Middle Permian fusulinoideans from Hatahoko in the Nyukawa area, Gifu Prefecture, Mino Belt, central Japan

Katsumi UENO*, Jun-ichi TAZAWA** and Yukio MIYAKE***

Abstract

A Middle Permian fusulinoidean fauna composed of 12 species in 10 genera, including *Cancellina nipponica* (Ozawa), *Neoschwagerina* cf. *simplex* Ozawa, *Neofusulinella praecursor* Deprat, *N.* cf. *giraudi* Deprat, etc., is described from Hatahoko in the Nyukawa area, east of Takayama, Gifu Prefecture, central Japan. The limestone containing this fauna is one of exotic limestone blocks with paleo-equatorial Panthalassan seamount origin in the Jurassic accretionary complexes of the Mino Belt, southwest Japan. Judging from the co-occurrence of *C. nipponica* and *N.* cf. *simplex*, the Hatahoko fauna is coeval with that reported from the upper part of the conventional *Cancellina nipponica* Zone (Nn) or the *Neoschwagerina simplex* to the *Pseudodoliolina ozawai* Zones of the Akasaka Limestone in the southern part of Gifu Prefecture, which is another world-famous limestone body with abundant fusulinoidean remains in the Mino Belt, and is referable to the early Murgabian (early Wordian).

Key words: Fusulinoidea, Middle Permian, Mino Belt, Murgabian, Hatahoko, Panthalassan seamount.

Introduction

The Mino Belt widely distributed in southwest Japan mainly comprises Jurassic accretionary complexes, containing a large number of Permian limestone-greenstone blocks (Mizutani,

---

* Department of Earth System Science, Faculty of Science, Fukuoka University, Fukuoka 814-0180, Japan
** Department of Geology, Faculty of Science, Niigata University, Niigata 950-2181, Japan
*** Ichinomiya-cho 331-1, Takayama 509-3502, Japan
(Manuscript received 30 January, 2006; accepted 15 February, 2006)

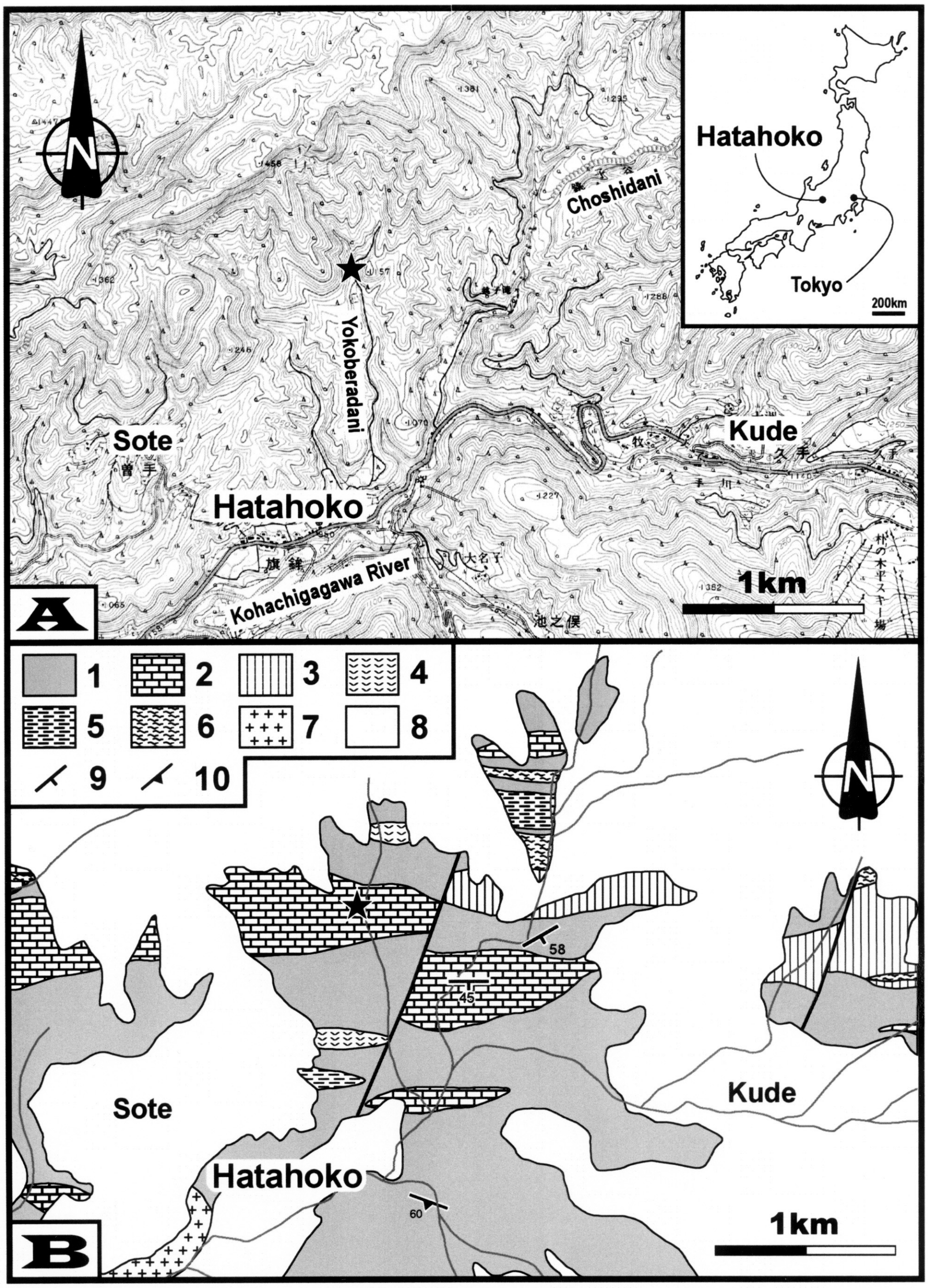


Fig. 1. **A**: Index map showing fossil locality (star mark) at Yokoberadani, north of Hatahoko, Takayama City, Gifu Prefecture, central Japan. A part of 1:25,000 scale topographic map "Hatahoko" published by the Geographical Survey Institute, Japan, is used for base map. **B**: Geologic map around fossil locality (star mark). Basic geologic map is adapted from Niwa et al. (2003). 1-5: Middle Jurassic Hirayu Complex (1: mudstone with various kinds of clasts, 2: limestone, 3: chert, 4: mafic volcanic rock, 5: alternating beds of sandstone and mudstone), 6: cataclasite zone, 7: Shimonohara Granodiorite (Cretaceous), 8: Cenozoic, 9: strike and dip of strata, 10: strike and dip of foliation.

1990). These limestones are generally fossiliferous and are interpreted as having paleo-equatorial Panthalassan seamount origin based on paleomagnetic (Hattori and Hirooka, 1977, 1979), sedimentologic (Sano, 1988; Sano and Kanmera, 1996), tectonostratigraphic (Sano et al., 1992), petrologic (Jones et al., 1993), and paleontologic (Ishii et al., 1985; Ozawa, 1987; Tazawa, 1991, 1992; Zaw Win, 2000) data. More recently, Tazawa and his colleagues (Tazawa, 1997a, b, 1998, 2000; Tazawa and Shen, 1997; Tazawa et al., 1998) insisted that brachiopods from some of these limestones can provide good paleobiogeographic constraints on the geographic positions of these seamounts within the Panthalassa Ocean and suggested some paleobiogeographic linkage of Permian faunas in the Mino Belt with those found from West Texas, U.S.A.

In the Nyukawa area (former Nyukawa Village), eastern part of Takayama City, Gifu Prefecture, central Japan, a Jurassic accretionary complex consisting mainly of mélange deposits of the Mino Belt is widely exposed. It was referred to as the Nyukawa Olistostrome (Adachi and Kojima, 1983) and the Dayoshi Formation (Yamada et al., 1985) in previous studies, and is, in more recent studies, called the Hirayu Complex (Otsuka, 1988; Niwa et al., 2003; Niwa, 2004). The Hirayu Complex contains many, exotic limestone blocks of Panthalassan seamount origin, in which fusulinoideans are the major fossil elements. The fusulinoideans were reported by Hanzawa (1949), Igo (1964a, b, 1965, 1967), Noda et al. (1975), and Igo and Ohana (2004), and also their specific compositions were listed by Isomi and Nozawa (1957) and Kojima (1984). Although these fusulinioideans indicate broadly Early and Middle Permian ages, many of them are from the Early Permian. Middle Permian fusulinoideans, particularly represented by neoschwagerinid species, were only described and illustrated by Igo (1967) from several localities in the Nyukawa area.

In this paper, we describe a Middle Permian fusulinoidean fauna characterized by *Cancellina nipponica* Ozawa from a limestone block of the Mino Belt exposed at upper Yokoberadani, north of Hatahoko in the Nyukawa area, and consider its affinity and age. All the specimens examined in this study are housed in the Department of Geology, Faculty of Science, Niigata University, with prefix NU-F.

Geology and sample

The fossils studied herein were collected by the junior authors (JT and YM) at a limestone outcrop (about 40 m wide and 20 m high; 36°11'08"N, 137°27'40"E) in the upper reaches of Yokoberadani, about 1.5 km north of Hatahoko in the Nyukawa area, Takayama City, Gifu Prefecture, central Japan (Fig. 1A). The limestone here is dark-gray to black and thin- to medium-bedded (5-20 cm thick beds), and strikes N45-72°W with dipping 45° northward. The fusulinoidea-bearing sample was collected from limestone in the lower part of this outcrop. According to Niwa et al. (2003) and Niwa (2004), the present limestone outcrop is located within a large limestone block of about 4 km (E-W) × 0.5 km (N-S) in the Middle Jurassic mélange of the Hirayu Complex (Fig. 1B). The thickness of this limestone block probably attains more than 500 m. The fossil locality is situated approximately at the middle part of this limestone block.

We prepared some 60 thin sections from the Hatahoko sample. Under the microscope, the limestone is composed of fusulinoidean shells, algal fragments, crinoids, brachiopod shell fragments, small bioclasts of unknown origin, aggregate grains, and fragments of *Tubiphytes*, among which fusulinoideans are the dominant allochem component. Interstitial space is generally filled by micritic matrix with a minor amount of sparry calcite cement. Thus, the limestone is classified as fusuline (-bioclastic) packstone/grainstone in Dunham's (1962) classification. The micritic matrix is, however, more or less weakly recrystallized into microsparry calcite cement. Moreover, the limestone is patchily and irregularly silicified by diagenesis.

Age of the Hatahoko fauna

The following fusulinoideans consisting of 12 species in 10 genera were discriminated from the sample examined. Of them, *Cancellina nipponica* is most abundant in the Hatahoko fauna.

Rauserella sp.
Minojapanella (*M.*) sp.
Schubertella sp.
Neofusulinella praecursor Deprat
N. cf. *giraudi* Deprat
Staffella sp.
Nankinella sp.
Pseudofusulina sp.
Chusenella? sp.
Cancellina nipponica (Ozawa)
C. aff. *primigena* (Hayden)
Neoschwagerina cf. *simplex* Ozawa

Among these fusulinoideans, *Cancellina nipponica* is known to occur from several limestone blocks in the Mino Belt (e.g., Ozawa, 1927a; Honjo, 1959; Morikawa and Isomi, 1961; Miyamura, 1967; Igo, 1967; Zaw Win, 1999) and has high, dating and correlation potentials. Particularly, the type locality of this species is situated in the Akasaka Limestone of the southern part of Gifu Prefecture (Ozawa, 1927a), which is one of large exotic limestone blocks in the Mino Belt and in which detailed Permian fusulinoidean biostratigraphy has been established by many students (e.g., Ozawa, 1927a, b, c; Akasaka Research Group, 1956; Morikawa, 1958; Honjo, 1959; Ozawa and Nishiwaki, 1992; Zaw Win, 1999). In this limestone, *C. nipponica* is restricted in a stratigraphic interval in the Zone of *Neoschwagerina* (*Cancellina*) *nipponica* (Nn) by Ozawa (1927a) or from the *Neoschwagerina* (*Cancellina*) *nipponica* Zone to the very basal part of the *Neoschwagerina craticulifera* Zone by Zaw Win (1999), both of which are broadly referable to the late Kubergandian (Roadian) and early Murgabian (Wordian) in the present Permian stage scale of the Tethyan region (Leven, 1975, 1980). Co-existence of *C. nipponica* and *N.* cf. *simplex* in the Hatahoko fauna is, however, more suggestive that it is time-equivalent to that found in the early Murgabian *Neoschwagerina simplex* and *Pseudodoliolina ozawai* Zones in the Akasaka Limestone although the zone species of the latter is not found in the Hatahoko fauna.

Neofusulinella praecursor is also evaluated to have some value for biochronology. Deprat (1913) originally stated that this species occurs in the base of the Moscovian in Laos, but this cannot be taken at its face value because "étage moscovien (Moscovian stage)" in the sense by Deprat (1913) does not necessarily mean the Moscovian of the Pennsylvanian (Upper Carboniferous) in the present sense (Toriyama et al., 1969, p. 17). Later, Toriyama et al. (1969, 1974) and Toriyama (1975) reported this species from the upper part of the *Maklaya sethaputi* Zone to the lower part of the *Presumatrina schellwieni* Zone of the Saraburi Limestone in the Khao Phlong Phrab section, Central Thailand. This interval can be correlated to the upper part of the *Cancellina* Zone to the lower part of the *Neoschwagerina* Zone (particularly *N. simplex* Zone of the lower part of the *Neoschwagerina* Zone). In the Akasaka Limestone, *Neofusulinella phairayensis* Colani, 1924, which, as noted later in the description of species, is considered to be a junior synonym of *N. praecursor*, was reported by Ozawa (1927a) from the Zone of *Neoschwagerina* (*Cancellina*) *nipponica* (Nn). The stratigraphic intervals in the Khao Phlong Phrab section and the Akasaka Limestone of *N. praecursor* more or less coincide each other and are referable to the late Kubergandian and early Murgabian.

In the Tethyan region, the Murgabian of the middle Middle Permian generally corresponds to the *Neoschwagerina* Zone in the genus-level fusulinoidean biostratigraphic framework (e.g., Leven, 1963, 1967, 1975, 1980). The Murgabian was conventionally subdivided into three fusulinoidean zones based on the phylogenetic development of *Neoschwagerina* species; in ascending order, the *N. simplex* Zone, *N. craticulifera* (or *N. schuberti*) Zone, and *N. margaritae* Zone (Leven, 1967, 1975). With the redefinition on the base of the next-younger Midian (Capitanian: late Middle Permian) by Leven (1996), the *N. margaritae* Zone has been now placed in the lower part of the Midian. This revision resulted in recognizing the *N. simplex* Zone as the standard fusulinoidean biostratigraphic unit in the lower half of the Murgabian Stage in the Tethyan region, and the *N. craticulifera* (and *N. schuberti*) Zone as that of its upper half. At present, fusulinoidean faunas characterized by *N. simplex* including its synomymy *N. sphaerica* Miklukho-Maklay, 1957, are known to occur widely not only in the Tethyan but also Panthalassan regions (e.g., Miklukho-Maklay, 1957; Sheng, 1963; Kanmera, 1963; Leven, 1967; Toriyama, 1975; Zhang and Dong, 1986; Ueno, 1991; Zhang, 1991;

Baghbani, 1993; Leven, 1997; Zaw Win, 1999).

In summary, the present Hatahoko fauna is referable to the early Murgabian in the standard Permian time-scale in the Tethyan-Panthalassan region (Leven, 1975, 1980; Ueno, 1996) based on the co-occurrence of *Cancellina nipponica* and *Neoschwagerina* cf. *simplex*. The occurrence of *Neofusulinella praecursor* also supports this age assignment. According to Jin et al. (1997) and Wardlaw et al. (2004), this chronostratigraphic level can be correlated with the early Wordian in the unified standard Permian time-scale although there exist increasing discrepancies by conodonts with respect to the intercontinental correlation of the Middle Permian regional stages between the Eurasian (Tethyan-Panthalassan) and North American (Midcontinent-Andean) regions (Henderson et al., 1999; Leven, 2001, 2004).

Description of species

(by KU)

Superfamily Fusulinoidea von Möller, 1878

Family Ozawainellidae Thompson and Foster, 1937

Genus *Rauserella* Dunbar, 1944

Type species.—*Rauserella erratica* Dunbar, 1944.

Rauserella sp.

Figs. 2.1, 2.2

Figured specimens.—Slightly oblique axial section (NU-F74), subaxial section (NU-F75).

Descriptive remarks.—The illustrated, slightly oblique axial section (Fig. 2.1) has an elliptical shell with the length of 1.20 mm and the diameter of 0.57 mm. The first two volutions are coiled at a large angle to remaining ones, forming a lenticular juvenarium. Spirotheca is thin and composed of a tectum and lower, thin structureless layer. Septa are very weakly fluted only in axial regions.

Because only several, poorly oriented specimens are available for study, its specific identification is open. The present species can be easily distinguished from *Rauserella erratica*, the type species of the genus, described by Dunbar (1944) from the upper part of the Guadalupian in Las Delicias, Mexico, in having a smaller shell and less developed, skew-coiled juvenarium.

Family Boultoniidae Skinner and Wilde, 1954

Genus *Minojapanella* Fujimoto and Kanuma, 1953

Type species.—*Minojapanella elongata* Fujimoto and Kanuma, 1953.

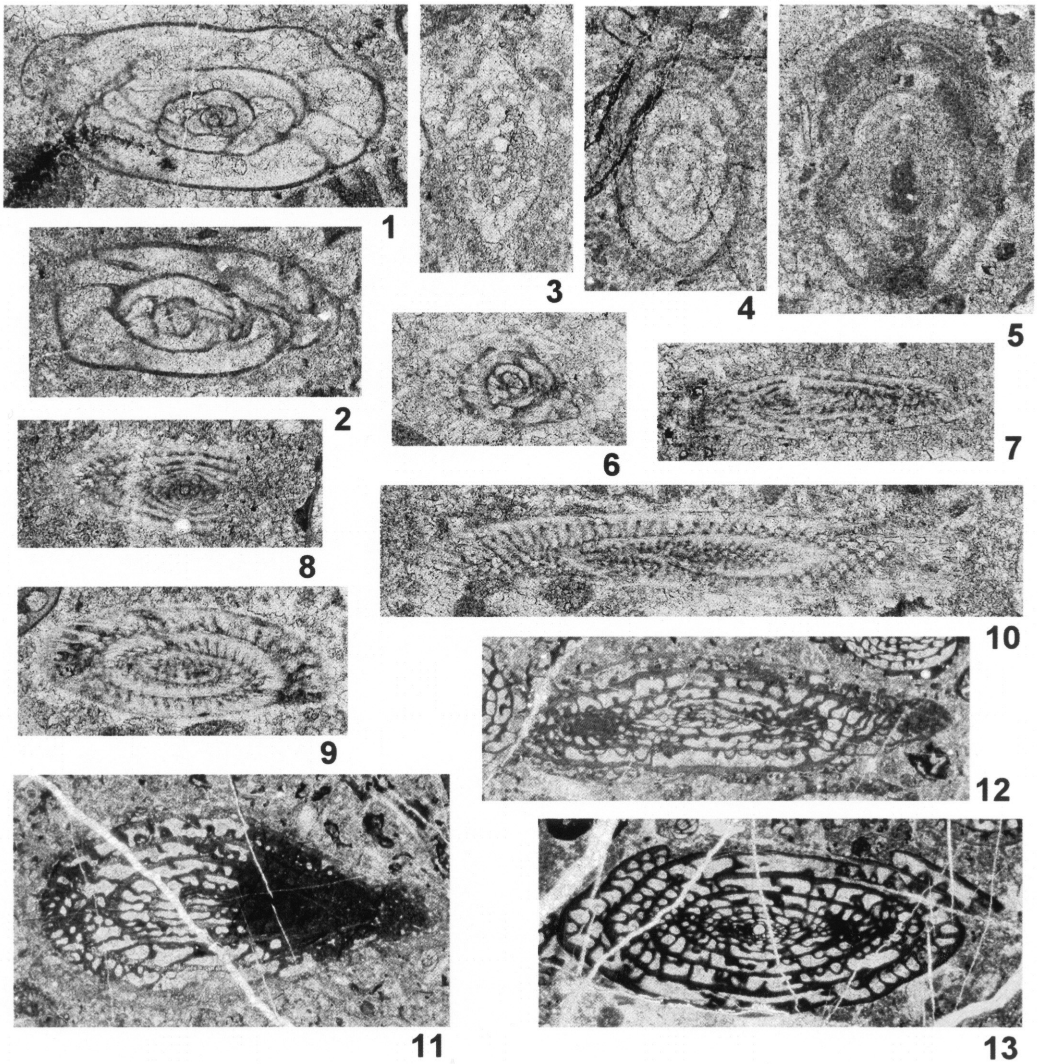


Fig. 2. 1, 2: *Rauserella* sp., 1: slightly oblique axial section, NU-F74, 2: subaxial section, NU-F75. **3**: *Nankinella* sp., axial section, NU-F76. **4, 5**: *Staffella* sp., tangential sections, NU-F77 and NU-F78. **6**: *Schubertella* sp., axial section, NU-F79. **7-10**: *Minojapanella* (*Minojapanella*) sp., 7: subaxial section, NU-F80, 8: slightly oblique axial section, NU-F81, 9: oblique section, NU-F82, 10: tangential section, NU-F83. **11**: *Chusenella*? sp., diagonal section, NU-F84. **12, 13**: *Pseudofusulina* sp., 12: tangential section, NU-F85, 13: oblique section, NU-F86. 11-13: × 10, 4, 5: × 30, 1-3, 6-10: × 40.

Remarks.—The genus *Minojapanella* is subdivided into two subgenera: *Minojapanella* (s.s.) and *Russiella* Miklukho-Maklay, 1957 (type species: *Russiella pulchra* Miklukho-Maklay, 1957).

Subgenus *Minojapanella* Fujimoto and Kanuma, 1953

Minojapanella (*Minojapanella*) sp.
Figs. 2.7-2.10

Figured specimens.—Subaxial section (NU-F80), slightly oblique axial section (NU-F81), tangential section (NU-F83), oblique section (NU-F82).

Remarks.—The Hatahoko specimens are potentially referable to *Minojapanella* (*M*.) *elongata* by their highly elongated fusiform shells, size, and nature of narrow and high septal loops. Because only poorly oriented specimens are available for the present study, however, I left the species identification open.

Family Schubertellidae Skinner, 1931
Subfamily Schubertellinae Skinner, 1931
Genus *Schubertella* Staff and Wedekind, 1910

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

Schubertella sp.
Fig. 2.6

Figured specimen.—Axial section (NU-F79).

Remarks.—In addition to the illustrated axial section, I got several specimens that have a small fusiform shell with two and a half to three and a half volutions, first skew-coiled volution, small chomata, weakly fluted septa only in axial regions, and spirotheca consisting of a tectum and thin, lower lighter layer. They are referable to the genus *Schubertella* by their basic shell features, but further specific identification is postponed until better and more numbers of specimens are available.

Genus *Neofusulinella* Deprat, 1912

Type species.—*Neofusulinella lantenoisi* Deprat, 1913.

Neofusulinella praecursor Deprat, 1913
Figs. 3.1-3.9

Neofusulinella praecursor Deprat, 1913, p. 40, pl. 7, figs. 6-16; Colani, 1924, p. 101, pl. 16, figs. 6, 11, 17, 23-43, pl. 17, figs. 1-22; Toriyama et al., 1969, p. 23-28, pl. 3, figs. 12-23; Toriyama, 1975, pl. 1, figs. 22-25.

Neofusulinella phairayensis Colani, 1924, p. 104-105, pl. 16, figs. 1-5, 7-10, 12-16, 20-22; Ozawa, 1927a, p. 151-152, pl. 37, figs. 3b, 5, 6c, pl. 38, figs. 2a, 7, 8, 11, 12, pl. 39, figs. 1, 2, pl. 44, fig. 6c, pl. 45, fig. 9; Leven, 1965, p. 135, pl. 4, fig. 5; Chen and Yang, 1978, p. 33, pl. 5, figs. 17-18; Liu et al., 1978, p. 21, pl. 2, fig. 5; Yang, 1985, pl. 1, fig. 9; Zhang and Dong, 1986, p. 74-75, pl. 1, figs. 5, 9.

Schubertella phairayensis (Colani): ?Kobayashi, 1957, p. 260-261, pl. 1, figs. 9, 10; Sheng, 1963, p. 35, 160, pl. 4, fig. 11; Zhang, 1982, p. 146, pl. 2, figs. 36, 38, 39, 42.

Neofusulinella lantenoisi Deprat: Leven, 1967, p. 126, pl. 1, figs. 9, 10; Leven, 1998, pl. 2, figs. 26, 27 (only).

Neofusulinella extumida Han, 1976, p. 27-28, pl. 8, figs. 9-14.

?*Schubertella phairayensis* Colani [sic]: Zhang, 1998, pl. 4, fig. 13, pl. 9, figs. 7, 8, 10, 12.

not *Fusulinella praecursor* (Deprat): Ozawa, 1925b, p. 24-25, pl. 9, figs. 5-6, pl. 10, figs. 4-8.

not *Neofusulinella phairayensis* Colani: Leven, 1967, p. 127, pl. 1, figs. 11, 12.

Figured specimens.—Axial sections (NU-F87, NU-F88, NU-F89, NU-F90, NU-F91, NU-F92, and NU-F93), sagittal sections (NU-F94 and NU-F95).

Description.—Shell is moderately large for genus and fusiform with slightly convex lateral slopes and bluntly pointed axial regions. Mature specimens having five and a half to seven and a half volutions are 1.43-2.00 mm in length and 0.74-1.06 mm in diameter. Form ratio varies from 1.72 to 2.14, averaging 1.87 in nine specimens. The first one and a half or two, rarely two and a half, volutions are skew-coiled, forming a nearly spherical juvenarium. Especially, the first volution is generally lenticular and coiled at a large angle to the coiling axis of outer, essentially planispiral volutions. Radius vectors of the first to seventh volutions in one illustrated axial section (Fig. 3.4) are 0.06, 0.09, 0.14, 0.20, 0.28, 0.40, and 0.53 mm, and their form ratios are 1.00, 1.33, 1.36, 1.80, 2.04, 1.93, and 1.66+, respectively

Proloculus is small and spherical. Its outside diameter ranges from 0.035 to 0.061 mm, averaging 0.048 mm in 11 specimens. Spirotheca is thin and composed of a single structureless layer in inner two or three volutions, but of a tectum and lower, lighter layer in outer ones. Fine perforations are partly developed in the lower lighter layer in some part of shell where spirotheca becomes slightly thickened (Fig. 3.3a). However, it generally looks structureless in most cases. Thickness of spirotheca of the second to seventh volutions in the above-mentioned axial section (Fig. 3.4) is 0.008, 0.008, 0.014, 0.015, 0.021, and 0.026 mm.

Septa are slightly anteriorly directed and only weakly fluted in polar regions. Septal counts of the second to sixth volutions in one illustrated sagittal section (Fig. 3.8) are 7, 11, 14, 18, and 19?. Septal pores are sometimes discernible in the lateral sides of septa (Fig. 3.3a). Chomata are developed generally beyond the third volution, and broad and asymmetrical; their tunnel sides are steep or sometimes overhanging. In contrast, their axial sides are gentle, extending laterally to polar regions. Tunnel is almost straight and becomes slightly wider through growth. Tunnel angles from the third to fifth, and fifth and a half volutions in an axial section illustrated on Fig. 3.1 are 20, 36, 42, and 48 degrees, respectively. Axial fillings are absent.

Remarks.—Although Deprat (1913) illustrated nine specimens of *Neofusulinella praecursor*, the types include only one, well-oriented axial section. Thus, the taxonomic concept of this species had been less clear based on the original description. Later, Toriyama et al. (1969) reported rich specimens of *N. praecursor* from the *Maklaya pamirica* to the *Neoschwagerina simplex* zones (late Kubergandian to early Murgabian) of the Saraburi Limestone in the Khao Phlong Phrab section, Changwat Saraburi, Central Thailand. The present Hatahoko specimens essentially agree with those from Khao Phlong Phrab although the latter has slightly thicker spirotheca, thus generally representing clearer development of fine pores in spirotheca, than the former.

Colani (1924) described *Neofusulinella phairayensis* from the Middle Permian of Phai-Ray in Vietnam. She noted that this species is distinguished from *N. praecursor* in having a slightly smaller diameter of shell (thus possessing a slightly larger form ratio), more loosely coiled volutions especially in the first one, smaller proloculus, thinner spirotheca and septa, and more number of septa. However, judging from Colani's (1924) original illustration of *N. phairayensis*, these differences are all subtle and, thus, indefinitive for separating it from *N. praecursor*. Thus, I judge these two as conspecific.

Neofusulinella praecursor can be distinguished from *N. lantenoisi*, the type species of the genus, in having a smaller shell and slightly fewer number of volutions although other characters are essentially similar to each other. It also differs from *N. tumida* described by Leven (1967) from the upper Kubergandian and lower Murgabian (the upper part of the *Cancellina* Zone to the *Neoschwagerina simplex* Zone) of the Southeast Pamir in *N. tumida* having a slightly larger, rhombic shell although the characteristic, rhombic shell shape in *N. tumida* is due probably to slight deformation.

Han (1976) established *Neofusulinella extumida* based on materials from the Sanmianjing Formation of Hubei Province, North China. According to Li (2000), this formation is referable to the Chihsian. The Chihsian involves the *Misellina* Genozone, *Cancellina* Genozone, and the lower part of the *Neoschwagerina* Genozone (*N. simplex* subzone) in the standard fusulinoidean zonation of China (Jin et al., 1999), and thus are correlated to the Bolorian (Kungurian) to the early Murgabian in the standard scale of the Tethyan region (e.g., Leven, 1975, 1980). Han (1976) noted that *N. extumida* can be distinguished from *N. praecursor* in having more weakly fluted septa in axial regions, thicker fusiform shell, more number of volutions, and smaller form ratio. These minor differences are, however, regarded insufficient to distinguish species, and merely represent intraspecific variability within a single species. Thus, *N. extumida* is judged as a junior synonym of *N. praecursor*.

Leven (1967, 1998) reported *Neofusulinella lantenoisi* from both the Southeast Pamir and the Transcaucasia. The Pamir specimens and two of the four Transcaucasia specimens (Leven, 1998, pl. 2, figs. 26 and 27) are smaller than the types of *N. lantenoisi*, and are better referable to *N. praecursor*.

Neofusulinella crassispira described by Li in Lin et al. (1977) from the Chihsia Formation of Guangxi, China, is somewhat close to *N. praecursor*. However, the former can be distinguished from the latter in having a slightly smaller shell and thicker spirotheca.

Ozawa (1925b) described *Fusulinella praecursor* (Deprat, 1913) from a "*Fusulina*"-bearing limestone exposed at Tahara in the Fukiya area of Takahashi City, Okayama Prefecture, southwest Japan. The limestone can now be regarded as one of exotic limestone blocks in Permian accretionary complexes of the Akiyoshi Belt. Judging from the illustration, the Tahara species can probably be subsumed in true *Fusulinella*, and thus is not conspecific with *Neofusulinella praecursor*.

Neofusulinella cf. *giraudi* Deprat, 1915
Figs. 3.10-3.17

Compare.—
Neofusulinella giraudi Deprat, 1915, p. 11-12, pl. 1, figs. 6-11.

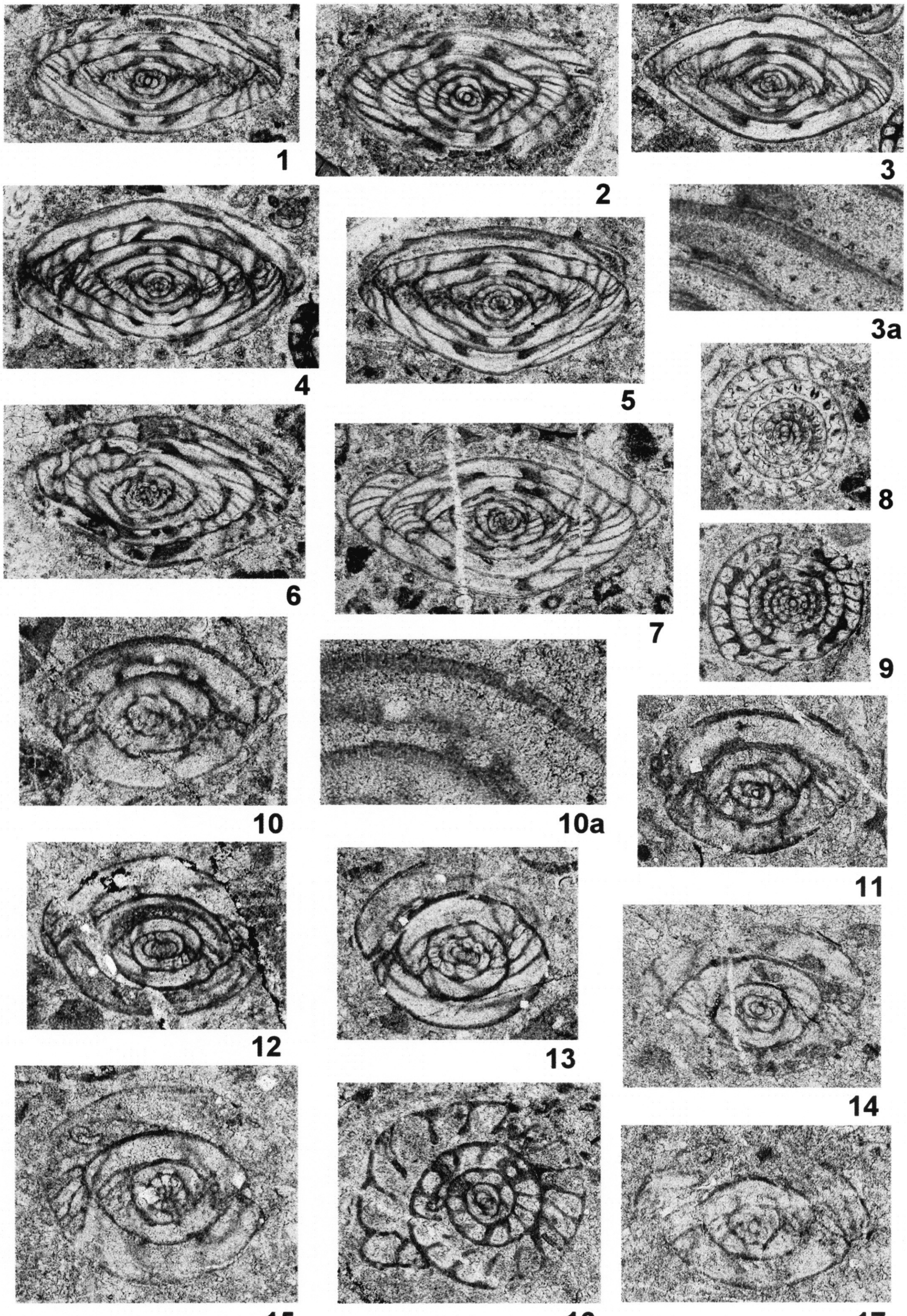
Figured specimens.—Axial (including slightly oblique) sections (NU-F96, NU-F97, NU-F98, NU-F99, NU-F100, NU-F101, and NU-F 103), sagittal section (NU-F102).

Description—Shell is small for genus and thickly oval with slightly convex lateral slopes and broadly rounded axial regions. Specimens with four to five volutions are 0.70-0.93 mm in axial length, 0.49-0.86 mm in diameter, and 1.22-1.63 in form ratio. The first one or two volutions are tightly and skew-coiled, in which the first one is generally lenticular and coiled almost perpendicular to the axis of coiling in outer volutions. Outer volutions are planispiral and expand gradually. Radius vectors of the first to fourth volutions in one illustrated axial section (Fig. 3.10) are 0.06, 0.09, 0.17, and 0.31 mm, and their form ratios are 0.50, 1.33, 1.35, and 1.45, respectively.

Proloculus is small and 0.034-0.054 mm in outside diameter, averaging 0.041 mm in seven specimens. Septa are slightly anteriorly directed . They are almost plane and only very weakly fluted in polar regions. Septal counts of the third and fourth volutions in the illustrated sagittal section (Fig. 3.16) are 10 and 15.

Spirotheca is thin and consists of a single structureless layer in inner volutions. It is composed of a tectum and lower less dense layer in outer two or three volutions. Though rather obscure, the lower less dense layer is finely perforated commonly in outer two volutions (Fig. 3.10a) of most specimens. Thickness of spirotheca of the second to fourth volutions in the above-mentioned axial section (Fig. 3.10) is 0.012, 0.032, and 0.032 mm. Chomata are small and visible in outer two volutions. Tunnel is rather broad. Tunnel angles of the third and fourth volutions in the mentioned axial section are 54 and 83 degrees.

Remarks.—The present Hatahoko specimens are somewhat more globose, thus giving a slightly smaller form ratio, than the Deprat's (1915) types although other essential characters


1
2
3
3a
4
5
6
7
8
9
10
10a
11
12
13
14
15
16
17

are similar to each other. Due to the slight difference in shell shape, its identification is qualified.

Neofusulinella giraudi was often subsumed into the genus *Schubertella* in most subsequent studies (e.g., Sheng, 1963; Kanmera, 1963; Kalmykova, 1967; Douglass, 1967; Han, 1976; Lin et al., 1977; Liu et al., 1978; Xie, 1982; Sun et al., 1983; Li, 1989; Leven, 1997). As noted by Toriyama et al. (1969), however, this view contradicts the fact that the Deprat's (1915) types have finely perforated spirotheca. It is, therefore, more reasonable to retain this species in the genus *Neofusulinella* as it originally is, because the presence of fine perforations in spirotheca is contrary to the generic concept of *Schubertella*. Due to the thinner spirotheca of *N. giraudi* than other, larger Neofusulinellas such as *N. lantenoisi* and *N. praecursor*, delicate spirothecal structures including finely perforated texture would easily become indistinct in *N. giraudi* during diagenesis. This may be the reason that the spirotheca of *N. giraudi* tends to be described as being composed of a tectum and lower structureless layer in many studies. In fact, fine perforations in the Hatahoko specimens (e.g., Fig. 3.10a) are not very easily discernible under the microscope in low magnification compared with fine keriotheca in the spirotheca of associated *Cancellina nipponica*.

Family Staffellidae Miklukho-Maklay, 1949

Genus *Staffella* Ozawa, 1925a

Type species.—*Fusulina sphaerica* Abich, 1859 (=*Staffella moellerana* Thompson, 1935).

Staffella sp.

Figs. 2.4-2.5

Figured specimens.—Tangential sections (NU-F77 and NU-F78).

Remarks.—Due to their completely recrystallized shells with rounded peripheries, the two illustrated specimens can be subsumed into the genus *Staffella* although further specific identification is impossible.

Genus *Nankinella* Lee, 1934

Type species.—*Staffella discoides* Lee, 1931.

⬅ **Fig. 3. 1-9**: *Neofusulinella praecursor* Deprat, 1913, 1-7: axial sections, NU-F87, NU-F88, NU-F89, NU-F90, NU-F91, NU-F92, and NU-F93, 3a: enlarged part of 3, showing finely perforated spirotheca in penultimate volution and well-developed septal pores, 8, 9: sagittal sections, NU-F94 and NU-F95. **10-17**: *Neofusulinella* cf. *giraudi* Deprat, 1915, 10-15,17: axial (including slightly oblique) sections, NU-F96, NU-F97, NU-F98, NU-F99, NU-F100, NU-F101, and NU-F103, 10a: enlarged part of 10, showing fine pores in spirotheca in outer two volutions, 16: sagittal section, NU-F102. 1-9: × 25, 10-17: × 40, 3a, 10a: × 100.

Nankinella sp.
Fig. 2.3

Figured specimen.—Axial section (NU-F76).

Remarks.—Several staffellid specimens, in which one is illustrated here, having angular peripheries throughout growth are available for study. They are referable to *Nankinella* based on their shell shape.

Family Schwagerinidae Dunbar and Henbest, 1930
Subfamily Schwagerininae Dunbar and Henbest, 1930
Genus *Pseudofusulina* Dunbar and Skinner, 1931

Type species.—*Pseudofusulina huecoensis* Dunbar and Skinner, 1931.

Pseudofusulina sp.
Figs. 2.12-2.13

Figured specimens.—Tangential section (NU-F85), oblique section (NU-F86).

Descriptive remarks.—*Pseudofusulina* sp. in this study has an elongate fusiform shell with six to seven and a half volutions, broadly arched peripheries, and bluntly pointed axial regions. Based on one tangential (closely subaxial) section (Fig. 2.12), its form ratio is about 3.8. Proloculus is spherical and 0.16 to 0.19 mm in outside diameter. Septa are moderately fluted in axial regions, decreasing their intensity toward the central part of shell. Faint axial fillings may be present.

Comparison of this species with others in *Pseudofusulina* is difficult because all the available specimens are not very well oriented.

Subfamily Chusenellinae Kahler and Kahler, 1966
Genus *Chusenella* Hsu, 1942

Type species.—*Chusenella ishanensis* Hsu, 1942.

Chusenella? sp.
Fig. 2.11

Figured specimen.—Diagonal section (NU-F84).

Remarks.—One, poorly oriented schwagerinid specimen is available for study. It has dense axial fillings and probably bluntly acute polar ends. These characters possibly suggest that the specimen is referable to the genus *Chusenella*.

Family Neoschwagerinidae Dunbar and Condra, 1927

Subfamily Lepidolininae Miklukho-Maklay, 1958

Genus *Cancellina* Hayden, 1909 emend. Kanmera, 1957

Type species.—*Neoschwagerina primigena* Hayden, 1909.

Cancellina nipponica (Ozawa, 1927a)

Figs. 4.1-4.11, 5.1-5.3

Neoschwagerina (*Cancellina*) *nipponica* Ozawa, 1927a, p. 160-161, pl. 34, figs. 12-17, pl. 35, figs. 8b, 10a, pl. 44, fig. 1a, pl. 45, figs. 4, 5; Ozawa, 1927c, pl. 9, figs. 10, 11a, 11b; Zaw Win, 1999, p. 41-42, pl. 1, figs. 1, 2.

Cancellina nipponica, new subspecies A: Kanmera, 1957, pl. 19, figs. 6, 7.

Cancellina nipponica (Ozawa): Kanmera, 1957, pl. 19, figs. 8-11; ?Chediya et al., 1986, pl. 3, fig. 4.

?*Cancellina* cf. *nipponica* Ozawa [sic]: Kobayashi, 1957, p. 302-303, pl. 9, fig. 15.

Neoschwagerina (*Minoella*) *nipponica* (Ozawa) [sic]: Honjo, 1959, p. 129-131, pl. 1, figs. 6-8, 10, pl. 2, pl. 6, fig. 1?.

Neoschwagerina nipponica (Ozawa) [sic]: Kanuma, 1960, p. 172-173, pl. 10, figs. 3-6; Igo, 1967, p. 15-16, pl. 6, figs. 7-9; Morikawa and Isomi, 1961, p. 26-27, pl. 20, figs. 15-19; Miyamura, 1967, pl. 6, figs. 9-12.

Minoella nipponica (Ozawa): Honjo, 1960, pl. 1, figs. a-c, pl. 2, figs. 1-6, pl. 3, figs. 7-12.

Neoschwagerina nipponica Ozawa: Morikawa and Suzuki, 1961, p. 49, pl. 4, figs. 3, 4, pl. 12, figs. 4-6.

Cancellina nipponica Ozawa [sic]: Hanzawa and Murata, 1963, pl. 4, figs. 5, 6, pl. 18, figs. 7, 8, 11, 12; Leven, 1967, p. 185-186, pl. 31, figs. 8, 10; Ozawa, 1970, pl. 6, figs. 18, 19.

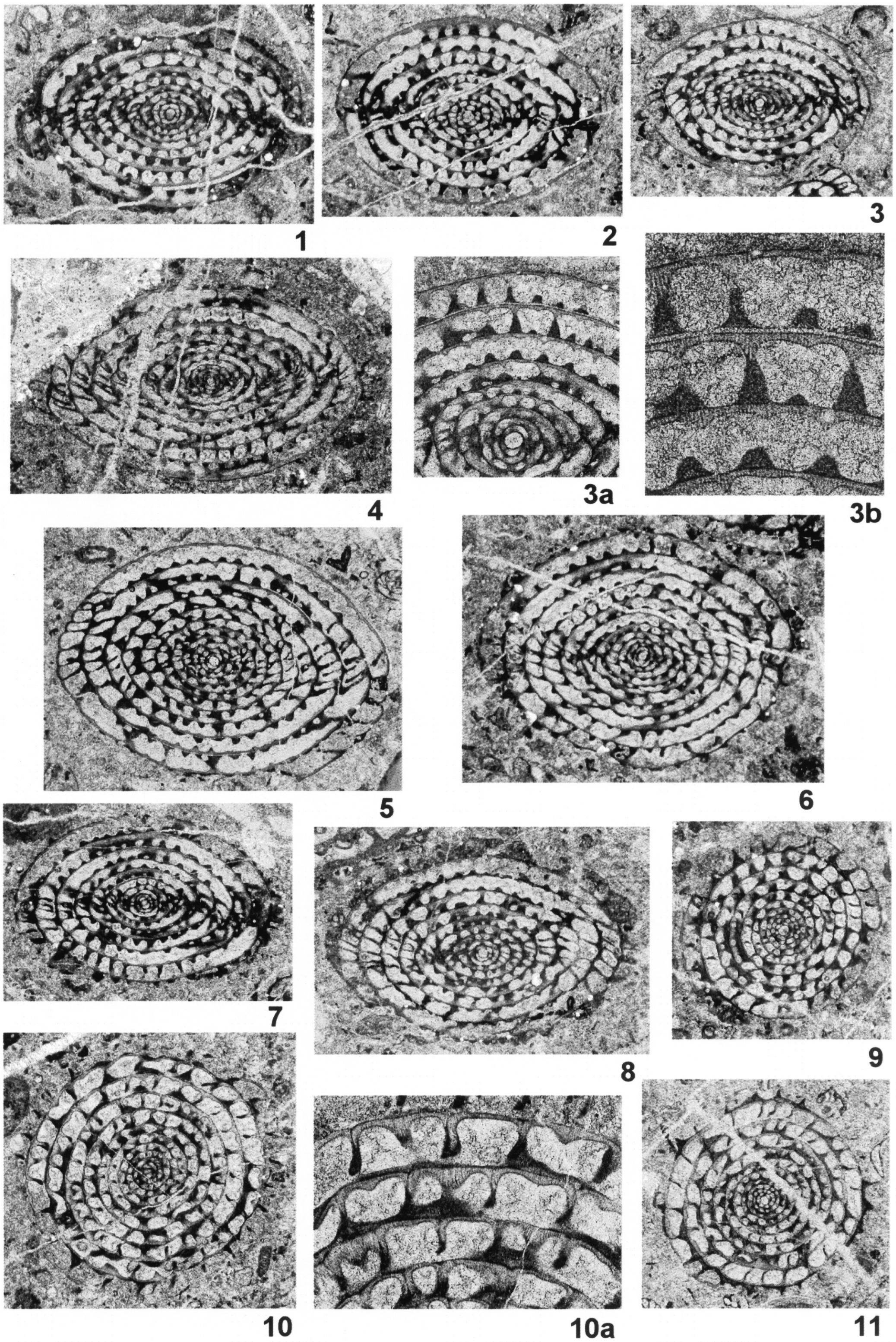
Neoschwagerina (*Cancellina*) *nipponica* (Form A): Zaw Win, 1999, p. 42-43, pl. 1. figs. 3, 4.

Neoschwagerina (*Cancellina*) *nipponica* (Form C): Zaw Win, 1999, p. 43-44, pl. 1, figs. 5, 6.

Neoschwagerina (*Cancellina*) *nipponica* (Form F): Zaw Win, 1999, p. 44-45, pl. 1, figs. 7, 8.

Figured specimens.—Axial sections (NU-F104, NU-F105, NU-F106, NU-F107, NU-F110, NU-F115, NU-F116, and NU-F117), slightly oblique axial sections (NU-F108, NU-F109, and NU-F111), sagittal sections (NU-F112, NU-F113, and NU-F114).

Description.—Shell is oval with broadly arched peripheries and rounded polar regions. Mature specimens having nine and a half to eleven and a half volutions are 2.42-3.48 mm in axial length and 1.59-2.76 mm diameter. Form ratio ranges from 1.35 to 1.63, averaging 1.47 in eight specimens. Coiling is planispiral throughout growth except for the first one of some specimens, which is slightly deviated. Early two or three volutions are slightly tightly coiled and middle ones expand gradually through growth. Outer two or three volutions are coiled


1
2
3
4
3a
3b
5
6
7
8
9
10
10a
11

uniformly. Radius vectors of the first to tenth volutions in an axial section illustrated on Fig. 4.4 are 0.08, 0.13, 0.17, 0.23, 0.31, 0.41, 0.56, 0.69, 0.83, and 1.02 mm, and their form ratios are 1.09, 1.00, 1.36, 1.48, 1.51, 1.62, 1.53, 1.53, 1.56, and 1.51, respectively.

Proloculus is small and spherical. Its outside diameter varies from 0.080 to 0.143 mm, averaging 0.106 mm in 12 specimens. Spirotheca is thin and composed of a single dense layer in early few volutions. Beyond the second or third volution, it consists of a tectum and lower, fine keriotheca (Fig. 4.3b). Upper tectorial deposits extending to parachomata partly cover the floor of chambers (Fig. 4.10a). Thickness of spirotheca of the third to tenth volutions of the above-mentioned axial section (Fig. 4.4) is 0.020, 0.027, 0.024, 0.026, 0.033, 0.027, 0.029, and 0.056 mm.

Septa are slightly anteriorly directed . Tips of septa are usually slightly swollen, darkened, and covered by epithecal deposits (Fig. 4.10a). Septal counts of the first to tenth volutions in an illustrated sagittal section (Fig. 4.11) are 6, 11, 12, 14, 15, 20, 19, 21, 22, and 24?, respectively. Primary transverse septula are generally low to moderately high (Figs. 4.3a, 4.3b), and well developed except for early few volutions. Axial septula are low and only rudimentarily developed as a downward deflection of spirotheca between two septa in outer few volutions (Fig. 4.10a). In most specimens, parachomata are developed beyond the second or third volutions.

Remarks.—Zaw Win (1999) recognized several morphotypes in *Cancellina nipponica* from the Akasaka Limestone, Gifu Prefecture, central Japan. Most of the Hatahoko specimens are close to his *C. nipponica* and *C. nipponica* (Form A).

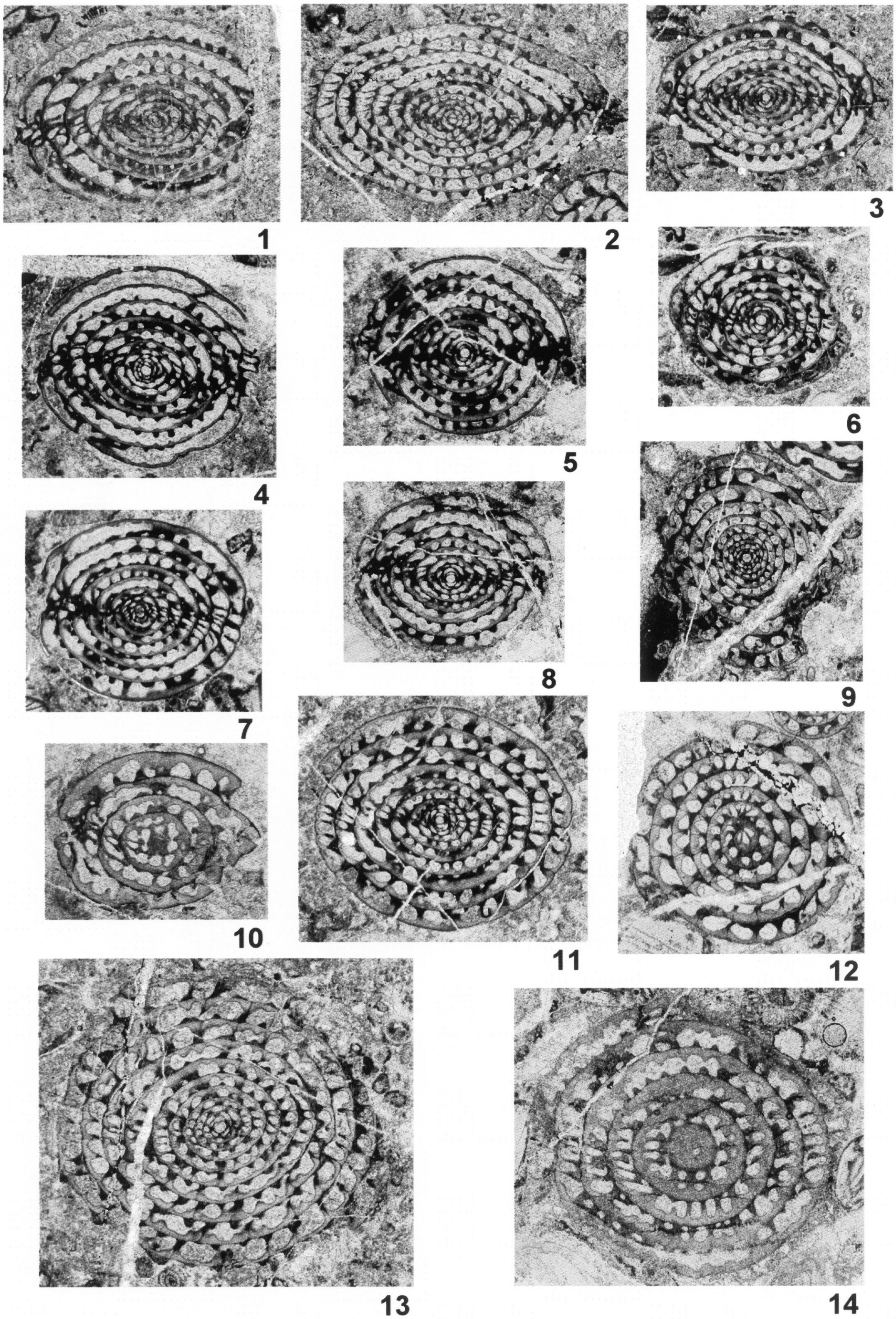
This species can be distinguished from *Cancellina primigena* in having a smaller proloculus and slightly thinner spirotheca. It also differs from *C. tenuitesta* described by Kanmera (1963) from the upper part of the Lower Member (the e and f members: early Murgabian) of the Kozaki Formation, southern Kyushu, Japan, in having a smaller form ratio and slightly thicker spirotheca.

Cancellina aff. *primigena* (Hayden, 1909)

Figs. 5.4-5.9

Cancellina primigena (Hayden): Huzimoto, 1936, p. 111-112, pl. 20, fig. 8.

⬅ **Fig. 4. 1-11**: *Cancellina nipponica* (Ozawa, 1927a), 1-4,7: axial sections, NU-F104, NU-F105, NU-F106, NU-F107, and NU-F110, 3a: enlarged part of 3, showing successive change of coiling expansion of shell and low but well-developed primary transverse septula except for inner volutions, 3b: enlarged part of 3, showing finely alvelolar structure in relatively thin spirotheca, 5, 6, 8: slightly oblique axial sections, NU-F108, NU-F109, and NU-F111, 9-11: sagittal sections, NU-F112, NU-F113, and NU-F114, 10a: enlarged part of 10, showing incipiently developed axial septula in outer volutions. 1-11: ×15, 3a: × 30, 10a: × 40, 3b: × 75.


1
2
3
4
5
6
7
8
9
10
11
12
13
14

Compare.—
Neoschwagerina primigena Hayden, 1909, p. 249, pl. 22, figs. 1-7.

Figured specimens.—Axial sections (NU-F118, NU-F119, NU-F120, NU-F121, and NU-F122), sagittal section (NU-F123).

Description.—Shell is subspherical with broadly arched peripheries and rounded but slightly compressed axial ends. Mature specimens with eight to ten volutions are 1.85-2.27 mm in length, 1.66-2.08 mm in diameter, and 1.09-1.22 in form ratio. Early one or two volutions are lenticular and their axis of coiling is slightly deflected; outer volutions are planispiral and subspherical, and expands gradually through growth. Radius vectors of the first to ninth volutions of one well-oriented axial section (Fig. 5.4) are 0.10, 0.14, 0.19, 0.26, 0.37, 0.49, 0.64, 0.80, and 1.01 mm, and their form ratios are 1.00, 1.00, 1.08, 1.20, 1.22, 1.22, 1.19, 1.20, and 1.13, respectively.

Proloculus is almost spherical and 0.107-0.123 mm in outside diameter. Spirotheca is composed of a single dense layer in inner few volutions, and of a tectum and lower, fine keriotheca in outer ones. Thickness of spirotheca of the first to ninth volutions in the above-mentioned axial section is 0.012, 0.011, 0.014, 0.017, 0.026, 0.027, 0.023, 0.029, and 0.032 mm.

Septa are plane and slightly anteriorly directed or almost perpendicular to the spiral wall. Primary transverse septula are low and triangular or semicircular in shape, and developed from the third or third and a half volution. In the last half volution, primary transverse septula are very low or absent in some specimens. Axial septula are only rudimentarily developed as a downward deflection of spirotheca between two septa in some part of outer few volutions. Parachomata are low and triangular or semicircular in section. Their height is generally lower than the half of chamber height.

Remarks.—The present specimens are very close to that described under the name of *Cancellina primigena* by Huzimoto (1936) from Komyosan in the Kanto Mountains, central Japan, in their size and subspherical shells. However, the Hatahoko and Komyosan specimens are different from the types by Hayden (1909) from the Bamian Limestone of Afghanistan in having smaller proloculus and less developed parachomata and primary transverse septula. The species identification of the Hatahoko specimens to *C. primigena* is, therefore, only qualified and they may even be different from it.

This species can be distinguished from *Cancellina nipponica* in having a subspherical shell, thus giving a slightly smaller form ratio, and slightly thicker spirotheca.

⬅ **Fig. 5.** **1-3**: *Cancellina nipponica* (Ozawa, 1927a), axial sections, NU-F115, NU-F116, and NU-F117. **4-9**: *Cancellina* aff. *primigena* (Hayden, 1909), 4-8: axial sections, NU-F118, NU-F119, NU-F120, NU-F121, and NU-F122, 9: sagittal section NU-F123. **10-14**: *Neoschwagerina* cf. *simplex* Ozawa, 1927a, 10, 14: tangential sections, NU-F124 and NU-F128, 11: slightly oblique axial section, NU-F125, 12: parallel section, NU-F126, 13: oblique section, NU-F127. 1-9, 11-14: × 15, 10: × 20.

Subfamily Neoschwagerininae Dunbar and Condra, 1927
Genus *Neoschwagerina* Yabe, 1903

Type species.—*Schwagerina craticulifera* Schwager, 1883.

Neoschwagerina cf. *simplex* Ozawa, 1927a
Figs. 5.10-5.14

Compare.—
Neoschwagerina (*Neoschwagerina*) *simplex* Ozawa, 1927a, p. 153-154, pl. 37, fig. 6g, pl. 38, figs. 14, 15, 16a, pl. 40, fig. 11b, pl. 44, fig. 6b.

Figured specimens.—Slightly oblique axial section (NU-F125), oblique section (NU-F127), tangential sections (NU-F124 and NU-F128), parallel section (NU-F126).

Remarks.—In this study, I found several specimens that have a slightly larger shell (generally 10-11 volutions in mature specimens) and definitely thicker spirotheca than the associated *Cancellina* species. They also have almost spherical to thickly oval shells with uniformly expanded volutions, slightly rotated axis of coiling in early one or two volutions, well-developed semicircular parachomata and fan-shaped primary transverse septula except for the first few volutions, and rudimentarily developed axial septula in some outer part of shell. These morphological features as a whole are indicative of the specimens being referable to *Neoschwagerina simplex*. However, their species identification is qualified because of the lack of axial section in available specimens for this study.

Acknowledgments

We sincerely thank I. Niikawa of the Department of Geology, Niigata University for critical reading of the manuscript. This study was supported by the grant from Fujiwara Natural History Foundation (No. H12-11) to the second author (JT).

References

Abich, H., 1859, Vergleichende Grundzüge der Geologie des Kaukasus wie der armenischen und nordpersischen Gebirge. *Mém. l'Acad. Imp. Sci. St. Pétersbourg, Classe Sci., Mathém., Phys. et Nat., Sér. 6*, **7**, 359-534.

Adachi, M. and Kojima, S., 1983, Geology of the Mt. Hikagedaira area, east of Takayama, Gifu Prefecture, central Japan. *Jour. Earth Sci., Nagoya Univ*., **31**, 37-67.

Akasaka Research Group, 1956, Geological studies of the Akasaka Limestone. *Earth Sci. (Chikyu Kagaku)*, nos. 26-27, 10-18. (in Japanese)

Baghbani, D., 1993, The Permian sequence in the Abadeh region, central Iran. *Occ. Publ. ESRI, N. S*., no. 9A-B, 7-22.

Chediya, I.O., Bogoslovskaya, M.F., Davydov, V.I. and Dmitriev, V.Yu., 1986, Fuzulinidy i ammonoidei v stratotipe kubergandinskogo yarusa (Yugo-vostochnyy Pamir). *Ezh. Vses. Paleont. Obsche.*, **29**, 28-53. (in Russian)

Chen, J.R. and Yang, Z.R., 1978, Fusulinida. *In* Xinan Institute of Geological Sciences, ed., *Paleontological Atlas of Southwest China, Sichuan Volume, No. 2*, Geol. Publ. House, Beijing, 17-123. (in Chinese)

Colani, M., 1924, Nouvelle contribution a l étude des Fusulinidés de l'Extrême-Orient. *Mém. Serv. Géol. l'Indochine*, **11,** 1-191.

Deprat, J., 1912, Étude géologique du Yun-nan Oriental, III[e] Partie. Étude des Fusulinidés de Chine et d'Indochine et classification des calcaires à fusulines. *Mém. Serv. Géol. l'Indochine*, **1**, 1-77.

Deprat, J., 1913, Étude des Fusulinidés de Chine et d'Indochine et classification des calcaires à fusulines, II[e] Memoire. Les Fusulinidés des calcaires carbonifériens et permiens du Tonkin, du Laos et du Nord-Annam. *Mém. Serv. Géol. l'Indochine*, **2**, 1-74.

Deprat, J., 1915, Étude des Fusulinidés de Chine et d'Indochine et classification des calcaires à fusulines, IV[e] Memoire. Les Fusulinidés des calcaires carbonifériens et permiens du Tonkin, du Laos et du Nord-Annam. *Mém. Serv. Géol. l'Indochine*, **4**, 1-29.

Douglass, R.C., 1967, Permian Tethyan fusulinids from California. *U. S. Geol. Surv. Prof. Pap.*, no. 593-A, 1-13.

Dunbar, C.O., 1944, Permian and Pennsylvanian (?) fusulines. *In* King, R.E., Dunbar, C.O., Cloud, P.E., Jr., and Miller, A.K., eds., *Geology and Paleontology of the Permian Area Northwest of Las Delicias, Southwestern Coahuila, Mexico. Geol. Soc. America*, *Spec. Pap.,* no. 52, 35-48.

Dunbar, C.O. and Condra, G.E., 1927, The Fusulinidae of the Pennsylvanian System in Nebraska. *Nebraska Geol. Surv., Bull., Second Ser.*, **2**, 1-135.

Dunbar, C.O. and Henbest, L.G., 1930, The fusulinid genera *Fusulina, Fusulinella* and *Wedekindella*. *Am. Jour. Sci., Ser. 5*, **20**, 357-364.

Dunbar, C.O. and Skinner, J.W., 1931, New fusulinid genera from the Permian of West Texas. *Am. Jour. Sci., Ser. 5*, **22**, 252-268.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture. *In* Ham, W.E., ed., *Classification of Carbonate Rocks, Am. Assoc. Petrol. Geol., Mem.*, **1**, 108-121.

Fujimoto, H. and Kanuma, M., 1953, *Minojapanella*, a new genus of Permian fusulinids. *Jour. Paleont.*, **27**, 150-152.

Han, J.X., 1976, Fusulinida. *In* Geological Bureau of Nei Mongol, ed., *Paleontological Atlas of North China, Nei Mongol Volume, No. 1*, Geol. Publ. House, Beijing, 23-62. (in Chinese)

Hanzawa, S., 1949, A new type of the fusulinid Foraminifera from central Japan. *Jour. Paleont.*, **23**, 205-209.

Hanzawa, S. and Murata, M., 1963, The paleontologic and stratigraphic considerations on the Neoschwagerininae and Verbeekininae, with the description of some fusulinid foraminifera from the Kitakami Massif, Japan. *Sci. Repts., Tohoku Univ., 2nd Ser.*, **35**, 1-31.

Hattori, I. and Hirooka, K., 1977, Paleomagnetic study of greenstone in the Mugi-Kamiaso area, Gifu Prefecture, central Japan. *Jour. Japan. Assoc. Min. Petrol. Econ. Geol.*, **72**, 340-353.

Hattori, I. and Hirooka, K., 1979, Paleomagnetic results from Permian greenstones in central Japan and their geologic significance. *Tectonophys.*, **57**, 211-235.

Hayden, H.H., 1909, Fusulinidae from Afghanistan. *Rec. Geol. Surv. India*, **38**, 230-256.

Henderson, C.M., Jin, Y.G., Wardlaw, B.R. and Mei, S.L., 1999, The conodont succession in Nashui/Luodian section, South China and its significance in correlation of Cisuralian and

Guadalupian conodont and fusulinacean zones. *Programme with Abstract to the XIV International Congress on the Carboniferous-Permian*, *Univ. Calgary, Calgary,* 57.

Honjo, S., 1959, Neoschwagerinids from the Akasaka Limestone (A paleontological study of the Akasaka Limestone, 1st report). *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **10**, 111-161.

Honjo, S., 1960, A study of some primitive *Neoschwagerina* by a new serial section technique. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **10**, 457-470.

Hsu, Y.C., 1942, On the type species of *Chusenella*. *Bull. Geol. Soc. China*, **22**, 175-176.

Huzimoto, H. (Fujimoto, H.), 1936, Stratigraphical and palaeontological studies of the Titibu System of the Kwanto-Mountainland, Part 2. Palaeontology. *Sci. Repts., Tokyo Bunrika Daigaku, Sec. C*, **1**, 29-125.

Igo, H., 1964a, On some *Pseudoschwagerina* and *Zellia* from Japan. *Jour. Paleont*., **38**, 281-293.

Igo, H., 1964b, Permian fusulinids from Nyukawa, central Japan, Part I. Some fusulinids from the Shiroi and Kono formations. *Jour. Paleont*., **38**, 637-649.

Igo, H., 1965, Permian fusulinids from Nyukawa, central Japan, Part 2. Some fusulinids from the lower part of the Sote Formation. *Jour. Paleont*., **38**, 210-223.

Igo, H., 1967, Permian fusulinids of Nyukawa, central Japan, Part 3. Some Fusulinids from the Upper Sote Formation and the Ozu Formation. *Mem. Mejiro Gakuen Woman's Junior Coll*., **4**, 1-19.

Igo, H. and Ohana, T., 2004, Gregarious occurrence of *Robustoschwagerina* (fusulinacean foraminifer) in limestone of the Nyukawa Group, Hida Mountains, central Japan. *Bull. Hikaru Mem. Mus*., no. 3, 10-21.

Ishii, K., Okimura, Y. and Ichikawa, K., 1985, Notes on Tethys biogeography with reference to Middle Permian fusulinaceans. *In* Nakazawa, K. and Dickins, J.M., eds., *The Tethys: Her Paleogeography and Paleobiogeography from Paleozoic to Mesozoic*, Tokai Univ. Press, Tokyo, 139-155.

Isomi, H. and Nozawa, T., 1957, *Explanation Text of the Geological Map of Japan, Scale 1:50,000, Funatsu (Kanazawa-44)*. Geol. Surv. Japan, Kawasaki, 43p. (in Japanese)

Jin, Y.G., Shang, Q.H., Wang, X.D., Wang, Y. and Sheng, J.Z., 1999, Chronostratigraphic subdivision and correlation of the Permian in China. *Acta Geol. Sinica*, **73**, 127-138.

Jin, Y.G., Wardlaw, B.R., Glenister, B.F. and Kotlyar, G.V., 1997, Permian chronostratigraphic subdivisions. *Episodes*, **20**, 10-15.

Jones, G., Sano, H. and Valsami-Jones, E., 1993, Nature and tectonic setting of accreted basalts from the Mino Terrane, central Japan. *Jour. Geol. Soc. London*, **150**, 1167-1181.

Kahler, F. and Kahler, G., 1966, *Fossilium Catalogus I: Animalia. Pars 112. Fusulinida (Foraminiferida), Teil 2*. Uitgeverij Dr. W. Junk, 's-Gravenhage, 255-538.

Kalmykova, M.A., 1967, Permskie fuzulinidy Darvaza: Kratkaya istoriya izucheniya Permi i permskikh fuzulinid Darvaza. *Tr. VSEGEI, N. S., Tom. 116, Biostratigraficheskiy Sbornik*, **2**, 116-287. (in Russian)

Kanmera, K., 1957, Revised classification of *Cancellina* and *Neoschwagerina*, and evolution of Sumatrininae and Neoschwagerininae. *Mem. Fac. Sci., Kyushu Univ., Ser. C,* **6**, 47-64.

Kanmera, K., 1963, Fusulinids of the Middle Permian Kozaki Formation. *Mem. Fac. Sci., Kyushu Univ., Ser. C,* **14**, 79-141.

Kanuma, M., 1960, Stratigraphical and paleontological studies of the southern part of the Hida Plateau and the northeastern part of the Mino Mountainland, central Japan. *Bull. Tokyo Gakugei Univ.*, **11**, 161-189.

Kobayashi, M., 1957, Paleontological study of the Ibukiyama Limestone, Shiga Prefecture, central Japan. *Sci. Repts., Tokyo Kyoiku Daigaku, Sec. C*, **5**, 247-311.

Kojima, S., 1984, Paleozoic-Mesozoic strata in the Takayama area, Gifu Prefecture, central Japan: Their stratigraphy and structure. *Jour. Geol. Soc. Japan*, **90**, 175-190. (in Japanese)

Lee, J.S., 1931, Distribution of the dominant types of the fusulinid foraminifera in the Chinese

seas. *Bull. Geol. Soc. China*, **10**, 273-290.
Lee, J.S., 1934, Taxonomic criteria of Fusulinidae with notes on seven new Permian genera. *Mem. Natl. Res. Inst. Geol., Nanking*, **14**, 1-32.
Leven, E.Ya., 1963, O filogenii vyschikh fuzulinid i raschlenenii verkhnepermskikh otlozheniy Tetisa. *Vop. Mikropaleont.*, **7**, 57-70. (in Russian)
Leven, E.Ya., 1965, O stratigraficheskom znachenii roda *Polydiexodina* Dunbar et Skinner, 1931. *Vop. Mikropaleont.*, **9**, 129-146. (in Russian)
Leven, E.Ya., 1967, Stratigrafiya i fuzulinidy permskikh otlozheniy Pamira. *Tr. Geol. Inst.*, **167**, 1-224. (in Russian)
Leven, E.Ya., 1975, Yarusnaya shkala permskikh otlozheniy Tetisa. *Byull. Mosk. Obsche. Isp. Pri. (MOIP), Otdel. Geol.*, **50**, 5-21. (in Russian)
Leven, E.Ya., 1980. *Ob'yasnitel'naya Zapiska k Stratigraficheskoy Shkale Permskikh Otlozheniy Oblasti Tetis*. VSEGEI, Leningrad, 51p. (in Russian)
Leven, E.Ya., 1996, The Midian Stage of the Permian and its boundaries. *Stratigraphy and Geological Correlation*, **4**, 540-551.
Leven, E.Ja. (Leven, E.Ya.) (edited by Stevens, C.H. and Baars, D.L.), 1997, Permian stratigraphy and Fusulinida of Afghanistan with their paleogeographic and paleotectonic implications. *Geol. Soc. Amer., Spec. Pap.*, no. 316, 1-134.
Leven, E.Ja., 1998, Permian fusulinid assemblages and stratigraphy of the Transcaucasia. *Riv. Ital. Paleont. Strat.*, **104**, 299-328.
Leven, E.Ja., 2001, On possibility of using the global Permian stage scale in the Tethyan region. *Stratigraphy and Geological Correlation*, **9**, 118-131.
Leven, E.Ja., 2004, Fusulinids and Permian scale of the Tethys. *Stratigraphy and Geological Correlation*, **12**, 139-151.
Li, J.X., 1989, *Guangxi Fusulinids*. Guangxi Normal Univ. Press, Guilin, 213p. (in Chinese)
Li, L., 2000, Sanmianjing Formation. *In* Editorial Committee of Stratigraphic Lexicon of China (Jin, Y.G., Shang, Q.H., Hou, J.P., Li, L., Wang, Y.J., Zhu, Z.L. and Fei, S.Y.), ed., *Stratigraphic Lexicon of China, Permian System*, Geol. Publ. House, Beijing, 89-90. (in Chinese)
Lin, J.X., Li, J.X., Chen, G.X., Zhou, Z.R. and Zhang, B.F., 1977, Fusulinida. *In* Hubei Institute of Geological Sciences et al., eds., *Paleontological Atlas of Central South China, No. 2 (Late Paleozoic),* Geol. Pub. House, Beijing, 4-96. (in Chinese)
Liu, Z.A., Xiao, X.M. and Dong, W.L., 1978, Protozoa. *In* Working Group of Stratigraphy and Paleontology of Guizhou, ed., *Paleontological Atlas of Southwest China, Guizhou Volume, No. 2 (Carboniferous to Quaternary)*, Geol. Pub. House, Beijing, 12-98. (in Chinese)
Miklukho-Maklay, A.D., 1949. *Verkhnepaleozoyskie Fuzulinidy Sredney Azii, Fergana, Darvaz i Pamir*. Leningrad. Gosud. Univ., Leningrad, 126p. (in Russian)
Miklukho-Maklay, A.D., 1957, Nekotorye fuzulinidy Permi Kryma. *Uche. Zap. Leningrad. Gosud. Univ., no. 225, Ser. Geol. Nauk*, **9**, 93-159. (in Russian)
Miklukho-Maklay, A.D., 1958, Sistematika vysshikh Fuzulinid. *Vestnik Leningrad. Univ., 1957, no. 12, Ser. Geol. Geogr.,* **2**, 5-14. (in Russian)
Miyamura, M., 1967, Stratigraphy and geological structure of the Permian formations of Mt. Ibuki and its vicinity, central Japan. *Geol. Surv. Japan, Report*, no. 224, 1-42.
Mizutani, S., 1990, Mino Terrane. *In* Ichikawa, K., Mizutani, S., Hara, I., Hada, S. and Yao, A., eds., *Pre-Cretaceous Terranes of Japan, Publication of IGCP No. 224: Pre-Jurassic Evolution of Eastern Asia,* Nippon Insatsu Shuppan, Osaka, 121-135.
Möller, V. von, 1878, Die spiral-gewunden Foraminiferen des russischen Kohlenkalkes. *Mém. l'Acad. Imp. Sci. St. Pétersbourg, Sér. 7*, **25**, 1-147.
Morikawa, R., 1958, Fusulinids from the Akasaka Limestone (Part 1). *Sci. Repts., Saitama Univ., Ser. B*, **3**, 93-130.

Morikawa, R. and Isomi, H., 1961, Studies of Permian fusulinids in the east of Lake Biwa, central Japan. *Geol. Surv. Japan, Rep.*, no. 191, 1-30.

Morikawa, R. and Suzuki, Y., 1961, Fusulinids from the Akasaka Limestone (Part 2). *Sci. Repts., Saitama Univ., Ser. B*, **4**, 43-74.

Niwa, M., 2004, Lithology, structure and correlation of the Hirayu Complex in the Mino Belt of the Takayama area, Gifu Prefecture, central Japan. *Jour. Geol. Soc. Japan*, **110**, 439-451. (in Japanese)

Niwa, M., Kashiwagi, K. and Tsukada, K., 2003, Jurassic, Triassic and Permian radiolarians from the Hirayu complex of the Mino Belt in the Nyukawa-Hirayu area, Gifu Prefecture, central Japan. *Jour. Earth Planet. Sci., Nagoya Univ.*, **50**, 13-42.

Noda, M., Ota, M., Nishida, T., Sugimura, A., Fujii, A., Haikawa, T. and Yoshimura, K., 1975, Geology and speleology of the Nyukawa District, central Japan. *Bull. Akiyoshi-dai Mus. Nat. Hist.*, no. 11, 1-12. (in Japanese)

Otsuka, T., 1988, Paleozoic-Mesozoic sedimentary complex in the eastern Mino Terrane, central Japan and its Jurassic tectonism. *Jour. Geosci., Osaka City Univ.*, **31**, 63-122.

Ozawa, T., 1970, Notes on the phylogeny and classification of the Superfamily Verbeekinoidea (Studies of the Permian verbeekinoidean foraminifera- I). *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **20**, 17-58.

Ozawa, T., 1987, Permian fusulinacean biogeographic provinces in Asia and their tectonic implications. *In* Taira, A. and Tashiro, M., eds., *Historical Biogeography and Plate Tectonic Evolution of Japan and Eastern Asia*, Terra Sci. Pub., Tokyo, 45-63.

Ozawa, T. and Nishiwaki, N., 1992, Permian Tethyan biota and sedimentary facies of the Akasaka Limestone Group. *In* Adachi, M. and Suzuki, K., eds., *29th IGC Field Trip Guidebook, Volume 1: Paleozoic and Mesozoic Terranes: Basement of the Japanese Island Arcs*, Nagoya Univ., Nagoya, 189-195.

Ozawa, Y., 1925a, On the classification of Fusulinidae. *Jour. Coll. Sci., Imp. Univ. Tokyo*, **45**, 1-26.

Ozawa, Y., 1925b, A brief critical revision of the *Fusulina*-species recently described, with additional studies on Japanese Fusulinae. *Jour. Geol. Soc. Japan*, **32**, 19-27.

Ozawa, Y., 1927a, Stratigraphical studies of the Fusulina limestone of Akasaka, Province of Mino. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2*, **2**, 121-164.

Ozawa, Y., 1927b, Stratigraphic study of the limestone of Akasaka, Part 1. *Jour. Geogr. (Chigaku Zasshi),* no. 460, 320-331. (in Japanese)

Ozawa, Y., 1927c, Stratigraphic study of the limestone of Akasaka, Part 2. *Jour. Geogr. (Chigaku Zasshi),* no. 461, 381-392. (in Japanese)

Sano, H., 1988, Permian oceanic-rocks of Mino Terrane, central Japan, Part II. Limestone facies. *Jour. Geol. Soc. Japan*, **94**, 963-976.

Sano, H. and Kanmera, K., 1996, Microbial controls on Panthalassan Carboniferous-Permian oceanic buildups, Japan. *Facies*, **34**, 239-256.

Sano, H., Yamagata, T. and Horibo, K., 1992, Tectonostratigraphy of Mino Terrane: Jurassic accretionary complex of southwest Japan. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **96**, 41-57.

Schwager, C., 1883, Carbonische Foraminiferen aus China und Japan. *In* Richthofen, F. F. von, ed., *Beiträge zur Paläontologie von China (F. von Richthofen's China Band IV).* Verlag von Dietrich Reimer, Berlin, 106-159.

Sheng, J.C. (Sheng, J.Z.), 1963, Permian fusulinids of Kwangsi, Kueichow and Szechuan. *Palaeont. Sinica, N. S. B*, no. 10 (Whole Number 149), 1-247.

Skinner, J.W., 1931, Primitive fusulinids of the Mid-Continent region. *Jour. Paleont.*, **5**, 253-259.

Skinner, J.W. and Wilde, G.L., 1954, The fusulinid subfamily Boultoniinae. *Jour. Paleont.*,

28, 434-444.

Staff, H. von and Wedekind, R., 1910, Der Oberkarbon Foraminiferensapropelit Spitzbergens. *Bull. Geol. Inst., Univ. Upsala*, **10**, 81-123.

Sun, X.F., Gao, C.X. and Zhang, L.X., 1983, Fusulinida. *In* Xi'an Institute of Geology and Mineral Resources, ed., *Paleontological Atlas of Northwest China, Shaanxi, Gansu and Ningxia Volume, Part 2 (Upper Paleozoic),* Geol. Pub. House, Beijing, 3-40. (in Chinese)

Tazawa, J., 1991, Middle Permian brachiopod biogeography of Japan and adjacent regions in East Asia. *In* Ishii, K., Liu, X., Ichikawa, K. and Huang, B., eds., *Pre-Jurassic Geology of Inner Mongolia, China: Reports of China-Japan Cooperative Research Group, 1987-1989*, Matsuya Insatsu, Osaka, 213-230.

Tazawa, J., 1992, Middle Permian brachiopod faunas in East Asia and their zoogeographic significance. *Jour. Geol. Soc. Japan*, **98**, 483-496. (in Japanese)

Tazawa, J., 1997a, Permian brachiopods from Hiyomo, east of Takayama, central Japan: A palaeobiogeographical data on the origin of limestone-greenstone blocks in the Mino Belt. *Jour. Geol. Soc. Japan*, **103**, 908-911. (in Japanese)

Tazawa, J., 1997b, *Coscinophora* (Permian Brachiopoda) from the Akasaka Limestone, Mino Belt, central Japan and its palaeobiogeographical significance. *Earth Sci. (Chikyu Kagaku)*, **51**, 447-451. (in Japanese)

Tazawa, J., 1998, Pre-Neogene tectonic divisions and Middle Permian brachiopod faunal provinces of Japan. *Proc. Roy. Soc. Victoria*, **110**, 281-288.

Tazawa, J., 2000, Permian brachiopod faunas and pre-Neogene tectonics in the Inner Side of Southwest Japan. *Monograph (Chidanken Senpo)*, no. 49, 5-22. (in Japanese)

Tazawa, J., Ono, T. and Hori, M., 1998, Two Permian lyttoniid brachiopods from Akasaka, central Japan. *Paleont. Res*., **2**, 239-245.

Tazawa, J. and Shen, S., 1997, Middle Permian brachiopods from Hiyomo, Mino Belt, central Japan: Their provincial relationships with North America. *Sci. Repts., Niigata Univ., Ser. E*, no. 12, 1-17.

Thompson, M.L., 1935, The fusulinid genus *Staffella* in America. *Jour. Paleont*., **9**, 111-120.

Thompson, M.L. and Foster, C.L., 1937, Middle Permian fusulinids from Szechuan, China. *Jour. Paleont*., **11**, 126-144.

Toriyama, R., 1975, Fusuline fossils from Thailand, Part IX. Permian fusulines from the Rat Buri Limestone in the Khao Phlong Phrab area, Sara Buri, Central Thailand. *Mem. Fac. Sci., Kyushu Univ., Ser. D,* **23**, 1-116.

Toriyama, R., Kanmera, K. and Ingavat, R., 1969, Fusulinacean fossils from Thailand, Part V. *Neofusulinella* from Thailand. *In* Kobayashi, T. and Toriyama, R., eds., *Geology and Palaeontology of Southeast Asia, Volume VII*, Univ. Tokyo Press, Tokyo, 15-32.

Toriyama, R., Kanmera, K., Kaewbaidhoam, S. and Hongnusonthi, A., 1974, Biostratigraphic zonation of the Rat Buri Limestone in the Khao Phlong Phrab area, Sara Buri, Central Thailand. *In* Kobayashi, T. and Toriyama, R., eds., *Geology and Palaeontology of Southeast Asia, Volume XIV*, Univ. Tokyo Press, Tokyo, 25-48.

Ueno, K., 1991, Early evolution of the families Verbeekinidae and Neoschwagerinidae (Permian Fusulinacea) in the Akiyoshi Limestone Group, southwest Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S*., no. 164, 973-1002.

Ueno, K., 1996, Late Early to Middle Permian fusulinacean biostratigraphy of the Akiyoshi Limestone Group, southwest Japan, with special reference to the verbeekinid and neoschwagerinid fusulinacean biostratigraphy and evolution. *Supplemento agli Annali dei Musei Civici di Rovereto, Sezione Archeologia, Storia e Scienze Naturali*, **11** (Reports of Shallow Tethys 4 International Symposium), 77-104.

Wardlaw, B.R., Davydov, V.I. and Gradstein, F.M., 2004, The Permian Period. *In* Gradstein, F.M., Ogg, S.G. and Smith, A.G., eds., *A Geologic Time Scale*, Cambridge Univ. Press, Cambridge, 249-270.

Xie, S.G., 1982, Protozoa. *In* Geological Bureau of Hunan, ed., *The Palaeontological Atlas of Hunan*, *Geol. Mem., Ser. 2*, no. 1, Geol. Publ. House, Beijing, 2-73. (in Chinese)

Yabe, H., 1903, On a Fusulina-limestone with *Helicoprion* in Japan. *Jour. Geol. Soc. Tokyo*, **10**, 1-13.

Yamada, N., Adachi, M., Kajita, S., Harayama, S., Yamazaki, H. and Bunno, M., 1985, *Geology of the Takayama District. Quadrangle Series, Scale 1:50,000, Kanazawa (10) No. 52*. Geol. Surv. Japan, Tsukuba, 111 p. (in Japanese)

Yang, Z.D., 1985, Restudy of fusulinids from the "Maokou Limestone" (Permian) at Datieguan, Langdai, Guizhou. *Acta Micropalaeont. Sinica*, **2**, 307-338. (in Chinese)

Zaw Win, 1999, Fusuline biostratigraphy and paleontology of the Akasaka Limestone, Gifu Prefecture, Japan. *Bull. Kitakyushu Mus. Nat. Hist*., **18**, 1-76.

Zaw Win, 2000, Paleoenvironmental and paleogeographical consideration on the Akasaka Limestone, Gifu Prefecture, Japan. *Bull. Kitakyushu Mus. Nat. Hist*., **19**, 9-23.

Zhang, L.X., 1982, Fusulinids of eastern Qinghai-Xizang Plateau. *In* Geological Surveying Team of Geological Bureau of Sichuan Province and Nanjing Institute of Geology and Palaeontology, eds., *Startigraphy and Palaeontology in W. Sichuan and E. Xizang, China, Part 2*, The People's Pub. House Sichuan, Chengdu, 119-244. (in Chinese)

Zhang, L.X., 1991. Early-Middle Permian fusulinids from Ngari, Xizang (Tibet). *In* Nanjing Institute of Geology and Palaeontology and Geological Surveying Team of Geological Bureau of Xizang, eds., *Stratigraphy and Palaeontology of the Permian, Jurassic and Cretaceous from the Rutog Region*, Nanjing Univ. Press, Nanjing, 42-67. (in Chinese)

Zhang, L. X., 1998, Fusulinids from Karakorum and Kunlun region. *In* The Comprehensive Scientific Expedition to the Qinghai-Xizang Plateau, Chinese Academy of Sciences, ed., *Palaeontology of the Karakorum-Kunlun Mountains*, Sci. Press, Beijing, 55-71. (in Chinese)

Zhang, L.X. and Dong, W.L., 1986. Order Fusulinida. *In* Xiao, W.M., Wang, H.D., Zhang, L.X. and Dong, W.L., eds., *Early Permian Stratigraphy and Faunas in Southern Guizhou*, The People's Pub. House Guizhou, Guiyang, 70-199. (in Chinese)