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Monodiexodina from the Daheshen Formation, Jilin, Northeast China

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Abstract

A small fusulinoidean fauna from the upper part of the Daheshen Formation of central Jilin, Northeast China is reported in this paper. The fauna is composed of *Monodiexodina rhaphidoformis* Han, *M.* sp., and *Parafusulina*? *daheshenica* Han, and indicates possibly a middle Middle Permian (Murgabian/Wordian) age. This fauna is characterized by the presence of the genus *Monodiexodina* and occurs in sandy limestone containing a large amount of detrital quartz grains. Sandy limestone and calcareous sandstone have been interpreted to be favorable and characteristic for the occurrence of the genus *Monodiexodina*. The stratigraphic and paleogeographic distributions of the genus *Monodiexodina* are discussed, and its paleobiogeographic peculiarity as a bitemperate (antitropical) taxon is verified. Moreover, the three species from this Daheshen fauna are described.

Key words: Daheshen Formation, Fusulinoidea, Jilin, Middle Permian, *Monodiexodina*, Northeast China.

Introduction

Northeast China is geologically situated in the eastern part of the Central Asian-Mongolian mobile belt between the Siberian and Sino-Korean (North China) platforms. In this area, Late Paleozoic strata dominated by acidic to intermediate volcaniclastics are distributed in association with Paleozoic metamorphic and granitic rocks (Yang et al., 1986; Wang, 1991; Zhang, 2000). Up to the present, fusulinoidean faunas in this area have been reported by some authors (Han, 1976, 1980b, 1982, 1985; Han and Guo, 1979; Xia, 1981, 1982; Xia and Ding, 1983; Ding et al., 1985). These data are very important not only for reconstructing the Permian paleogeography of east Asia but also for providing strong paleobiogeographic constraints when elucidating the

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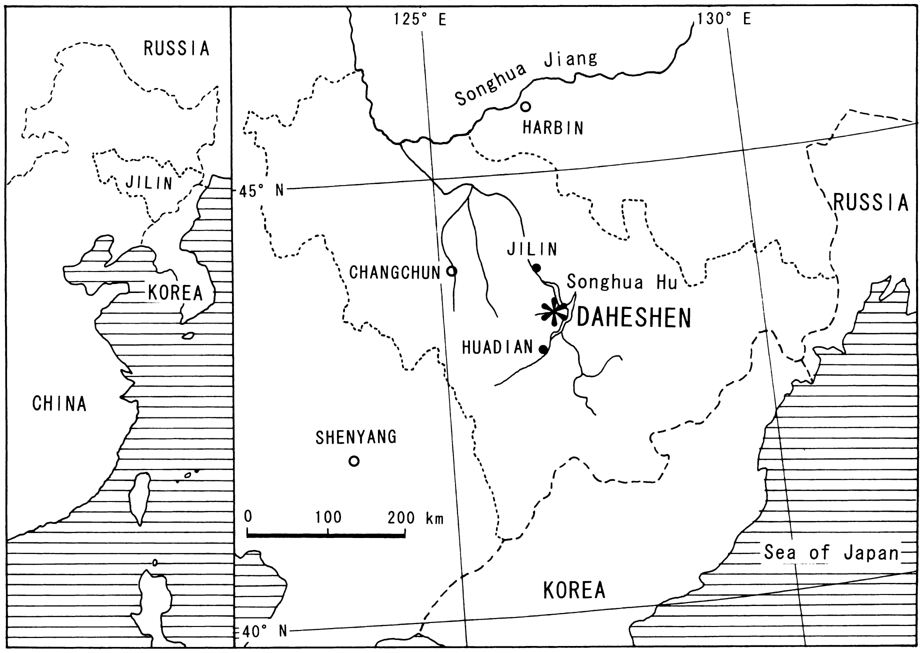

Fig. 1. Index map of fossil locality in Daheshen, central Jilin Province, Northeast China.

geologic connection of pre-Jurassic terranes in Japan with east Asian Continent proper. Many of the reports on fusulinoideans from Northeast China are, however, of eastern Inner Mongolia. Their paleontologic information has been still poor in other parts of Northeast China, and additional data are still very desirable.

In this paper, we report a small fusulinoidean fauna collected from the upper part of the Daheshen Formation at Daheshen in central Jilin Province, Northeast China. This assemblage yields a paleobiogeographically important genus, *Monodiexodina*, and was recovered from very sandy limestone containing plenty of detrital quartz grains. *Monodiexodina* has been reported from several localities in Northeast China by some Chinese students, but its mode of occurrence, particularly on the lithofacies of sediments in which the genus is contained, has been scarcely documented.

The fusulinoidean specimens studied herein are registered and housed in the paleontological collections of the Department of Geology, Faculty of Science, Niigata University, Niigata, Japan, with the prefix NU-F.

Stratigraphy and fauna

The fusulinoidea-bearing rock sample studied in this paper was collected by the junior author (JT) from Daheshen of Huadian County, Jilin Province, Northeast China (Fig. 1) in the course of his field work in central and east Jilin, Northeast China in 2001. According to the Bureau of Geology and Mineral Resources of Jilin Province (1988) and Li (2000a), the Daheshen Formation is a Middle Permian stratigraphic unit distributed in the Daheshen-Shoushangou area, central Jilin Province. It attains more than 4000 m in thickness and can be subdivided into three parts. The lower part is composed of gray to yellowish brown acidic volcaniclastics, about 830 m thick; the middle part is made up by dark-gray to grayish green intermediate volcaniclastics with intercalations of intermediate to acidic tuff and lava, about 1330 m thick; and the upper part consists of yellowish brown to grayish green acidic volcaniclastics, rhyolite, dark gray sandstone, granular conglomerate, shale, and limestone, about 2070 m thick. The upper part contains many fossils of fusulinoideans, corals, and plant remains. The sample for this study came from a sandy calcareous bed in the lower horizon of the upper part of the Daheshen Formation.

The sample is pale-green tuffaceous, sandy limestone, and fusulinoidean individuals were seen on its surface, showing their shells oriented almost parallel to the bedding plane. We made a total of 31 thin sections from the sample for paleontologic and lithologic examnations. Under the microscope, a large number of angular to subangular, medium-sized detrital quartz grains and volcanic rock fragments are observed. They are cemented by sparry calcite together with other small skeletal grains and much larger fusulinoidean shells. In the interstitial space, irregular-shaped small lumps of chlorite are scattered. They would be formed from small volcaniclastic particles by alteration, and therefore, the sample is considered as tuffaceous originally. Fusulinoidean remains are more or less abraded or fragmented, and even deformed in various degrees, so that their preservation is rather poor.

In the present study, the following three species of fusulinoideans can be recognized: *Monodiexodina rhaphidoformis* Han, *M.* sp., and *Parafusulina*? *daheshenica* Han. From the Daheshen Formation at Daheshen, Han (1980b) reported two *Monodiexodina* and one *Parafusulina* species, but their mode of occurrence, particularly the lithologic character of sediments yielding the *Monodiexodina* specimens, was poorly described in his paper. Our study confirmed that the *Monodiexodina* from the Daheshen Formation also occurs in very sandy limestone, which is uncommon for rocks bearing fusulinoideans except *Monodiexodina*.

As to the age of the present Daheshen fauna, it is difficult to estimate only by our own materials because of a lack of age-indicating species in it. According to Han (1981), the *Monodiexodina sutschanica-Pseudodoliolina lettensis* Zone can be established in the Sijiashan Formation of the southern Daxinganling Range of eastern Inner Mongolia, which can be correlated with the Daheshen Formation of central Jilin and also with the upper Chihsia Formation (Chihsian Subseries of Jin et al., 1999) of South China. Li (2000b) noted that shallow-marine fossils including fusulinoideans occur in bioclastic limestone of the upper part of the Sijiashan Formation. The *Monodiexodina sutschanica-Pseudodoliolina lettensis* Zone yields such genera as *Monodiexodina*, *Pseudodoliolina*, *Parafusulina*, *Schwagerina*, and *Codonofusiella*.

The Chihsian is now subdivided into the lower Luodianian and the upper Xiangboan stages, and the latter stage (namely upper Chihsian) corresponds to the *Cancellina elliptica* Zone to the *Neoschwagerina simplex-Presumatrina neoschwagerinoides* Zone in the standard fusulinoidean zonation of China (Editorial Committee of Stratigraphic Lexicon of China, 2000), which further means that the Xiangboan can be correlated with the Kubergandian (Roadian) to early Murgabian (Wordian). Although the Sijiashan Formation as a whole may be correlated with the Xiangboan (Kubergandian to early Murgabian), the generic and some specific composition of fusulinoideans in the *Monodiexodina sutschanica-Pseudodoliolina lettensis* Zone strongly suggests that the fusulinoidean-bearing levels situated in the upper part of the Sijiashan Formation would be correlated with the upper part of the Xiangboan, namely early Murgabian rather than Kubergandian. Particularly, the occurrence of *Pseudodoliolina lettensis* (Schubert) and *Codonofusiella* species strongly suggest a Murgabian or younger age. If this correlation is reasonable and available, then the present *Monodiexodina*-bearing fauna from the upper part of the Daheshen Formation of Jilin, together with other *Monodiexodina*-bearing levels in Northeast China, except for *Monodiexodina sutschanica* (Dutkevich) from the Kedao Formation reported by Han (1980b), may possibly be assigned to the early Murgabian. As the genus *Monodiexodina* occurs also in the Midian (Capitanian) in South Primorye (Sosnina, 1965; Kotlyar et al., 1989) and South Kitakami (Ehiro and Misaki, 2002), the genus itself is a rather long-ranging taxon, spanning from the Bolorian (Kungurian) up to the Midian (see discussion in the next chapter).

Note on geographic and stratigraphic distributions of *Monodiexodina*

The genus *Monodiexodina* has been frequently mentioned as a subject for discussion in the context of fusulinoidean paleobiogeography (e.g., Han, 1980a; Ozawa, 1987; Ishii, 1990; Ueno, 2003), and is often referred to as an antitropical or bitemperate fusulinoidean genus (Tazawa et al., 1993; Shi et al., 1995; Shi and Grunt, 2000). It has been reported from the Khisor Range and Salt Range of NE Pakistan (Schwager, 1887; Dunbar, 1933; Douglass, 1970), West Timor, Indonesia (Schubert, 1915; Thompson, 1949), SE Pamir of Tajikistan (Leven, 1967), Karakorum (Reichel, 1940; Dunbar, 1940), Kongkashan Pass of Xinjiang, China (Sun and Zhang, 1988; Zhang, 1998), Doumar and Gegyai of Tibet, China (Wang et al., 1981; Nie and Song, 1983; Yang et al., 1990; Zhang, 1991), Mae Sariang and Tak of NW Thailand (Ingavat and Douglass, 1981), Wang Pisang of Perlis, Peninsular Malaysia (Basir Jasin and Koay, 1990), Zhesi of Inner Mongolia, China (Ding et al., 1985), Zhengxiangbaiqi of Inner Mongolia, China (Han, 1976), Jalaidqi of Inner Mongolia, China (Han, 1980b),

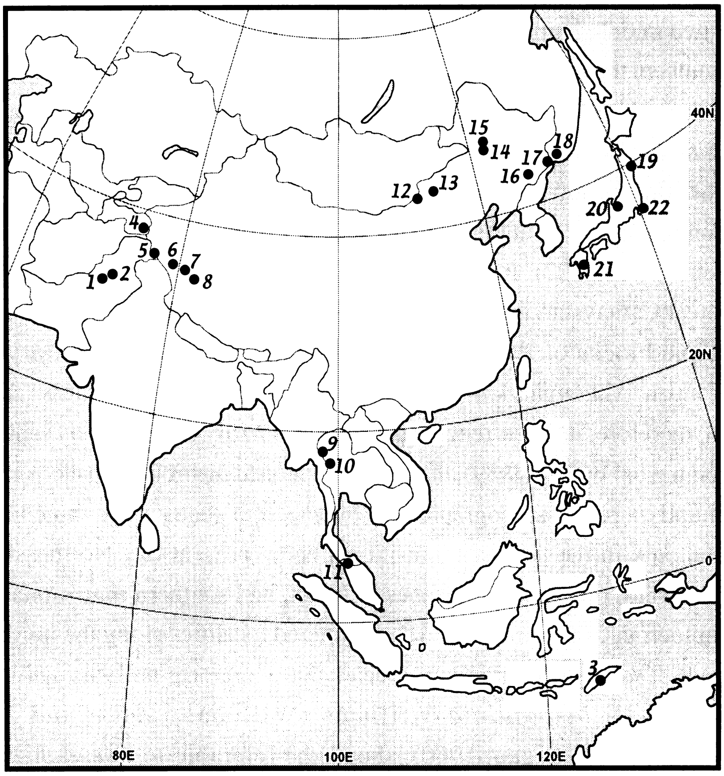

Fig. 2. Geographic distribution of *Monodiexodina*. 1: Khisor Range, NE Pakistan, 2: Salt Range, NE Pakistan, 3: West Timor, Indonesia, 4: SE Pamir, Tajikistan, 5: Shaksgam Valley, Aghil Range, Karakorum, 6: Kongkashan Pass, Xinjiang, China, 7: Doumar, Tibet, China, 8: Gegyai, Tibet, China, 9: Mae Sariang, NW Thailand, 10: Tak, NW Thailand, 11: Wang Pisang, Perlis, Peninsular Malaysia, 12: Zhesi, Inner Mongolia, China, 13: Zhengxiangbaiqi, Inner Mongolia, China, 14: Jalaidqi, Inner Mongolia, China, 15: Longjiang, Heilongjiang, China, 16: Huadian, Jilin, China, 17: Hunchun, Jilin, China, 18: South Primorye, Russian Far East, 19: South Kitakami, northeast Japan, 20: Hida Gaien, central Japan, 21: Kuma Mountains, southwest Japan, 22: Choshi Peninsula, central Japan. See text for each reference of data source.

Longjiang of Heilongjiang, China (Han, 1980b), Huadian and Hunchun of Jilin, China (Han, 1980b), South Primorye of the Russian Far East (Dutkevich in Likharev, 1939; Sosnina in Kiparisova et al., 1956; Sosnina, 1965), South Kitakami, northeast Japan (Fujimoto, 1956; Choi, 1973), Hida Gaien, central Japan (Tazawa et al., 1993), Kuma Mountains, southwest Japan (Kanmera, 1963), and Choshi Peninsula, central Japan (Maeda and Mitsuoka, 1961) (Fig. 2).

As has been discussed in Ueno (2003), these mentioned *Monodiexodina*-bearing areas can be reconstructed in either northern (12 to 22 in Fig. 2) or southern (1 to 11 in Fig. 2) middle latitudes in generally accepted Permian paleogeographic maps (e.g., Scotese and McKerrow, 1990). These two middle latitudinal regions in different hemispheres almost correspond to the northern and southern transitional zones of Shi et al. (1995). Moreover, it can be further recognized in the southern middle latitudinal region two paleogeographically independent areas of *Monodiexodina* distributions. One is of the northern margin of Gondwanaland where the Salt Range, Khisor Range, and Timor (1 to 3 in Fig. 2) were located, and the other is of the Cimmerian Continent (4 to 11 in Fig. 2), which separated from Gondwanaland at Early Permian time (e.g., Ueno et al., 2002). It is noteworthy that the genus has not been known from the equatoro-tropical Cathaysian and Panthalassan domains, such as the South China Block and exotic limestone blocks of Panthalassan seamount origin in pre-Tertiary accretionary complexes of Japan. Although *Monodiexodina* mostly occurs in more or less sandy calcareous sediments and, therefore, its occurrence seems to be primarily controlled by sedimentary facies as has been pointed out by Igo (1989), the above-mentioned distribution pattern clearly indicates that it is essentially a paleobiogeographically bitemperate genus at the same time. The genus was distributed only in the northern transitional zone (present-day Northeast China, South Primorye, and several pre-Jurassic terranes in Japan) and southern transitional zone (eastern part of the Cimmerian Continent and several scattered localities along the northern margin of Gondwanaland). Two North American species that were originally assigned to the genus *Monodiexodina*, *M. bispatulata* Williams (Williams, 1963) and *Parafusulina* (*Monodiexodina*?) sp. (Coogan, 1960), should be referable to *Pseudofusulina* and true *Parafusulina*, respectively.

The stratigraphic range of *Monodiexodina* is also slightly different in northern and southern transitional zones. In the Cimmerian continent of the southern transitional zone, *Monodiexodina* mostly occurs in probably Bolorian or possibly Kubergandian (Ueno, 2003). *Monodiexodina kattaensis* (Schwager) from the Amb Formation of the Salt Range and Khisor Range, NE Pakistan, is the only example of reliable younger Middle Permian (possibly late Murgabian or Midian?) occurrence of the genus in the southern transitional zone. On the contrary, in northern transitional zone, the genus *Monodiexodina* is very common in Murgabian (Choi, 1973; see also discussion in the previous chapter) although *M. kumensis* Kanmera reported from the lower part of the Kozaki Formation of the Kuma Mountains, Kyushu, by Kanmera (1963) is probably of Kubergandian. Moreover, the genus even ranges up to the Midian in northern transitional zone since it occupies the same stratigraphic levels as strongly Midian-suggesting *Metadoliolina dutlkevichi* Sosnina in South Primorye (Sosnina, 1965; Kotlyar et al., 1989) and *Lepidolina* species in South Kitakami (Ehiro and Misaki, 2002).

Choi (1973) recognized two morphological groups in the genus *Monodiexodina*, namely the *M. kattaensis* group and the *M. sutschanica* group. Later, Han (1980a) considered that the former group was derived from the *Alaskanella yukonensis* group whereas the latter evolved from the *A. linearis* group, and depicted that the *M. kattaensis* group appeared slightly earlier than the *M. sutschanica* group (Table 2 of Han, 1980a). However, these conclusions cannot be supported instantaneously by existing data. As discussed above, *Monodiexodina* appeared earlier in the southern transitional zone (probably Bolorian) than in the northern transitional zone (possibly Kubergandian), and this suggests that the genus was originated in the southern transitional zone (exactly in the eastern part of the Cimmerian Continent) and later migrated northerly into the northern transitional zone and southerly into the northern margin of Gondwanaland (such as the Salt Range) although the migration mechanism is still highly equivocal. In the southern transitional zone, the oldest representatives of the genus with more or less reliable age assignment are *M. shiptoni* (Dunbar) and *M. sutschanica* (Dutkevich) reported by Ingavat and Douglas (1981) and Basir Jasin and Koay (1990) from the Sibumasu Block of the eastern Cimmerian Continent, and they can be dated as possibly Bolorian (Ueno, 2003). These two species are of the *M. sutschanica* group by the definition of Choi (1973) and Han (1980a), but *Alaskanella* species similar to "*A.*" *linearis* (Dunbar and Skinner) has not been known in slightly older strata of the Cimmerian Continent.

Probably, Sakmarian or Yakhtashian (Artinskian) *Eoparafusulina* species with particularly elongate shells and regularly fluted septa, like which Leven (1993) reported from the Central Pamir, would be a possible ancestor of the genus *Monodiexodina*. Species belonging to *Monodiexodina* in the northern transitional zone would probably be later immigrants from the southern transitional zone, or may possibly constitute an homeomorphic counterpart taxon derived independently from another ancestral stock within the northern transitional zone when taking into account the fact that homeomorphy is one of the most essential features in fusulinoidean evolution (e.g., Ueno, 1992). However, the latter scenario is likely to be less promising because of too close morphological resemblance of *Monodiexodina* species from both southern and northern transitional zones. The origin, phylogeny, evolution, and dispersion of the genus *Monodiexodina* have still remained being matters of controversy.

Systematic description

(by KU)

Superfamily Fusulinoidea von Möller, 1878

Family Schwagerinidae Dunbar and Henbest, 1930

Subfamily Monodiexodininae Kanmera, Ishii and Toriyama, 1976

Genus *Monodiexodina* Sosnina *in* Kiparisova, Markovsky and Radchenko, 1956

Monodiexodina rhaphidoformis Han, 1980b

Figs. 3A-L

1980b *Monodiexodina rhaphidoformis* Han, p. 67-68, pl. 19, figs. 5-9.

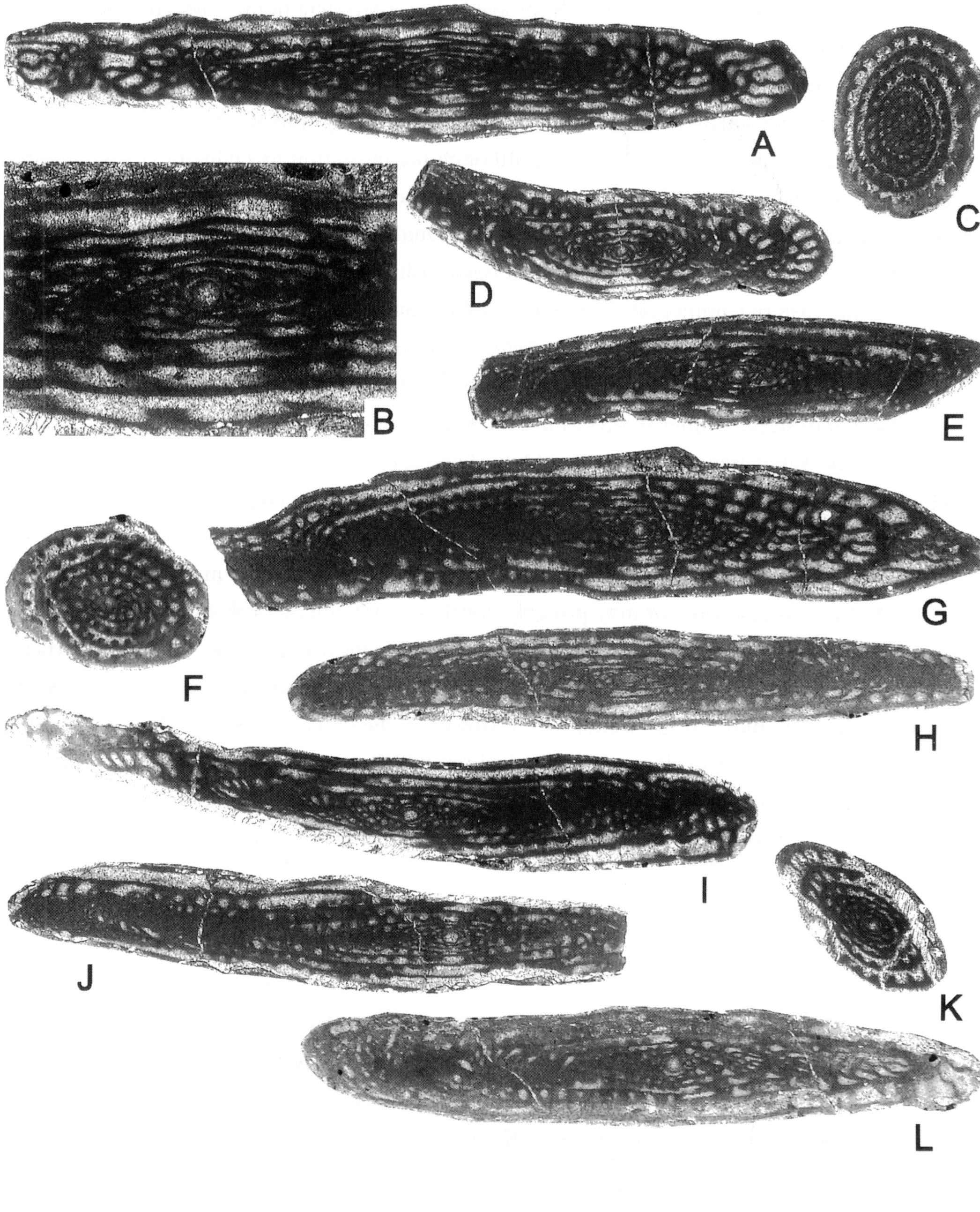

Fig. 3. *Monodiexodina rhaphidoformis* Han. A,D,E,G-J,L: axial sections, NU-F21, NU-F23, NU-F24, NU-F26, NU-F27, NU-F28, NU-F29, NU-F31, B: enlarged part of A, C,F,K: sagittal sections, NU-F22, NU-F25, NU-F30. A,C-L: × 10, B: × 20.

Materials.- Axial sections (NU-F21, NU-F23, NU-F24, NU-F26, NU-F27, NU-F28, NU-F29, NU-F31), sagittal sections (NU-F22, NU-F25, NU-F30).Most of specimens under examination are abraded and slightly deformed.

Description.- Shell moderate for genus, slenderly elongate fusiform or cylindrical with bluntly pointed polar ends, almost straight or broadly convex median part, and straight axis of coiling. Mature shell with 6 or 7 volutions, 9.65 to 12.50 mm in length and 1.48 to 2.35 mm in width, giving form ratios of 5.2 to 7.6. Shell rather tightly coiled in inner volutions, and expanding gradually through growth. Radius vectors of the first to sixth volutions of one well-oriented axial section (Fig. 2I) 0.12, 0.18, 0.29, 0.40, 0.57, and 0.74 mm, and form ratios 2.25, 4.00, 4.66, 5.08, 5.79, and 6.91, respectively. Proloculus almost spherical and 0.19 to 0.33 mm in outside diameter, averaging 0.23 mm for 7 specimens. Spirotheca thin and poorly preserved in studied specimens, but seemingly composed of a thin tectum and keriotheca. Thickness of spirotheca of the first to sixth volutions of above-mentioned axial section 0.040, 0.050, 0.060, 0.070, 0.080, and 0.125 mm. Septa regularly fluted throughout shell except for central part, forming regularly arranged semicircular septal loops, and become irregular toward polar ends. Their height reaches about one third to half of chamber height. Tunnel well developed and almost straight. Chomata most likely absent. Axial fillings very faint in most specimens.

Remarks.- This species was originally described from the Daheshen Formation of Huadian (Daheshen), Jilin. In his original description, Han (1980b) illustrated three matured axial sections (Han, 1980b, pl. 19, figs. 5-7) and noted that the form ratio of this species ranges from 8.57 to 9.00. Such larger values of form ratio in his specimens would be more or less attributed to some deformation of the specimens, and the values of form ratio in the type specimens could be slightly larger than they really are.

This species can be distinguished from other *Monodiexodina* species by its needle-like shell shape, tightly coiled inner volutions, and thinner spirotheca.

Distribution.- Middle Permian (late Chihsian) Daheshen Formation of Huadian (Daheshen), Jilin, Northeast China.

Monodiexodina sp.

Figs. 4A-C

Materials.-Axial section (NU-F32), oblique section (NU-F33), sagittal section (NU-F34).

Remarks.- *Monodiexodina* sp. clearly has a larger shell and thicker spirotheca than *M. rhaphidoformis* Han in this study, and therefore, can be easily distinguished from the latter.

This unidentified species somewhat resembles *Monodiexodina sutschanica* (Dutkevich) described originally by Dutkevich (in Likharev, 1939) from South Primorye and *M. ordinata* Han described originally by Han (1980b) from the Daheshen Formation of Huadian

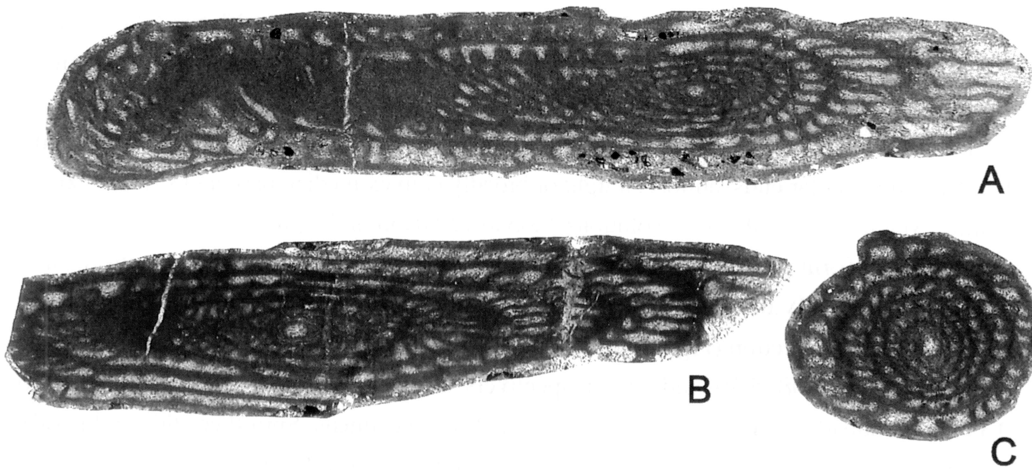

Fig. 4. *Monodiexodina* sp. A: axial section, NU-F32, B: oblique section, NU-F33, C: sagittal section, NU-F34. All × 10.

(Daheshen), Jilin, and the Sijiashan Formation of Longjiang (Zhonghetun), Heilongjiang, by its larger and elongate shell with strongly and rather regularly fluted septa. The specific identification of our specimens, however, is postponed because of insufficiency of material at hand.

Subfamily Schwagerininae Dunbar and Henbest, 1930

Genus *Parafusulina* Dunbar and Skinner, 1931

Parafusulina? *daheshenica* Han, 1980b

Figs. 5A-G

1980b *Parafusulina daheshenica* Han, p. 63-64, pl. 23, figs. 4-6.

Materials.- Axial sections (NU-F35, NU-F36, NU-F37, NU-F38, NU-F40), sagittal section (NU-F39).

Description.- Shell large for genus and elongate fusiform to cylindrical with rounded axial regions, representing a cigar-like profile. Mature specimens having 7 volutions about 14.0 mm in length and 3.1 mm in width, giving form ratio of about 4.5. Early volutions smaller in form ratios than the outer ones and fusiform to elongate fusiform in shape. Axis of coiling straight throughout shell growth. Radius vectors of the first to seventh volutions of one well-oriented axial section (Fig. 5A) 0.32, 0.46, 0.62, 0.80, 1.02, 1.28, and 1.52 mm, and form ratios 1.19,

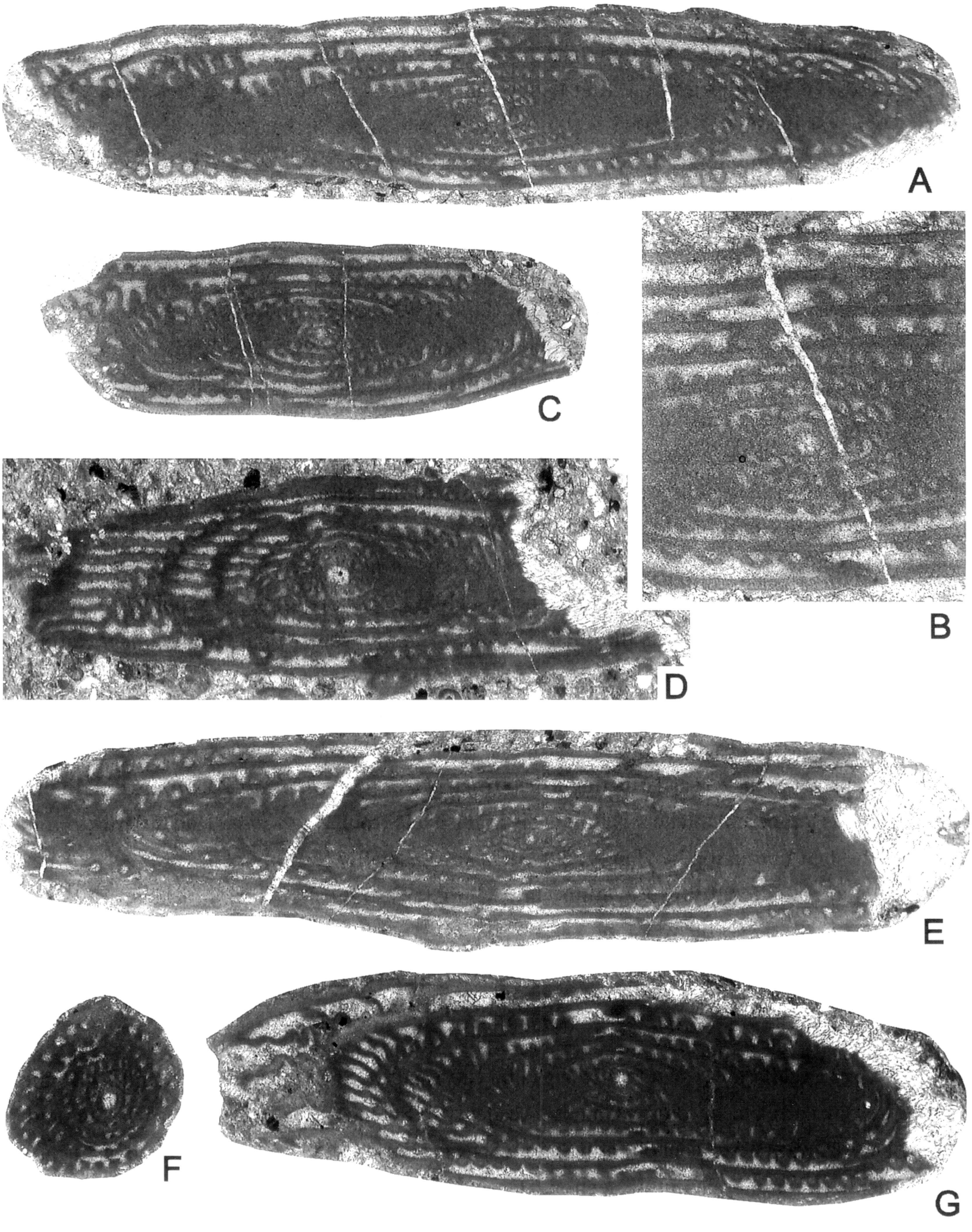

Fig. 5. *Parafusulina*? *daheshenica* Han. A, C-E, G: axial sections, NU-F35, NU-F36, NU-F37, NU-F38, NU-F40, B: enlarged part of A, F: sagittal section, NU-F39. A, C-G: × 10, B: × 20.

1.76, 2.74, 3.70, 4.86, 4.95, and 4.74?, respectively. Proloculus almost spherical and 0.22 to 0.39 mm, averaging 0.30 mm for 6 specimens. Spirotheca moderately thick, poorly preserved in examined specimens, but may possibly consist of a tectum and lower thick keriotheca. Thickness of spirotheca of the first to seventh volutions in above-mentioned axial section 0.050, 0.060, 0.065, 0.095, 0.095, 0.100, and 0.100 mm. Septa thick, and strongly and regularly fluted. Their fluting tends to become stronger and more irregular toward polar ends. Septal loops high and narrow, reaching about half to two thirds of chamber height, and regularly arranged throughout shell except for tunnel. Tunnel narrow and almost straight. Chomata seemingly absent. Axial fillings well developed.

Remarks.- In the original description, Han (1980b) illustrated three specimens of this species. Our specimens quite agree with one of two paratypes (Han, 1980b, pl. 23, fig. 6), and have a slightly thicker diameter of shell and smaller form ratio than the holotype and another paratype. The difference may be due to the deformation of the original specimens although Han (1980b) made no reference about it.

Han (1980b) originally assigned this species to the genus *Parafusulina* because of its stronger septal fluting and higher septal loops than *Monodiexodina*. Although some of the general shell morphology of the present species is not like typical representatives of *Monodiexodina*, the cigar-like shell shape and highly regularly arranged septal loops of this species somewhat remind us the shell of *Monodiexodina* rather than that of *Parafusulina*. Especially, the holotype and one paratype specimens by Han (1980b, pl. 23, figs. 4-5) are morphologically very similar to *Monodiexodina*. In this study, therefore, we questionably assign *daheshenica* to the genus *Parafusulina*.

This species can be easily distinguished from *Monodiexodina rhaphidoformis* Han in this study by its larger and thicker shell. It is distinguishable from *M. ordinata* Han described from the Daheshen Formation by Han (1980b) in having a smaller form ratio.

Distribution.- Middle Permian (late Chihsian) Daheshen Formation of Huadian (Daheshen), Jilin, Northeast China.

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