A fusuline fauna from the basal part of the Sakamotozawa Formation in the Kamiyasse area, South Kitakami Belt, Northeast Japan

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Abstract

This paper describes schwagerinid fusulines from a sandstone bed in the basal part of the Sakamotozawa Formation distributed in the Kamiyasse area of Kesennuma, South Kitakami Belt, Northeast Japan. The fauna includes *Dutkevitchia*? *hindukushiensis*, *Pseudofusulina* cf. *callosa*, *Pseudochusenella* ex gr. *cushmani*, *Nipponitella* sp., *Eoparafusulina* sp., and others, and is referable to the Sakmarian of the Early Permian. Thus, this study first clarified the age of the basal part of the Permian succession in the Kamiyasse area with solid paleontological evidence. It also suggests that the basal part of the Sakamotozawa Formation in this area is almost coeval with that in the type locality of the Nagaiwa-Sakamotozawa area farther to the northeast in the South Kitakami Mountains although the faunal compositions are essentially different in these two areas.

Key words: Early Permian, fusuline, Kamiyasse, Northeast Japan, Sakamotozawa Formation, Sakmarian, South Kitakami Belt.

Introduction

The Kamiyasse area of Kesennuma in the South Kitakami Belt, Northeast Japan, represents one of classic regions on the study of Paleozoic stratigraphy and paleontology in the Japanese Islands and is well-known as the locality where the Permian was first discovered in Japan by

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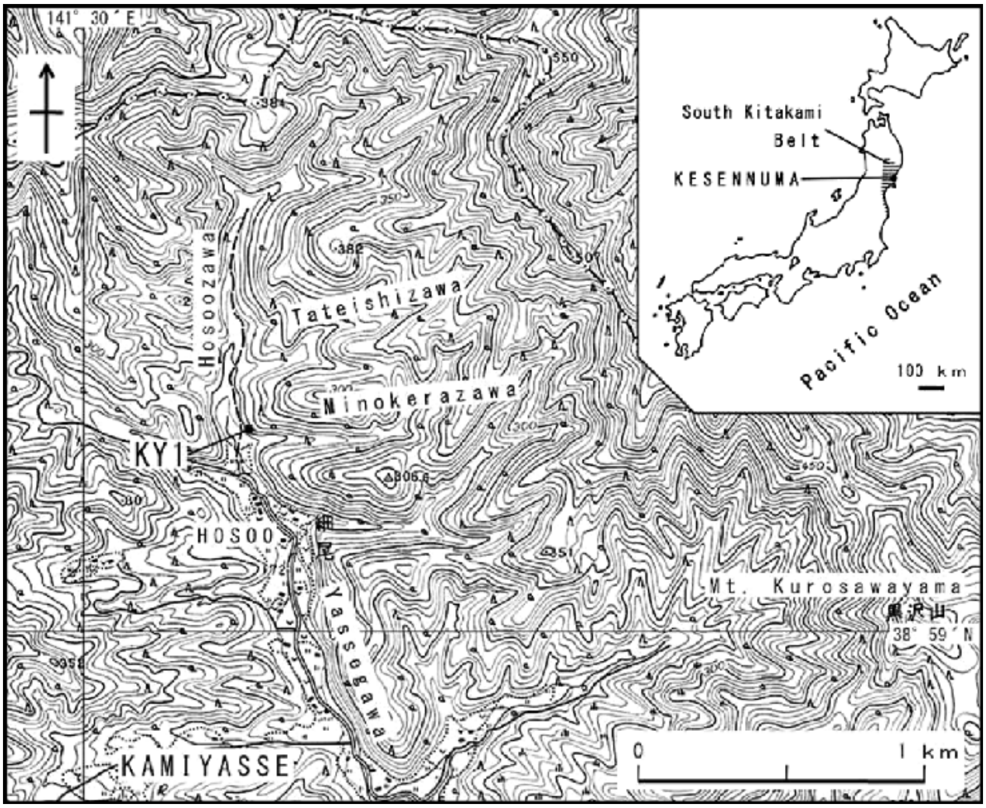

Fig. 1. Index map showing locality of KY1 in Kamiyasse area, South Kitakami Belt, Northeast Japan. Base map is from 1:25,000 scale topographic map "Shishiori" published by Geospatial Information Authority of Japan.

K. Jimbo in 1887 (Harada, 1890). The Permian in this area consists mainly of limestone, sandstone, and shale with minor conglomerate. Various groups of marine fossils, such as brachiopods, ammonoids, fusulines, pelecypods, gastropods, corals, bryozoans, crinoids, trilobites, cartilaginous fishes, and others, have been reported until now (e.g., Yabe and Hayasaka, 1915; Hayasaka, 1925; Kanomata and Miyawaki, 1967; Tazawa, 1973, 1976; Misaki and Ehiro, 2004; Ehiro and Misaki, 2004; Shiino et al., 2008; Kobayashi et al., 2009). These fossils provided solid bases for establishing chronostratigraphy of the Permian System in the South Kitakami Belt.

After a pioneer work by Shiida (1940), Kambe and Shimazu (1961), Tazawa (1973, 1976), and Misaki and Ehiro (2004) studied Permian stratigraphy of the Kamiyasse area. Although these studies established slightly different lithostratigraphic classifications, they agreed that the lower part of Permian succession in that area is dominated by limestone with subordinate sandstone and shale, and rare conglomerate. Tazawa (1973) correlated this part to the Early Permian Sakamotozawa Formation, which type locality is in the Nagaiwa-Sakamotozawa area of Hikoroichi in Ofunato, about 22-23 km to the northeast of Kamiyasse. With respect to the fossil occurrence of this part, the above-mentioned studies reported some fusuline, coral, brachiopod, and a pelecypod species, but these fossils mainly occurred from limestone members in the main part of the formation and they, in particular fusulines, are essentially those indicating an Artinskian age in the Early Permian. Chronostratigraphical information supported by paleontological evidence from the basal clastic part of the Sakamotozawa Formation in Kamiyasse is still being barren substantially although Misaki and Ehiro (2004) proposed a Sakmarian age for that part. This fact further bears an important issue to be solved in terms of Permian regional basin development in the South Kitakami Belt. That is, whether or not the Permian really started deposition simultaneously in Sakmarian time both in the Kamiyasse and Nagaiwa-Sakamotozawa areas.

In the course of reinvestigation of the Kamiyasse area by one of junior authors (TS) for establishing its Permian litho- and biostratigraphy, he found a sandstone bed yielding calcareous fossil remains in the basal part of the Sakamotozawa Formation exposed at Hosoo in the northwestern part of the Kamiyasse area in Kesennuma, eastern Miyagi Prefecture, Northeast Japan (Fig. 1). In this sandstone, we found several fusuline species, which indicate a Sakmarian age. In this paper, we report this fusuline fauna from the basal part of the Sakamotozawa Formation as evidence representing that the formation in the Kamiyasse area started deposition almost simultaneously with that of the type (Nagaiwa-Sakamotozawa) area. This is the first fossil evidence showing a Sakmarian age reported from the Kamiyasse area. The fusuline specimens treated in this study are housed in the Department of Geology, Faculty of Science, Niigata University, with prefix NU-F.

Stratigraphy and sample

Stratigraphic study on the Permian in the Kamiyasse area started with Shiida (1940), who subdivided it into the Kamiyasse Formation in the lower and the Futatsumori Formation in the upper. He distinguished the basal conglomerate member of the former formation and referred to it as the Yamaya Conglomerate. Later, Kambe and Shimazu (1961) recognized three lithostratigraphic units in the Permian succession of Kamiyasse; they are the Sakamotozawa, Kanokura, and Toyoma groups in ascending order. Tazawa (1973, 1976) essentially followed this three-fold subdivision and established basic chronostratigraphic correlation of these stratigraphic units. Recently, Misaki and Ehiro (2004) restudied Permian stratigraphy of the Kamiyasse-Imo area and proposed a different stratigraphic subdivision from previous studies, with placing formation boundaries at different horizons. They recognized the Nakadaira, Hosoo, Kamiyasse, and Kurosawa formations in ascending order.

In our study, we essentially follow the view by Tazawa (1973, 1976) in terms of the stratigraphic classification of the Permian System in the Kamiyasse area, particularly for the definition of the Sakamotozawa Formation. This is mainly based on the fact that the

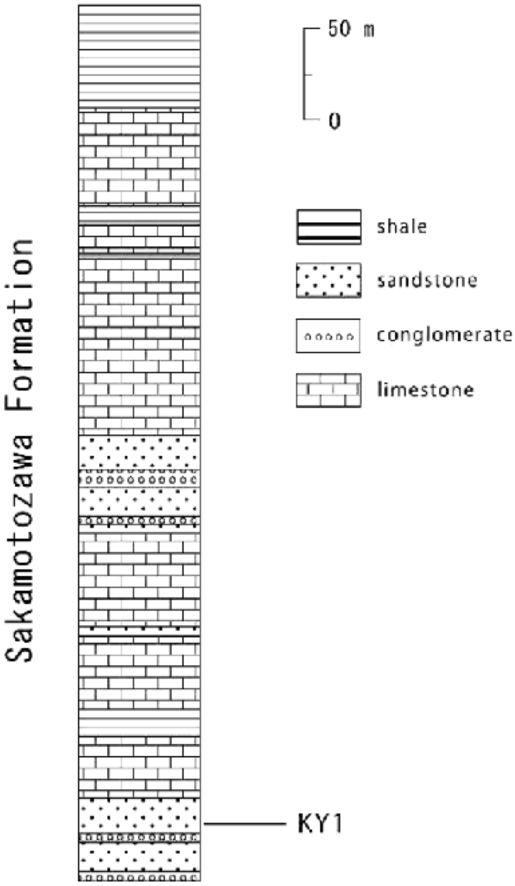

Fig. 2. Generalized geologic log of Sakamotozawa Formation in Kamiyasse area, showing sample horizon of KY1.

lithostratigraphic succession observed in the Lower Permian of the Kamiyasse area is essentially similar to that established in the type (Nagaiwa-Sakamotozawa) area of the Sakamotozawa Formation although the former area is slightly more dominated in siliciclastics than the latter. Based on recent field investigation by the second author, the Sakamotozawa Formation in the Kamiyasse area attains 479 m thick. It is composed essentially of limestone with a subordinate amount of shale, sandstone, and conglomerate (Fig. 2). In the basal and middle parts, sandstone and conglomerate are dominated, whereas in its topmost part shale becomes primary lithology.

With respect to the stratigraphic succession in the basal part of the Sakamotozawa Formation, Tazawa (1973) noted that the basal conglomerate, which is well recognized in the Nagaiwa-Sakamotozawa area (Mikami, 1965; Kanmera and Mikami, 1965a), might be missing in the Kamiyasse area although he acknowledged its presence reported by earlier workers (Shiida, 1940; Kambe and Shimazu, 1961). Misaki and Ehiro (2004) also depicted that the basal part of the Permian succession (their Nakadaira Formation) starts with limestone. Recently, the second author found a new road cut at Hosoo near the confluence of Hosoozawa and Minokerazawa (Fig. 1), which exposes an approximately 41-m-thick succession consisting of

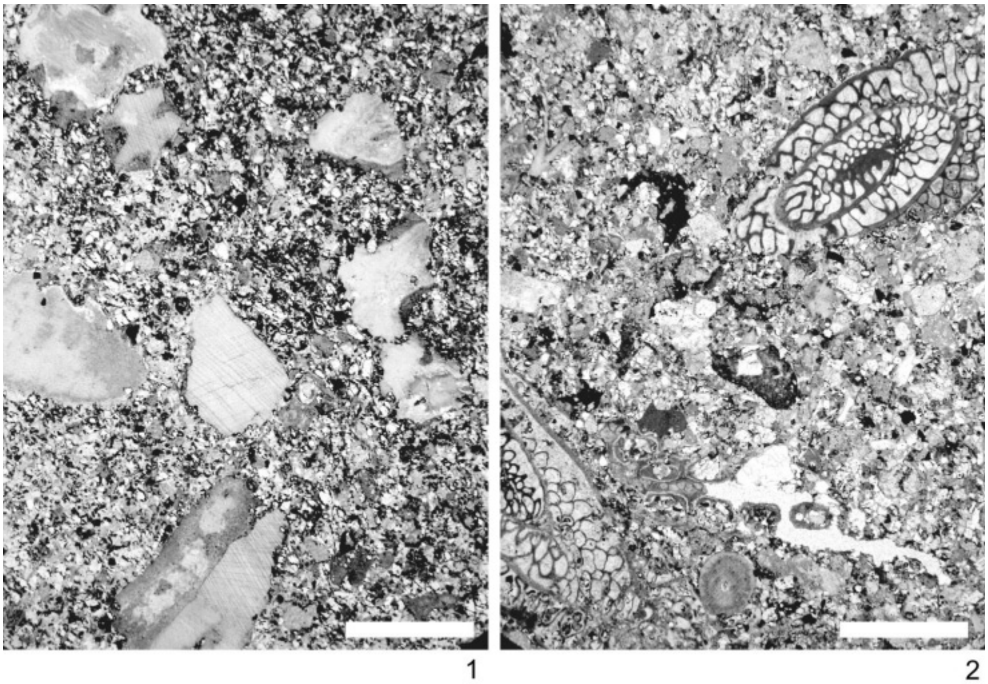

Fig. 3. Photomicrographs of thin sections showing microfacies of sample studied herein. **1**. Fine- to medium-grained calcareous sandstone, with large calcareous debris (mainly crinoidal and brachiopod bioclasts) scattered within finer-grained sediments. **2**. Medium- to coarse-grained calcareous sandstone with large bioclasts such as crinoids and fusulines. Finer particles consist of calcareous fragments (brachiopods, bryozoans, and others of unknown origin), subangular quartz grains, and volcanic and lithic fragments. Scale bar = 2mm.

conglomerate and sandstone in the very basal part of the Sakamotozawa Formation (Fig. 2). The conglomerate at the base crops out along an anticlinal axis running an almost N-S direction parallel to the general extension of Hosoozawa. In the Kamiyasse area, the Sakamotozawa Formation is essentially exposed at the eastern flank of this anticline.

The fusuline-bearing sample (KY1) studied herein was collected at this new road cut (38˚59’23”N and 141˚30’25”E) (Fig. 1). This level is about 31 m above the base of the Sakamotozawa Formation (Fig. 2). The sandstone is calcareous and fine- to medium-grained, but becomes coarse-grained in some parts. It contains several layers, which yield a number of granular (sometimes fine pebbly) calcareous debris such as brachiopods, bryozoans, crinoids, and fusulines (Fig. 3). They are usually weathered and dissolved, showing porous occurrence on the surface. Sand grains are mainly of volcaniclastic, lithic, and calcareous fragments and subangular quartz particles (Fig. 3). In this sandstone, brachiopods are particularly rich in some levels.

In the type (Nagaiwa-Sakamotozawa) area of the Sakamotozawa Formation, Mikami (1965) and Kanmera and Mikami (1965a) recognized four members (Sa to Sd) in two subformations, which are bounded by unconformity. Recently, Ueno et al. (2009) called them the Yubanosawa Sandstone Member (Sa), Tashiroyama Limestone Member (Sb), Shiratorizawa Limestone Member (Sc), and Shiraishi Sandstone-Limestone Member (Sd) in ascending order. Judging from basic lithostratigraphic similarity, the conglomerate-sandstone succession at the base of the Sakamotozawa Formation in the Kamiyasse area, where the present fusuline-bearing sample was derived, is considered to correspond to the Yubanosawa Sandstone (Sa) Member in the type area.

Fusuline fauna and age

In the examined sample KY1, we discriminated seven species belonging to five genera of schwagerinid fusulines. They are *Dutkevitchia*? *hindukushiensis* (Leven), *Pseudofusulina* cf. *callosa* (Rauser-Chernousova), *P*. sp. A, *P*. sp. B, *Nipponitella* sp., *Eoparafusulina* sp., and *Pseudochusenella* ex gr. *cushmani* (Chen). Their occurrence is not very abundant in this sample and their preservation is by no means good due mainly to weathering and slight abrasion.

Among them, *Dutkevitchia*? *hindukushiensis* was originally described from Sakmarian strata of North Afghanistan (Leven, 1971), which is reconstructed paleogeographically by Heubeck (2001) in his Permian paleomap to constitute a continental chain consisting of the Turan, Tarim, Qaidam, North China, and other blocks to the north of the Paleo-Tethys Ocean. Later, an additional occurrence of this species was reported from the upper part of the Grenzland Formation (Sakmarian) of the Carnic Alps in Austria and the Born Formation (late Asselian) of the Karavanke Mountains in Slovenia (Forke, 2002). *Pseudofusulina callosa* was also originally reported from the Sakmarian (Sterlitamakian) of the Urals, Russia (Rauser-Chernousova, 1940). As noted in the description, moreover, *Pseudofusulina* sp. A in this study is identical with *P.* sp. A reported by Leven and Scherbovich (1980) from the Shagon area of the Southwestern Darvaz, Tajikistan. In that area, this species is known from a Sakmarian succession. It is also important to note paleobiogeographically that the Southwestern Darvaz is reconstructed to have been located in Early Permian time to the north of the Paleo-Tethys, constituting the continental chain in which North Afghanistan is also included (Heubeck, 2001).

The type stratum of *Pseudochusenella cushmani* is the "Swine" Limestone of the Chihsia Formation in southern Jiangsu, South China (Chen, 1934). This stratigraphic level is not easy to express in modern chronostratigraphic terminology of the Permian, but Zhang (1983) clarified that the "Swine" Limestone in the type section at Zhenjiang, Jiangsu, is conformably underlain by the Chuanshan Formation with *Sphaeroschwagerina moelleri* (probably indicating the younger Asselian or older Sakmarian) and overlain by the Chihsia Formation with *Misellina claudiae* (referable to the Bolorian). He established the *Darvasites ordinatus* Zone in this limestone and correlated it to the *Robustoschwagerina schellwieni* Zone of Guizhou, South China, which is generally referred to the Sakmarian (Jin et al., 1997). Recent study rather prefers the Artinskian for the age of the *Darvasites ordinatus* Zone (Jin et al., 2003).

Later, Zhou (1982) reported several forms of *Pseudochusenella cushmani* from the Chihsia Formation of southeastern Hunan, South China. Their occurrence is restricted in the basal part of the formation, to which he proposed the *Schwagerina cushmani* Zone. Zhou (1982) considered that it can be correlated with the "Swine" Limestone of the Chihsia Formation in the Nanjing Hills of Jiangsu. The *cushmani*-bearing interval in southeastern Hunan is underlain by the strata of the *Pseudoschwagerina* Zone of the Chuanshan Limestone and overlain by those of the *Staffella vulgaris* and *Misellina claudiae* zones of the middle part of the Chihsia Formation (Zhou, 1982, 1984). Although it is not easy to estimate the age of the *cushmani*-bearing interval of Hunan exactly, these fusuline zones above and below are suggestive that the Sakmarian cannot be ruled out completely for it. In the Southwestern Darvaz, similar species to *P. cushmani* were also reported by Leven and Scherbovich (1980) from the Sakmarian under the name of *Pseudofusulina postcallosa* and *P*. sp. F. Moreover, Forke (2002) recently reported *P. cushmani* from the Upper "*Pseudoschwagerina*" Limestone (late Sakmarian-early Artinskian) of the Carnic Alps. To sum up, the known stratigraphic interval of *P. cushmani* is supposed to be broadly from the upper Sakmarian to the lower Artinskian.

All these lines of evidence lead to a conclusion that the schwagerinid fusuline fauna from KY1 is probably referable to the Sakmarian. Thus, we clarified the age of the basal part of the Permian succession in that area with solid paleontological evidence for the first time. Our result also suggests that the basal part of the Sakamotozawa Formation in the Kamiyasse area is almost coeval with that in the type locality of the Nagaiwa-Sakamotozawa area farther to the northeast in the South Kitakami Mountains and the deposition of the formation started in Sakmarian time in both areas, showing essentially similar stratigraphy to each other. In the latter area, however, the reported fusuline fauna from the basal Yubanosawa Sandstone (Sa) Member consists of *Eoparafusulina* aff. *perplexa* (Grozdilova and Lebedeva, 1961), *Nipponitella explicata* Hanzawa, 1938, *Quasifusulina*? sp., and others (Ueno et al., 2007). The faunal compositions are very different in the basal part of the Sakamaotozawa Formation in these two areas.

Systematic paleontology

Superfamily Fusulinoidea von Möller, 1878
Family Schwagerinidae Dunbar and Henbest, 1930
Subfamily Rugosofusulininae Davydov, 1980
Genus *Dutkevitchia* Leven and Scherbovich, 1978

Type species.—*Rugosofusulina devexa* Rauser-Chernousova, 1937.

Dutkevitchia? *hindukushiensis* (Leven, 1971)

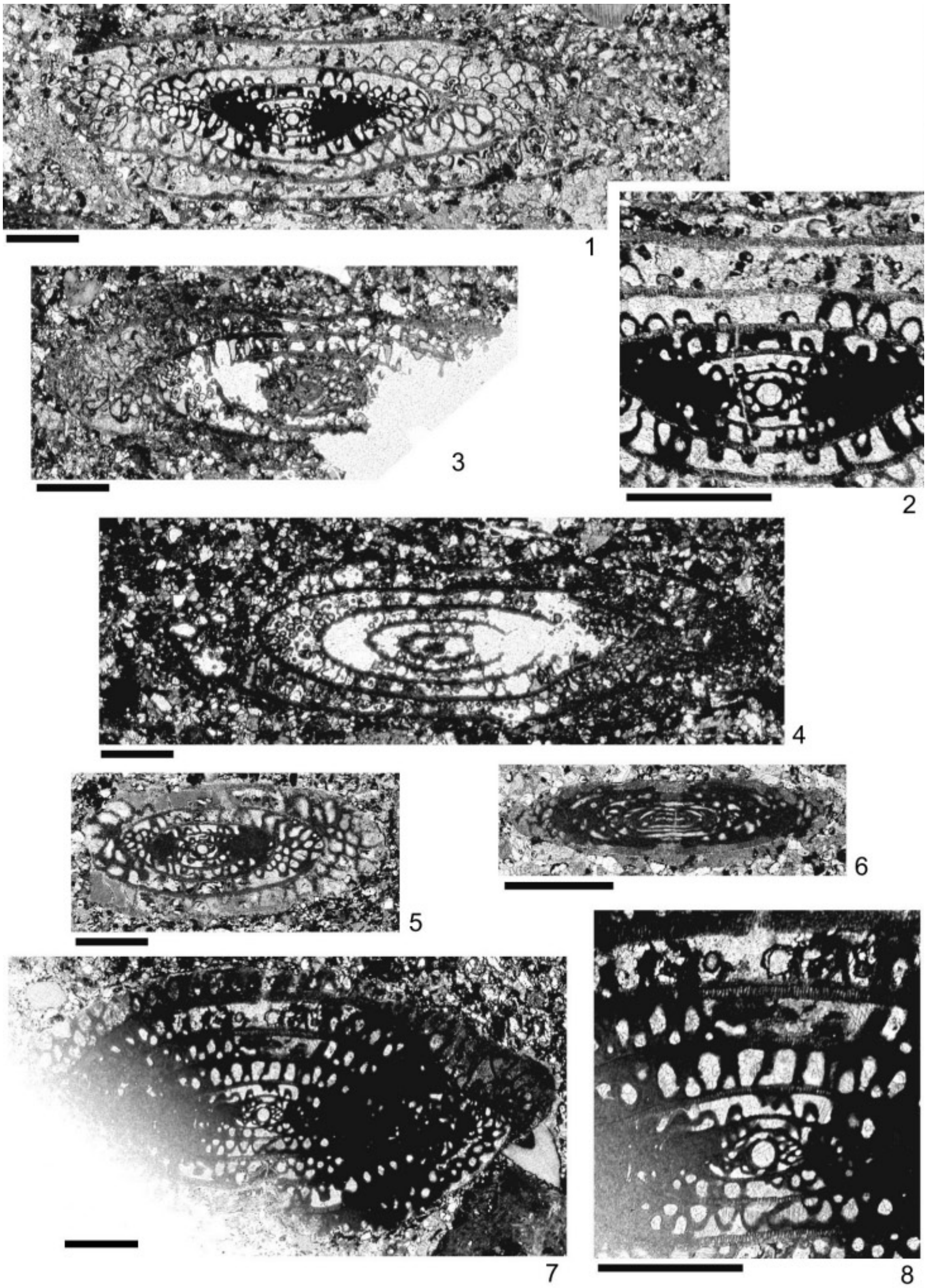

Fig. 4. 1-4. *Dutkevitchia*? *hindukushiensis* (Leven, 1971), 1: axial section, NU-F266, 2: enlarged part of Fig. 4.1, 3: tangential (nearly axial) section of weathered specimen, NU-F267, 4: tangential (nearly axial) section of weathered specimen, NU-F268. **5**. *Pseudofusulina* cf. *callosa* (Rauser-Chernousova, 1940), axial section, NU-F269. **6**. *Eoparafusulina* sp., tangential section, NU-F270. **7, 8**. *Pseudochusenella* ex gr. *cushmani* (Chen, 1934), 7. axial section, NU-F271, 8. enlarged part of Fig. 4.7. Scale bar = 1mm.

Figs. 4.1-4.4

Pseudofusulina hindukushiensis Leven, 1971, p. 27-28, pl. 5, figs. 9-11.
Ruzhenzevites hindukushiensis (Leven): Forke, 2002, p. 230, pl. 36, fig. 8.
Nonpseudofusulina hindukushiensis (Leven): Leven, 2009, p. 135, pl. 19, fig. 11.

Figured specimens.—Axial section (NU-F266), tangential (nearly axial) sections (NU-F267, NU-F268).

Description.—Shell is large and elongate subcylindrical with rounded axial regions and almost flat to slightly concave central part of shell. One oriented specimen with 6 volutions (Fig. 4.1) is 9.53 mm in length and 3.10 mm in diameter. Radius vectors of the first to sixth volutions of this specimen are 0.17, 0.32, 0.50, 0.75, 1.11, and 1.28 mm, their half lengths are 0.39, 0.68, 1.27, 2.07, 3.93, and 5.88 mm, and their form ratios are 2.29, 2.13, 2.54, 2.76, 3.54, and 4.59, respectively. The first four volutions are oval to slightly elongate fusiform, but outer two volutions become elongated rather rapidly in axial direction, forming a large subcylindrical shell. Well-developed axial fillings and slightly tight coiling in the first three volutions mark a well-recognizable juvenile stage of shell growth. Proloculus in the available axial section is spherical and 0.21 mm in outside diameter. Spirotheca is composed of a tectum and keriotheca in the third to sixth volutions. Thicknesses of spirotheca of the first to sixth volutions in the above-mentioned specimen are 0.018, 0.047, 0.076, 0.068, 0.082, and 0.071 mm. Septa are regularly and rather strongly fluted except the central part of shell. Small chomata are present only in the first two volutions.

Remarks.—*Dutkevitchia*? *hindukushiensis* was established by Leven (1971) based on materials from the Sakmarian exposed at Bangui of North Afghanistan. One of the present Sakamotozawa specimens, illustrated in Fig. 4.1, has a characteristic juvenarium, which possesses heavy axial fillings and slightly tight coiling. This diagnostic feature, as well as its elongate subcylindrical shell shape with regularly and strongly fluted septa, are observed in the types from North Afghanistan although the former has a slightly smaller shell than the latter. The other two figured specimens herein are not only badly oriented but also poorly preserved due to weathering. However, their elongate cylindrical shells with narrow and high septal loops are suggestive that they are also potentially referable to this species although it is not conclusive whether or not they have a characteristic juvenarium with heavy axial fillings because of severe weathering in the inner volutions. We thus only provisionally include these two specimens in *D.*? *hindukushiensis* in this taxonomy.

Originally, this species was subsumed in the genus *Pseudofusulina* Dunbar and Skinner, 1931 by Leven (1971). Later, Forke (2002) considered that it can be included in the genus *Ruzhenzevites* Davydov, 1986 because of its large subcylindrical shell with strong and regular septal fluting and lack of rugosity. At the same time, however, he became vaguely aware of some similarities between *hindukushiensis* and certain *Dutkevitchia* species in their common development of characteristic juvenarium.

Recently, Leven (2008) erected the genus *Nonpseudofusulina* with *Pseudofusulina blochini* Korzhenevsky, 1940 as the type species. He noted that it should be necessary to erect a new genus to accommodate those reported from Eurasia under the name of *Pseudofusulina* but lacking rugosity because *Pseudofusulina huecoensis* Dunbar and Skinner, 1931, the type species of the genus from North America, has rugosity in its wall as is observed in the genus *Rugosofusulina* (Skinner and Wilde, 1965, 1966). He named it *Nonpseudofusulina*, emphasizing their non-pseudofusuline attribution. Leven (2009) later included the present *hindukushiensis* in *Nonpseudofusulina*. But this taxonomic treatment remains questionable because, except this species, all what he included in *Nonpseudofusulina* lack clearly recognized juvenile volutions with heavy axial fillings. In this meaning, it can be said that Leven (2009) essentially accommodated in his new genus the very species that have been conventionally included in the genus *Pseudofusulina* by most fusuline researchers at that time.

All these three genera to which the present species have been attributed in its taxonomic history are not very suitable for the generic assignment of *hindukushiensis* judging from its basic morphology such as the well-recognized juvenarium with heavy axial fillings and slightly tight coiling. As Forke (2002) passingly supposed, probably based on the development of distinct juvenile volutions, we incline to relate this species essentially with *Dutkevitchia*. Because of the lack of rugosity in its wall, which is considered to be one of diagnostic features of the relevant genus, however, we questionably assign it to this genus.

Subfamily Pseudofusulininae Dutkevich, 1934

Genus *Pseudofusulina* Dunbar and Skinner, 1931

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

Discussion.—The usage of the generic name *Pseudofusulina* for Eurasian forms is being the subject of controversy. This problem roots in two arguments. One is based on an idea that schwagerinid fusuline faunas may potentially be disparate between Eurasia and North America, reflecting paleobiogeographic distinction of these two regions after the formation of Pangaea at around mid-Carboniferous time, and the other is the observation of rugosity in wall in the type species of the genus (*P. huecoensis* from the Hueco Limestone of the North American Wolfcampian/Lower Permian) by Skinner and Wilde (1965, 1966). The former suggests the possibility of current pseudofusulinids showing large variability being polyphyletic; in some cases they may have completely different origins in Eurasia and North America. The latter issue potentially results in turning out many Eurasian forms with regularly fluted septa, obvious secondary deposits, and absence of rugosity, which have been identified under the name of *Pseudofusulina* in many taxonomic works, from the relevant genus. This let Leven (2008) propose *Nonpseudofusulina* for accommodating many Eurasian species with such characters.

Although the introduction of *Nonpseudofusulina* by Leven (2008) could partly solve this long-lasting taxonomic problem on this genus, there still remains the fundamental issue on whether or not *Nonpseudofusulina* is indeed monophyletic or not because, as Leven (2009) also admitted, the genus allows very large variability in terms of basic morphology. This highly suggests a possibility that several distinct lineages may have been included within *Nonpseudofusulina*. Due to the remaining, too many basic problems on the taxonomy of pseudofusulinids, in this study we simply use the conventional generic name *Pseudofusulina* for fusiform to subcylindrical schwagerinids having regularly fluted septa and lacking distinct rugosity in their wall.

Pseudofusulina cf. *callosa* Rauser-Chernousova, 1940
Figs. 4.5, 5.3

Compare.—
Pseudofusulina callosa Rauser-Chernousova, 1940, 88-89, 95, pl. 5, figs. 5-7.

Figured specimens.—Axial section (NU-F269), tangential (nearly axial) section (NU-F273).

Remarks.—*Pseudofusulina callosa* was established by Rauser-Chernousova (1940) based on materials from the Sterlitamakian (Upper Sakmarian) of the Urals, Russia. The present Sakamotozawa specimens are almost similar in shell dimension to the types, but axial fillings are slightly stronger in the former. *Pseudofusulina* cf. *callosa* can be distinguished from *Dutkevitchia*? *hindukushiensis* in having a less clearly defined juvenarium.

Pseudofusulina sp. A
Figs. 5.5-5.7

Pseudofusulina sp. A: Leven and Scherbovich, 1980, pl. 9, fig. 6.

Figured specimens.—Slightly oblique axial section (NU-F275), parallel section (NU-F276).

Remarks.—The present species is most probably identical with *Pseudofusulina* sp. A reported by Leven and Scherbovich (1980) from the Sakmarian of Shagon in the Southwestern Darvaz, Tajikistan. They share many similarities in shell shape and dimension, prolocular size, nature of septal fluting, expansion of shell through growth, and presence of rare phrenotheca.

Pseudofusulina sp. B
Figs. 5.1, 5.2

Rugosofusulina alpina (Schellwien): Kanmera and Mikami, 1965b, p. 291-292, pl. 50,

Figured specimen.—Axial section (NU-F272).

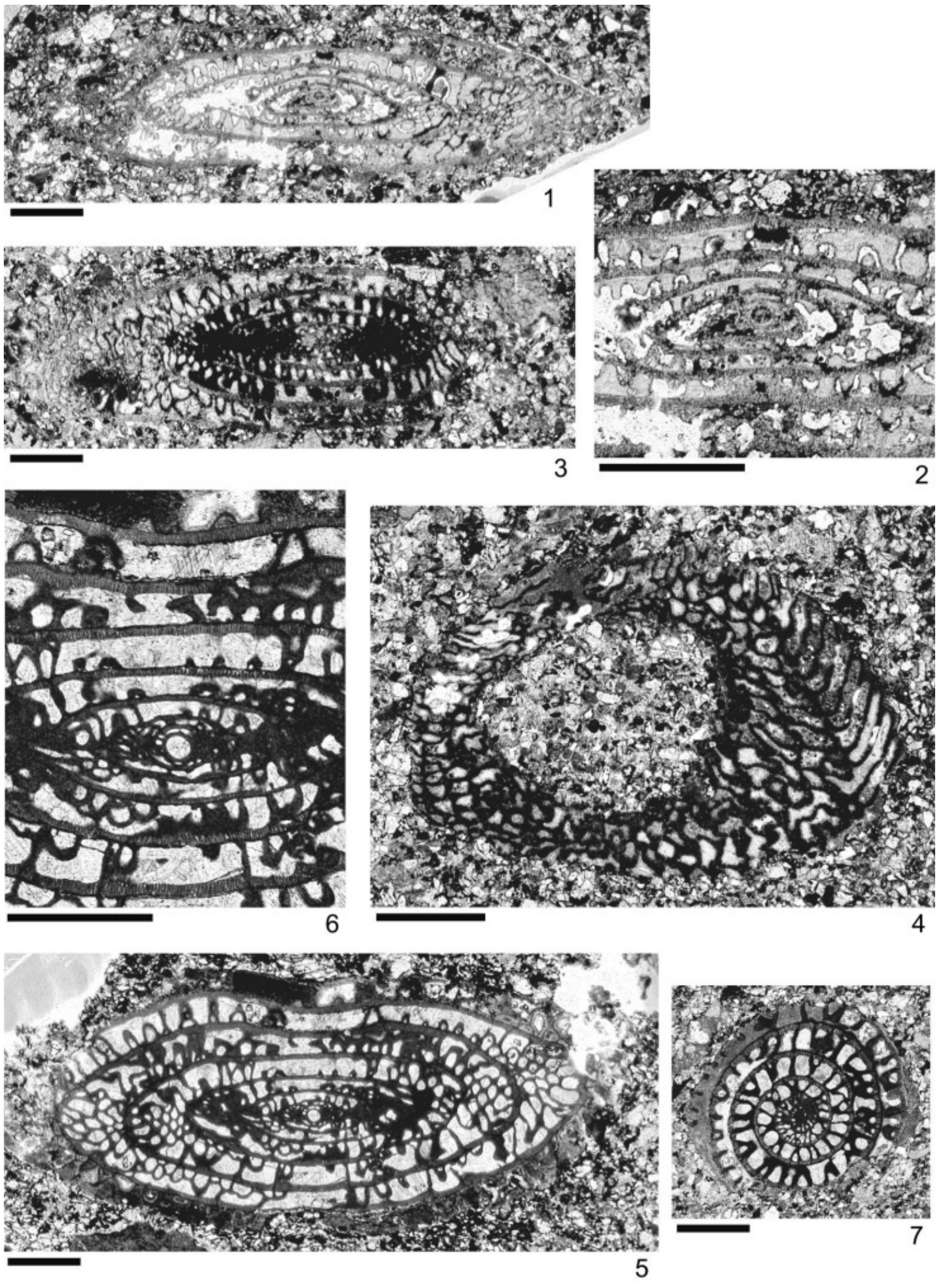

Fig. 5. 1, 2. *Pseudofusulina* sp. B, 1: axial section of weathered specimen, NU-F272, 2: enlarged part of Fig. 5.1. **3**. *Pseudofusulina* cf. *callosa* (Rauser-Chernousova, 1940), axial section, NU-F273. **4**. *Nipponitella* sp., tangential section of uncoiled part, NU-F274. **5-7**. *Pseudofusulina* sp. A, 5: slightly oblique axial section, NU-F275, 6: enlarged part of Fig. 5.5, 7: parallel section, NU-F276. Scale bar = 1mm.

Remarks.—Kanmera and Mikami (1965b) described a large schwagerinid with an elongate subcylindrical and gradually expanding shell and low and regularly fluted septa from Sb2 (middle part of the Tashiroyama Limestone Member of Ueno et al., 2009) of the Sakamotozawa Formation in the type (Nagaiwa-Sakamotozawa) area under the name of *Rugosofusulina alpina* (Schellwien, 1898). This identification is questionable because a restudy of topotypes of that species (*alpina*) from the Auernig Formation of the Carnic Alps, Austria/Italy by Forke (2007) revealed that the types include two distinct species that can be subsumed in *Daixina*. The Sakamotozawa specimens reported by Kanmera and Mikami (1965b) are essentially different from those topotypes.

In this study, we obtained a weathered and poorly preserved schwagerinid fusuline specimen, which is similar to those of "*Rugosofusulina alpina*" by Kanmera and Mikami (1965b). This form may probably be a new species of *Pseudofusulina*. We, however, treat it open nomenclaturally and simply identified it as *P*. sp. B in this study because of only poorly preserved material available for this study. It is also not advisable to erect a new species by designating one of specimens by Kanmera and Mikami (1965b) as a holotype because, as they noted, there is some possibility of secondary deformation in their specimens, which would have partly masked true shell features of this species.

Subfamily Darvasitinae Leven, 1992

Monodiexodininae Kanmera, Ishii and Toriyama, 1976, p. 135 (name not available because of no description).
Darvasitinae Leven, 1992, p. 84-85 (name transferred from the family Darvasitidae).

Discussion.—Kanmera et al. (1976) introduced in a figure the subfamily Monodiexodininae for accommodating *Monodiexodina* Sosnina in Kiparisova et al., 1956, *Eoparafusulina* Coogan, 1960, and *Ferganites* Miklukho-Maklay, 1959. This name has been used as valid in some subsequent taxonomic studies (Rauser-Chernousova et al., 1996; Ueno and Tazawa, 2003; Ueno et al., 2005; Ueno, 2006; Leven, 2009, 2010). However, Monodiexodininae is regarded here unavailable nomenclaturally because it lacked proper description in words when it was introduced, which action conflicts with Article 13.1 of the Code (ICZN, 1999). Later, Leven (1992) established the family Darvasitidae and included *Darvasites* Miklukho-Maklay, 1959, *Nagatoella* Thompson, 1936, *Eoparafusulina*, *Mccloudia* Ross, 1967, and questionably *Nipponitella* Hanzawa, 1938. This taxonomic name is considered to be appropriate for subsuming the genera that Kanmera et al. (1976) included in Monodiexodininae, except *Ferganites* of different phylogenetic branch (Davydov, 1988), and also some other ones in Leven's (1992) Darvasitidae. We use this taxonomic name for accommodating all these relevant genera in the family Schwagerinidae after transferring it from a family rank to a subfamily one.

Genus *Eoparafusulina* Coogan, 1960

Type species.—*Fusulina gracilis* Meek, 1864. See Wilson (1967) for the details of complicated history on the fixation of the type species of the genus and on the taxonomic and nomenclatural change of the species *gracilis*.

Eoparafusulina sp.
Fig. 4.6

Figured specimen.—Tangential section (NU-F270).

Remarks.—A cylindrical shell with rather compact coiling, regular septal fluting, and broad chomata is suggestive that this specimen is referable to the genus *Eoparafusulina*. However, specific identification is not possible due to its poor orientation.

Genus *Nipponitella* Hanzawa, 1938

Type species.—*Nipponitella explicata* Hanzawa, 1938.

Nipponitella sp.
Fig. 5.4

Figured specimen.—Tangential section of uncoiled part (NU-F274).

Remarks. —One specimen representing an uncoiled part of shell is available for this study. The present specimen is probably identified as *Nipponitella explicata* by its dimension and the nature of septal fluting. However, we treat the present form open nomenclaturally in this taxonomy due to its poor orientation.

Subfamily Chusenellinae Kahler and Kahler, 1966
Genus *Pseudochusenella* Bensh, 1987

Type species.—*Pseudofusulina pseudopointeli* Rauser-Chernousova in Scherbovich, 1969.

Pseudochusenella ex gr. *cushmani* (Chen, 1934)
Figs. 4.7, 4.8

Pseudofusulina cushmani Chen, 1934, p. 72-73, pl. 4, figs. 4-6.
Pseudofusulina diversitiformis (Dunbar and Skinner): Bensh, 1972, 136-137, pl. 30, figs. 10-12.
Pseudofusulina postcallosa Bensh: Leven and Scherbovich, 1980, pl. 10, fig. 9.
Pseudofusulina sp. F: Leven and Scherbovich, 1980, pl. 10, fig. 12.

Schwagerina cushmani (Chen): Zhou, 1982, p. 231, pl. 1, figs. 1-3.
Schwagerina cushmani longa Zhou, 1982, p. 231, pl. 1, figs. 4-7.
Schwagerina cushmani robusta Zhou, 1982, p. 231-232, pl. 1, figs. 8, 9.
Pseudochusenella cushmani (Chen): Forke, 2002, p. 240, pl. 37, figs. 4-7.

Figured specimen.—Axial section (NU-F271).

Remarks.—The available axial section having six and a half volutions exhibits an almost hexagonal shell with moderately large proloculus followed by rather compactly coiled first two volutions, strongly and regularly fluted septa, and heavy axial fillings particularly in the early and middle volutions. *Pseudochusenella cushmani*, originally reported by Chen (1934) from the "Swine" Limestone (Chihsia Formation) of Jiangsu, South China, essentially shares these characters. Later, Zhou (1982) recognized three subspecies, *cushmani* (s.s.), *cushmani longa*, and *cushmani robusta*, in this species. Among them, the present Sakamotozawa specimen is closest to some specimens of what Zhou (1982) named *cushmani longa*. However, it is not clear whether or not the observed morphological variability really represents subspecific difference as Zhou (1982) considered, or it may happen to show specific difference, or it merely exhibits intraspecific morphological difference. In this study, we thus treat them as *Pseudochusenella* ex gr. *cushmani* in a broad sense and include this Sakamotozawa specimen in this convenient taxonomic unit. For the generic attribution of this species, we follow the view proposed by Forke (2002).

Bensh (1972) described *Pseudofusulina diversitiformis* from the *Sphaeroschwagerina glomerosa* Zone (late Asselian) of southern Fergana, Uzbekistan. That species is very different in shell size, nature of septal fluting, prolocular size, and the coiling of inner volutions from that reported originally by Dunbar and Skinner (1937) from the Wolfcampian of Texas, U.S.A. Judging from the basic shell morphology, the Fergana species can be included in *Pseudochusenella* ex gr. *cushmani*. Later, Leven and Scherbovich (1980) illustrated *Pseudofusulina postcallosa* Bensh, 1972 and *P*. sp. F from Sakmarian strata of the Southwestern Darvaz, Tajikistan. Although they identified them as different species, these two have generally hexagonal shells, moderately large proloculus, slightly tightly coiled inner volutions, and heavy axial fillings. These shell features demonstrate that they are also referable to *P.* ex gr. *cushmani*.

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