** Hsu, 1942
Chusenella atlinensis (Ross, 1971)

Figures 5.2, 5.3

Schwagerina atlinensis Ross, 1971, p. 97, pl. 17, figs. 1–5.
Chusenella urulungensis Wang, Sheng, and Zhang, 1981; Leven and Grant-Mackie, 1997, p. 477, 479, fig. 3J.

Discussion.—This species has more loosely coiled inner whorls and a larger proloculus than most other species of *Chusenella*. Although the morphologic variation of the present materials cannot be well understood on account of the small number of well-oriented specimens, they are probably identical with *Chusenella atlinensis*, originally assigned to *Schwagerina* by Ross (1971) from Wordian limestone of northwest British Columbia. The New Zealand material of *Chusenella* by Leven and Grant-Mackie (1997) is more similar to this species than *Chusenella urulungensis* proposed from Xizang by Wang *et al.* (1981) with respect to more loosely coiled inner whorls, more slowly expanding outer whorls, and more strongly fluted septa throughout the test in the former.

Family Neoschwagerinidae Dunbar and Condra, 1927
Subfamily Neoschwagerininae Dunbar and Condra, 1927
Genus ***Yabeina*** Deprat, 1914
Yabeina higoensis Kobayashi, 2001

Figures 6.1–6.17

Yabeina higoensis Kobayashi, 2001, p. 72, Fig. 6.4, 6.8; pl. 5, figs. 1–9.
Neoschwagerina craticulifera (Schwager, 1883). Huzimoto, 1936, p. 112, 113; pl. 22, figs. 6, 7; pl. 23, fig. 6.
Yabeina globosa (Yabe, 1906). Huzimoto, 1936. p. 119, 120; pl. 25, figs. 1–4.

Discussion.—Diagnostic characters and affirmation of the taxonomic independence of *Yabeina higoensis* were already given by Kobayashi (2001), in which three specimens referable to this species from the sample Kaize-1 were shown (Kobayashi, 2001, pl. 5, figs. 3, 4, 9). Diagnostic characters of this species are represented by smaller height of the whorl in the middle and late stages than that of other species of *Yabeina*, and good development of secondary transverse septula and axial septula in comparison with a relatively small test.

The seventeen additional specimens from Kaize illustrated herein are also quite identical with six specimens from the Kuma Formation (Kobayashi, 2001). Wide intrapopulational as well as intraspecific variation of this species is well understood from them. Specimens from Kaize identified as *Neoschwagerina craticulifera* and *Yabeina globosa* by Huzimoto (1936) are in part thought to be incomplete specimens referable to *Yabeina higoensis*. These particular specimens have secondary transverse septula more well developed than those of *Neoschwagerina craticulifera* and less well developed than those of *Yabeina globosa*.

Yabeina kaizensis Huzimoto, 1936

Figures 7.1–7.11

Yabeina kaizensis Huzimoto, 1936, p. 121, 122, pl. 25, figs. 5–10.

Lectotype.—An incomplete tangential section (Reg. No. 301b), illustrated in pl. 35, fig. 6 in Huzimoto (1936).

Diagnosis.—Inflated fusiform *Yabeina* having relatively large proloculus and less well-developed secondary transverse septula.

Description.—Test inflated fusiform, with rounded to bluntly pointed poles and straight axis of coiling. Mature specimens with 16 to 18 whorls, about 9 mm in length, about 5 mm or more in median width, giving form ratio 1.5:1 to 1.6:1. Proloculus spherical, and 42 to 233 microns, averaging 109 microns in the 57 specimens. Inner one to one-and-a-half whorls subspherical, succeeding ones fusiform with pointed to bluntly pointed poles, slowly expanding outwards. Beyond the eighth to tenth whorls, outer whorls become fusiform to inflated fusiform with narrowly rounded to bluntly pointed poles, and have nearly the same chamber height.

Wall rather thin for the genus, composed of tectum

⬅ **Figure 6. 1–17.** *Yabeina higoensis* Kobayashi: 1, D2-025941a; 2, D2-030097a; 3, D2-025948; 4, D2-030118a; 5, D2-023822; 6, D2-030114; 7, D2-023849; 8, D2-030103; 9, D2-030111a; 10, D2-023823; 11, D2-030092a; 12, D2-023817a; 13, D2-023830a; 14, D2-025944a; 15, D2-025951a; 16, D2-023824a; 17, D2-025938A, all Kaize-1 except for 7, Kaize-2, all X10.

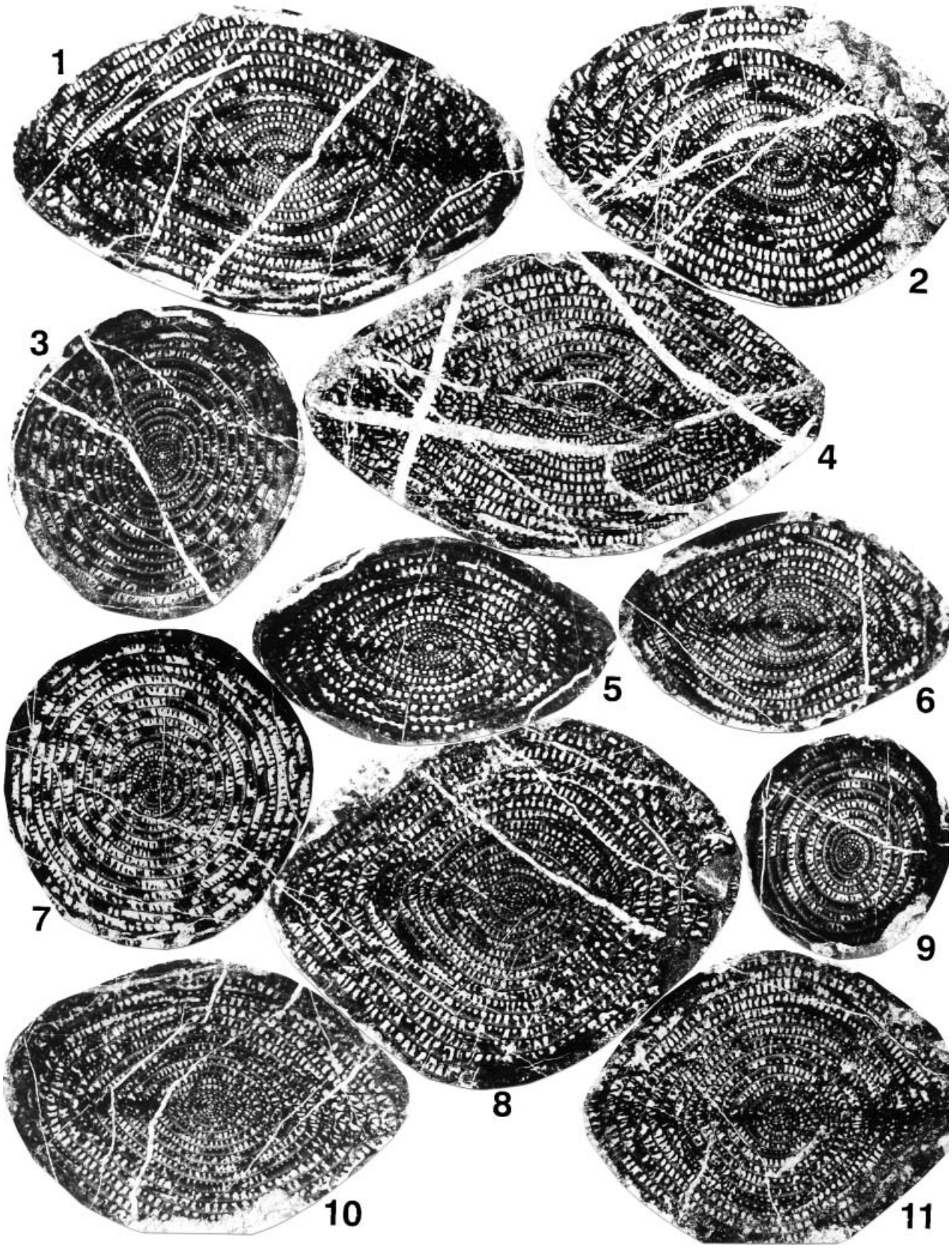

Figure 7. 1–11. *Yabeina kaizensis* Huzimoto: 1, D2-023854; 2, D2-023860; 3, D2-025954; 4, D2-023883; 5, D2-025967; 6, D2-025955; 7, D2-023873; 8, D2-023882; 9, D2-025961; 10, D2-025958; 11, D2-023878; 1–3, 6, 9, 10, Kaize-3; 4, 5, 8, Kaize-5; 7, 11, Kaize-4, all X10.

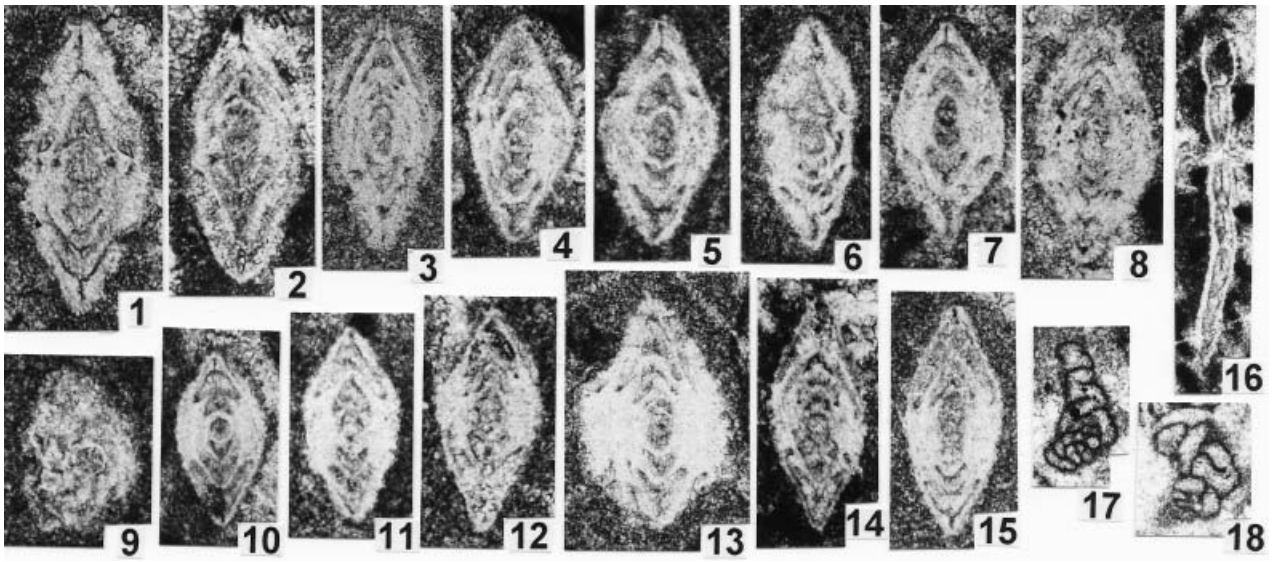

Figure 8. 1–15. *Robuloides acutus* Reichel: 1, D2-030101a; 2, D2-025780b; 3, D2-023834; 4, D2-025777a; 5, D2-030098c; 6, D2-030119a; 7, D2-023832; 8, D2-025775a; 9, D2-023825a; 10, D2-030119b; 11, D2-030098b; 12, D2-023827a; 13, D2-023836b; 14, D2-023816a; 15, D2-023836a, all Kaize-1, all X125 except for 10, X100. **16.** *Vervilleina* sp., D2-023829, Kaize-1, X40. **17.** *Brunsiella* sp., D2-030115a, Kaize-1, X50. **18.** *Calcivertella* sp., D2-023837a, Kaize-1, X50.

and fine alveolar keriotheca. Septa relatively slender and widely spaced. They are not easy to distinguish from axial septula inserted laterally between the adjacent septa, and were not exactly counted.

Primary transverse septula well developed, rather slender and long, and generally connected with parachomata. Secondary transverse septula short and first appear in the eighth whorl. One, rarely two, secondary transverse septula distinguishable between the adjacent primary transverse septula in outer whorls. Low parachomata present throughout the test.

Material examined.—Eleven illustrated (six axial, two sagittal, and two tangential sections, and one parallel section) and other specimens.

Discussion.—Huzimoto (1936) recognized this species as a new one based on its having a more elongate fusiform test, and slenderer and shorter secondary transverse septula than those of *Yabeina globosa*. Test form, number of whorls, and development of secondary transverse septula of the present materials are thought to agree well with the six specimens figured by Huzimoto (1936). Regular meshwork structure produced by the combination of septa and septula is simple for the genus on account of less well-developed secondary transverse septula in this species.

Yabeina kaizensis is easily distinguishable from *Yabeina higoensis* by its larger test and proloculus, larger height of whorls throughout the test, and less well-developed secondary transverse septula. In many test characters, especially the larger proloculus, more elongate form, less well-developed secondary transverse septula, *Yabeina kaizensis* is considered to be morphologically more closely related to *Yabeina columbiana*, characteristic of the west North American Cordillera, than to *Yabeina globosa*, the commonest species of the genus in Japan.

Occurrence.—Abundant to common in samples Kaize-2 to -5, and always associated with *Chusenella atlinensis*, *Dunbarula cascadensis*, and others (Table 1).

Suborder Lagenina
Superfamily Robuloidacea
Family Robuloididae
Genus ***Robuloides*** Reichel, 1946
Robuloides acutus Reichel, 1946

Figures 8.1–8.15

Robuloides acutus Reichel, 1946, p. 537, Figs. 27–29, pl. 19, fig. 9.

Description.—Test small, lenticular with pointed periphery, consisting of four to five whorls, and recrystallized in various degree. Proloculus large for the small test. Outer whorls planispirally coiled and gradually enlarging, and divided into five to eight chambers per whorl by anteriorly curved septa. Wall calcareous, hyaline, very finely perforated, and rather thick.

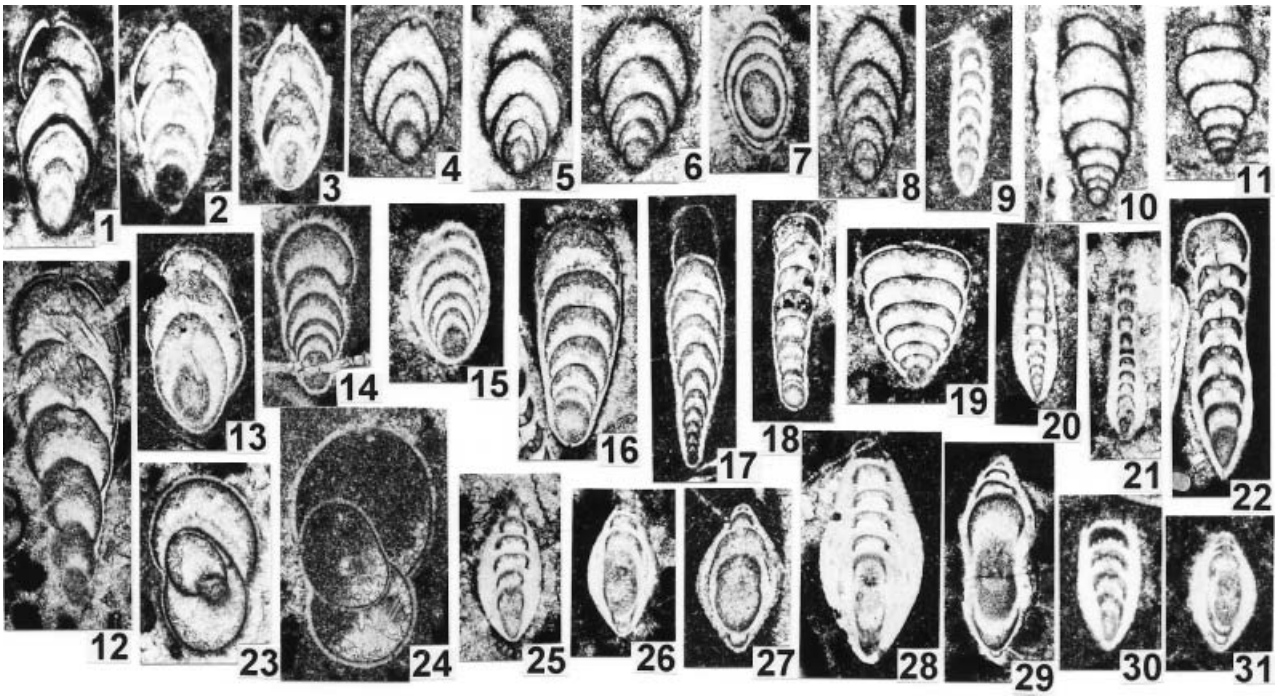

Figure 9. 1–3. *Cryptoseptida* sp.: 1, D2-030116b; 2, D2-023831b; 3, D2-023833c, all Kaize-1, 1, 2, X40; 3, X50. **4–8.** *Frondina palmata* (Wang, 1974): 4, D2-025765; 5, D2-025762d; 6, D2-030101c; 7, D2-023826d; 8, D2-025769d, all Kaize-1, X50. **9, 20, 21.** *Pachyphloia schwageri* Sellier de Civrieux and Dessauvagie, 1965: 9, D2-023837c, X50; 20, D2-030119c; X40; 21, D2-025944c; X50, all Kaize-1. **10, 11.** *Lunucammina*? sp.: 10, D2-025777e; 11, D2-025776d, both Kaize-1, X50. **12–14, 16.** *Langella fragilis* (Sellier de Civrieux and Dessauvagie, 1965): 12, D2-023828g, X30; 13, D2-030118b, X40; 14, D2-025766, X40; 16, D2-030110a, X40; all Kaize-1. **15**. *Langella* sp., D2-023838b, Kaize-1, X50. **17, 18.** *Nodosinelloides*? spp.: 17, D2-030093f; 18, D2-023827b, both Kaize-1, X40. **19.** *Geinitzina postcarbonica* Spandel, 1901, D2-025942, Kaize-1, X50. **22.** *Pachyphloia* sp., D2-030110b, Kaize-1, X40. **23, 24.** *Partisania* sp.: 23, D2-023826e; 24, D2-030118c, both Kaize 1 X40. **25–31.** *Pachyphloia ovata* Lange, 1925: 25, D2-023818b; 26, D2-025771d; 27, D2-023848b; 28, D2-030095c; 29, D2-030110c; 30, D2-025780d; 31, D2-025771e; 27, Kaize-2; others, Kaize-1; 29, X40; others, X50.

Dense transparent calcite deposited in and around the axial plane of the test.

Material examined.—Fifteen illustrated and other specimens.

Discussion.—The genus *Robuloides* was established on the basis of specimens from Upper Permian limestone north of Athens and on Hydra Island, Greece (Reichel, 1946). In addition to its common occurrence from the Upper Permian of Tethyan regions (e.g., Reichel, 1946; Miklukho-Maklay, 1954; Lys *et al.*, 1980; Vachard, 1980; Pronina, 1989; Lin *et al.*, 1990), *Robuloides* has also been reported from the Upper Permian and the upper part of the Middle Permian of the Circum-Pacific in places such as Sikhote-Alin (Sosnina, 1978), Japan (Kobayashi, 1997c; 2001) and New Zealand (Vachard and Ferrière, 1991).

As pointed out by Reichel (1946), *R. acutus* is distinguished from *R. lens* Reichel, 1946, *R. gibbus* Reichel, 1946, and *R. gourisiens* Reichel, 1946, in its smaller and less thick lenticular test. Among the described examples, the Kaize materials are closely similar to the type material and to South Chinese specimens assigned to Loeblichiidae by Lin *et al.* (1990) in size and shape of external test and number of whorls.

Occurrence.—*Robuloides acutus* is associated with *Palaeofusulina*, *Reichelina* and other genera north of Athens, and *Codonofusiella nana* Erk, 1941, *Robuloides lens*, and others on Hydra (Renz and Reichel, 1946). In the sample Kaize-1, it is associated with two species of *Yabeina*, *Dagmarita chanakchiensis*, and many others (Table 1).

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